

18 Flooding and drainage

This chapter assesses flooding and drainage impacts associated with the project. The assessment includes:

- The identification of existing flood behaviour and drainage infrastructure
- Assessment of the potential impacts of the project on flooding during construction and operation
- Identification of appropriate management and safeguard measures to minimise and manage flooding impacts.

This chapter has been informed by:

- Technical working paper: Surface water (**Appendix N**)
- Technical working paper: Flooding (**Appendix P**).

Table 18-1 sets out the Secretary's Environmental Assessment Requirements (SEARS) as they relate to flooding and drainage, and where in the environmental impact statement (EIS) these have been addressed.

Table 18-1 SEARS – flooding and drainage

SEARS	Where addressed
Identification of potential impacts of the proposal on existing flood regimes, consistent with the <i>Floodplain Development Manual</i> (Department of Infrastructure, Planning and Natural Resources, 2005), including impacts to existing receivers and infrastructure and the future flood mitigation options for and development potential of affected land, demonstrating consideration of the changes to rainfall frequency and/or intensity as a result of climate change on the proposal. The assessment must demonstrate due consideration of flood risks during construction and in the proposal design.	An assessment of the potential impacts of the project on flooding is provided in Section 18.3. Consideration of the changes to rainfall frequency and/or intensity as a result of climate change on the project is presented in Chapter 25 (Climate change and risk adaptation).

18.1 Assessment methodology

18.1.1 Policy and planning setting

The assessment of potential flooding impacts of the project on existing flood regimes has been conducted in line with the requirements of the *Floodplain Development Manual* (Department of Infrastructure, Planning and Natural Resources, 2005), which incorporates the NSW Government's Flood Prone Land Policy. The key objectives of this policy are to identify potential hazards and risks, reduce the impact of flooding and flood liability on owners and occupiers of flood prone property and to reduce public and private losses resulting from floods. This policy also recognises the benefits of the use, occupation and development of flood prone land.

Other relevant government policies and guidelines were considered as part of the assessment of the project's potential flooding impacts. These are outlined in Technical working paper: Flooding (**Appendix P**).

In addition, the Local Environment Plans and Development Control Plans for the Local Government Areas of Canterbury, Hurstville, Rockdale, Marrickville, Sydney and Botany Bay were considered in terms of relevant floodplain planning provisions. The *Sydney Regional Environmental Plan No 33 – Cooks Cove* was also considered in relation to the potential flooding impacts in the area surrounding the Kogarah Golf Course in the suburb of Arncliffe (refer to Technical working paper: Flooding in **Appendix P** for further details).

18.1.2 Flooding impact assessments

Flooding impact assessments have been undertaken for localised and mainstream flooding for construction and operation of the project. Localised flooding occurs when components of the drainage system are undersized or blocked and cannot accommodate the incoming overland surface flows, resulting in the flooding of a localised area. Mainstream flooding refers to the flooding of land when water overflows the natural or artificial banks of a water body.

The flooding impact assessment included:

- Identification of the flooding assessment study area. The relevant study area for flooding impacts includes:
 - The upper Wolli Creek extent. This area is located within the Upper Wolli Creek Floodplain and between King Georges Road, Kingsgrove in the west, Illoura Park, Earlwood in the east, Poole Street, Kingsgrove in the north and the East Hills railway line, Beverly Hills to the south. This section of the study area, including its existing flooding behaviour, is shown on **Figure 18-1**
 - The lower Cooks River and Alexandra Canal extent. This area is located within the Lower Cooks River Floodplain and between Banksia in the south west and Wolli Creek to the north-west, and to just west of Sydney Airport in the east, for the Cooks River extent. For the Alexandra Canal extent, the study area includes the area from Mascot in the south to just north of Sydney Park Road, between St Peters and Alexandria from west to east. These sections of the study area, including existing flooding behaviour, is shown on **Figure 18-2** and **Figure 18-3** respectively
- A qualitative assessment of flooding during construction, using the existing flood behaviour and drainage infrastructure, for:
 - Localised flooding impacts relevant to the surface works, construction compounds and other structures such as noise barriers
 - Mainstream flooding impacts on the construction process and an assessment of the potential for construction activities to impact mainstream flooding behaviour and adversely affect inundation patterns for nearby properties
- A qualitative assessment of flooding during operation for localised flooding. The impacts of the project on localised flooding and drainage during operation of the project were made based on the connection of new and upgraded drainage systems to existing local drainage networks. Details of the existing networks were sought from the various authorities that own and maintain these networks, typically local councils and Sydney Water, and where available historical information about existing localised flooding issues were gathered
- A quantitative assessment of the potential mainstream flooding impacts during operation in upper Wolli Creek, lower Cooks River and Alexandra Canal.

The assessment methodology for the quantitative flooding assessment included:

- Development of a flood model and characterisation of the existing flood behaviour and drainage infrastructure within the flooding assessment study area. The frequency with which a flood event of a certain size occurs is generally described in terms of its average recurrence interval (ARI). For example, for a flood having a 20 year ARI, there would be floods of equal or greater magnitude once in 20 years on average. Flooding behaviour in the flooding assessment study area was defined for the 20 year ARI flood, 100 year ARI flood and probable maximum flood (PMF). The PMF is the largest flood that could conceivably occur at a particular location. The PMF is defined as the upper limiting value of floods that could reasonably be expected to occur. The 200 year ARI flood was also modelled and is contained in the Technical working paper: Flooding (**Appendix P**). The following flood models were used in the assessment:
 - RAFTS and DRAINS rainfall-runoff modelling software packages were used to generate design discharge hydrographs for input into the hydraulic models

- TUFLOW two-dimensional (in plan) hydraulic modelling software was used to define flooding patterns in the study area. The structure of the upper Wolli Creek and lower Cooks River TUFLOW models was adjusted to incorporate details of the project
- HEC-RAS hydraulic modelling software was used to define the upper envelope of flooding in the vicinity of Bexley Road in the upper Wolli Creek floodplain
- Assessment of the impacts that the operation of the project would have on flooding behaviour during the 20 year ARI flood, 100 year ARI flood and PMF. The future development potential of flood affected land outside the project corridor for residential (and by default commercial and industrial type development) and critical / vulnerable infrastructure was also considered
- Assessment of the impacts of flooding on the project during the 20 year ARI flood, 100 year ARI flood and PMF
- Assessment of the impacts a particle blockage (ie the accumulation of debris) of major hydraulic structures would have on flooding behaviour during operation of the project
- Assessment of the impact future climate change would have on flooding behaviour during operation of the project
- Identification of appropriate management and safeguard measures to minimise and manage flooding impacts.

The 20 year ARI flood and 100 year ARI flood were targeted in the flooding assessment because the:

- 20 year ARI flood provides a frequent flood event
- 20 year ARI flood is relevant to construction due to the duration and temporary nature of the construction works. The likelihood of a 100 year ARI event or a PMF occurring during the construction of the project is low
- 100 year ARI flood is considered the standard flooding planning level during operation. The *Floodplain Development Manual* requires land use planning to consider the 100 year ARI flood for residential development (and by default commercial and industrial type development).

Further details of the assessment of localised flooding impacts during construction and operation, and mainstream flooding impacts during construction are presented in the Technical working paper: Surface water (**Appendix N**). The assessment of mainstream flooding impacts during operation is presented in Technical working paper: Flooding (**Appendix P**).

18.2 Existing environment

A general description of the geomorphology and water quality of the existing catchment and watercourse environments is provided in **Chapter 16** (Soils and water quality). This section outlines:

- Existing drainage infrastructure and surface water management infrastructure of the flooding assessment study area
- The existing flood behaviour of the flooding assessment study area.

18.2.1 Existing drainage infrastructure

The components of the project would include western surface works, Bexley surface works, Arncliffe surface works and St Peters interchange and local road upgrade surface works areas. Within these areas surface water is currently conveyed as overland flow and is collected in established stormwater networks by a combination of stormwater infrastructure elements. These include lined and unlined drainage channels, kerb and gutter networks, and dish drains, all feeding into a well-developed subsurface pit and pipe network. Drainage infrastructure in the area is owned and operated by local councils and Sydney Water.

The existing systems were designed to accommodate the ten year ARI rainfall event, but more likely exceed capacity at around the five year ARI rainfall event. Local flooding usually occurs once the design capacity is exceeded in limited overland flow paths, and where limited downstream inlet capacity exists, resulting in rising water levels.

Table 18-2 summarises key aspects of the existing drainage systems of the sub-catchments relevant to the project.

Table 18-2 Existing drainage systems

Catchment	Project area	Existing drainage systems
Wolli Creek sub-catchment	Western surface works, Kingsgrove Road surface works and Bexley Road surface works	The upper Wolli Creek catchment is completely urbanised with a drainage system comprising of extensive pit and pipe networks. Runoff from the western surface works area and Bexley Road surface works area is conveyed as overland flow that currently flows into the M5 East Motorway drainage system. There is an open channel section of Wolli Creek between Kingsgrove Road and Bexley Road, as well as transverse drainage lines which convey runoff into Wolli Creek from areas north of the M5 East Motorway. The transverse drainage system was designed to convey flows up to the 100 year ARI flood magnitude. Several underpasses were also provided between King Georges Road, Bexley Road, and Kingsgrove Road provide additional capacity to convey flows greater than the 100 year ARI flood.
Cooks River catchment	Arncliffe surface works	The Cooks River catchment is highly urbanised, with extensive subsurface pit and pipe networks. The Arncliffe surface works would be located on the Kogarah Golf Course and would drain directly to the Cooks River.
Alexandra Canal sub-catchment	St Peters interchange and local roads upgrade	Alexandra Canal is a constructed canal, which flows into the Cooks River near the north-western corner of Sydney Airport. The canal is owned and operated by Sydney Water as are the major trunk drainage lines discharging into it. Numerous minor drains in the Alexandra Canal sub-catchment are managed by Sydney, Marrickville and Botany Bay Councils. Three channels discharge into Alexandra Canal: Munni Street Stormwater Channel, Sheas Creek Channel and the Botany Road to Doody Street Channel.

Catchment	Project area	Existing drainage systems
Eastern Channel sub-catchment	St Peters interchange and local roads upgrade	Stormwater runoff is presently generated by a significant catchment along Campbell Road, as far east as the Princess Highway and drains towards the intersection of Campbell Street / May Street / Bedwin Road / Unwins Bridge Road. An existing piped drainage system at the intersection directs runoff into a pipe, then a box culvert that crosses the adjacent railway line before connecting into the Eastern Channel. In larger storm events, stormwater ponds at the intersection before surcharging into an existing detention basin located at the western end of Camdenville Park. The existing basin cannot drain via gravity, and is dewatered by two pumps that direct stormwater into the above-mentioned box culvert. The intersection of Campbell Street / May Street / Bedwin Road / Unwins Bridge Road is frequently flooded as a result of both limited local inlet capacity in the piped drainage network, as well as limited hydraulic capacity in the downstream trunk drainage system.

18.2.2 Existing flood behaviour

Development within the study area is typically well established with a high proportion of residential and commercial land use. Land within the surface water study area is also predominantly of an urbanised nature with small pockets of open space, notably along some of the watercourses. Flood risk in the study area has increased since the onset of urbanisation, leading to catchments with a high percentage of impermeable land causing increased runoff during rainfall events. In addition, concrete drainage lines, relatively low levels of infiltration and reduced flood storage capacity within the catchments also results in a quick response to rainfall events. This is particularly significant in small, frequent storm events and results in high peak flows which can cause flooding in parts of the study area.

Localised flooding may occur within the area during high intensity rainfall events. It is anticipated that these localised flooding events would be of short duration and would have limited impacts to surrounding receptors and infrastructure. The potential for localised flooding is currently managed through the existing drainage and surface water management infrastructure as described above.

As presented in **Section 18.1**, the quantitative assessment focused on the Lower Cooks River floodplain and Upper Wolli Creek floodplain. The existing flood behaviour for these areas for the 20 and 100 year ARI flood is presented on **Figure 18-1** and **Figure 18-2** respectively, and discussed in the following sections.

A detailed assessment of the Eastern Channel was not undertaken as there would be no major structures constructed in its catchment. The mainline alignment tunnels have not been modelled as flooding impacts would not be expected as a result of subsurface works. The quantitative assessment is described in further detail below.

Upper Wolli Creek floodplain

Flooding patterns along Wolli Creek and within the flooding assessment study area were assessed for design floods of 20, 100 and 200 year ARI flood, as well as the PMF.

The areas around the western surface works that would be inundated as a result of a 20 year ARI flood are shown on **Figure 18-1** and include:

- The section of Wolli Creek running along the southern side of the M5 East Motorway, at Kirrang Street. Floodwater surging the channel at this location flows in an easterly direction, where it does not fully re-enter the channel system until it reaches the Kindilan Street underpass
- Residential property at 78 Tallawalla Street, on the southern side of the M5 East Motorway, between Kooemba Road and the Kindilan Street underpass. Property fencing would cause increased inundation, resulting in flows diverting into Tallawalla Street
- Commercial and industrial development located between Beverly Grove Park and Kingsgrove Road, which would be inundated as a result of floodwater surcharging from the southern arm of Wolli Creek. Inundation depths at several properties would exceed one metre.

The areas around the western surface works and Bexley Road surface works that would be inundated as a result of a 100 year ARI flood are shown on **Figure 18-1** and include:

- The northern side of the M5 East Motorway, within the Canterbury Golf Course, and from downstream of Beverly Grove Park to east of Arinya Street
- The southern side of the M5 East Motorway, within properties along the northern side of Tallawalla Street, between Kooemba Road and the Kindilan Street underpass
- Within the Kindilan Street underpass. Floodwater surcharging the main arm of Wolli Creek at Kingsgrove Road discharges in a northerly direction where it initially ponds beneath the M5 East Motorway underpass before discharging in an easterly direction along the northern side of the elevated M5 East Motorway
- The commercial and industrial development located between Beverly Grove Park and Kingsgrove Road, and extending along the northern side of Commercial Road, which would be inundated as a result of floodwater surcharging the from the southern arm of Wolli Creek. Inundation depths at several properties would exceed one metre.

The areas around the western surface works and Bexley Road surface works that would be inundated as a result of a PMF are:

- Areas along the northern side of the M5 East Motorway in the vicinity of Canterbury Golf Course, and to the east and west of Kingsgrove Road, which would experience major ponding of floodwaters during a PMF event
- Properties adjacent to the Wolli Creek canal between King Georges Road and Bexley Road, with major ponding extending along the southern side of the M5 East Motorway between Kooemba Road and Bexley Road.



Figure 18-1 Upper Woll Creek existing flooding behaviour for the 20 year ARI and 100 year ARI

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Lower Cooks River floodplain

The present day flooding patterns along within the Lower Cooks River floodplain within the flooding assessment study area were assessed for design floods of 20, 100 and 200 year ARI, as well as the PMF.

The areas within the Lower Cooks River floodplain that would be inundated as a result of a 20 year ARI flood are shown in **Figure 18-2** and include:

- Cahill Park, on the eastern bank of the Cooks River, and adjacent properties
- Gough Whitlam Park and Mackey Park, to the north of the confluence between Wolli Creek and the Cooks River
- Kogarah Golf Course
- Barton Park South
- Lance Studdert Reserve
- Properties around Lynwen Crescent, Banksia, and northwards towards Spring Street, Banksia
- Properties along William Street, Rockdale.

During a 100 year ARI flood, the magnitude of flooding at the areas inundated during the 20 year ARI flood would increase, with additional flooding occurring in some adjacent areas. In the case of the PMF event, the Kogarah Golf Course would be inundated to depths exceeding two metres, with the peak flood level along its common boundary with Marsh Street reaching about 4.4 metres AHD.

Alexandra Canal flood extent

The present day flooding patterns along Alexandra Canal were assessed for design floods of 20, 100 and 200 year ARI flood, as well as the PMF.

The areas along Alexandra Canal that would be inundated as a result of a 20 year ARI flood are shown in **Figure 18-3** and include:

- Industrial areas south of Huntley Road, immediately upstream of where Sheas Creek becomes Alexandra Canal
- Industrial areas upstream of Campbell Road, St Peters
- Industrial areas along the western extent of Coward Street, and between Coward Street, Mascot and Alexandra Canal
- Downstream of the railway line, between Alexandra Canal and Swamp Road.

During the 100 year ARI flood, the main areas of additional flooding occur within Sydney Airport, and eastwards along Coward Street and Ricketty Street, Mascot. The PMF would cause flooding along the length of Alexandra Canal, extending beyond Kent Street, Mascot and up to the Princes Highway, St Peters. The PMF would also cause flooding within the Alexandria Landfill site.

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Figure 18-2 Lower Cooks River existing flooding behaviour for the 20 year ARI and 100 year ARI

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Figure 18-3 Alexandra Canal existing flooding behaviour for the 20 year ARI and 100 year ARI

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18.3 Assessment of potential impacts

Construction works and operational infrastructure have the potential to change flood behaviour and impact on the surrounding environment. In addition, flooding has the potential to impact on areas within and near construction sites and operational facilities (ie potential inundation of project sites).

An assessment of the flood risks to the project and the surrounding environment, along with development of appropriate mitigation measures, has been carried out in accordance with the Floodplain Development Manual (Department of Infrastructure, Planning and Natural Resources, 2005), the requirements of relevant environmental approvals and industry guidelines.

18.3.1 Construction

During construction, flooding and drainage impacts could result in localised and mainstream flooding. The potential impacts are considered further below.

Localised flooding

All construction works and facilities would have the potential to impact local overland flows and existing minor drainage paths through the disruption of existing flow mechanisms, both of constructed drainage systems or those of overland flow paths. Additionally, flooding during construction of the project could impact areas within and near construction sites (potential inundation of construction sites).

Existing drainage and surface water management infrastructure is identified in **Table 18-2**.

Potential localised flood-related impacts during the construction phase of the project include:

- Interruption of overland flow paths by installation of temporary construction ancillary facilities
- Blocking of drainage networks through increased sedimentation of surface water
- Damage to construction plant or machinery caused by inundation from flood waters
- Increased flooding of adjacent areas due to temporary loss of floodplain storage or conveyance of floodwaters
- Disruption to existing drainage lines during decommissioning, upgrade or replacement of drainage pits and pipes, resulting in localised flooding upstream
- An increase in runoff volumes, peak flows and/or time of concentration following rainfall events due to an increase in impermeable surfaces (ie construction compounds)
- Flow of water into the tunnel construction access points
- Localised areas of flooding and scour from the diversion of drainage lines
- The interruption or diversion of existing flood routes from the location of bunding or spoil within construction compound, resulting in a reduction of flood storage and an increased flood risk to adjacent areas
- Diversion of flow away from designed drainage structures and into new receiving areas, through the removal of existing pavement
- Increased flow rates and volumes in watercourses due to the discharge of treated water from the construction water treatment plants.

These potential impacts would be relatively minor and would be effectively managed through the implementation of mitigation and management measures, as detailed in **Section 18.4**. Further, the potential impacts would be considered during the detailed design phase to ensure that appropriate flood management and flood protection measures are included in the design of the project. For further information refer to Section 6.2.2 of the Technical working paper: Surface water (**Appendix N**).

Expected changes to flow rates and volumes would be managed through the control of discharge flow rates from the construction water treatment plants and standard construction management measures. Erosion and sediment controls would direct water away from the tunnel construction access points. Despite this, there remains a low potential for water to flow into the tunnel during high rainfall events.

During construction planning, an emergency response plan would be developed including the evacuation of the tunnel of construction personnel based on certain heavy rainfall events.

Mainstream flooding

The potential for mainstream flooding to affect the construction process has been assessed, as well as the potential for construction activities to impact flooding behaviour at any nearby properties.

Details of potential flooding impacts to construction compounds are provided in **Table 18-3**. Potential construction flooding impacts of a 20 year ARI flood have been assessed and are considered appropriate due to the duration of the construction works. The likelihood of a 100 year ARI flood or a PMF occurring during the construction of the project is low, and design of flood mitigation and management measures for these events during construction would not be reasonable.

Potential mainstream flooding impacts are generally minor in nature and readily mitigated by managing specific detailed design aspects of the construction compound and site planning to better suit identified flooding conditions and avoid the potential for off-site flooding impacts. Mitigation measures that would be employed are outlined in **Section 18.4**.

Potential flooding during tunnelling excavation

Tunnel boring and cut and cover excavation would occur through temporary shafts at a number of construction compounds and the tunnel portals. Ingress of floodwater into the shafts or portals would pose significant risk to personal safety to those working in the tunnel. Tunnelling excavation works would occur at the following compounds:

- Kingsgrove North construction compound (C1)
- Commercial Road construction compound (C3)
- Bexley Road North construction compound (C4)
- Bexley Road South construction compound (C5)
- Arncliffe construction compound (C7)
- Canal Road construction compound (C8).

Protection such as bunding would be provided to ensure floodwaters do not enter shafts or portals. A detailed risk assessment would be undertaken to inform the flood protection measures put in place, prior to construction. The flood immunity that would be adopted would take into consideration the duration of construction, magnitude of inflows, including local overland flows, and potential risks. The flood mitigation measures adopted to protect shafts and portals would be designed in a way that would not worsen flooding on adjacent property.

Flood management plans would be developed as part of the Construction Environmental Management Plan (CEMP) prior to construction to guide the design of compounds so as to minimise impacts of flooding.

Table 18-3 Potential construction flooding impacts

Project component	Existing flooding conditions	Potential impacts of activities for 20 year ARI event
Western surface works		
Kingsgrove North construction compound (C1)	The construction compound would be located outside of the 20 year ARI flood extent but partially within the 100 year ARI flood extent. The 100 year ARI flood extent would be predominantly confined to the construction compound car park and laydown area. The tunnel dive shaft would be located outside of the 20 year ARI flood, 100 year ARI flood and PMF extents.	None anticipated as the site would only be partially within the 100 year ARI flood extent.
Kingsgrove South construction compound (C2)	The construction compound would be located marginally within the 20 year and 100 year ARI flood extents along areas of the construction compound bordering Wolli Creek. Due to the local topography, the 20 and 100 year ARI flood extents within the compound boundaries are similar.	None anticipated as the 20 year ARI flood extent would not extend into the construction compound beyond inundating the fence/ boundary.
Commercial Road construction compound (C3)	The construction compound would be located completely within the 20 year ARI flood, 100 year ARI flood and PMF extent (including tunnel dive shaft).	All activities would be impacted by a 20 year ARI flood event. The acoustic shed and flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. Temporary compensatory drainage works would be implemented to minimise impacts adjacent to existing development as far as practicable.
Bexley Road surface works		
Bexley Road North construction compound (C4)	The construction compound would be located completely within the 20 year and 100 year ARI flood extents.	All activities would be impacted by a 20 year ARI flood event. The acoustic shed and flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. However these impacts are unlikely to impact existing development.

Project component	Existing flooding conditions	Potential impacts of activities for 20 year ARI event
Bexley Road South construction compound (C5)	The construction compound would be located partially within the 20 year and 100 year ARI flood extents. The boundaries of the 20 year and 100 year ARI flood extents are similar at this location. The compound (including tunnel drive shafts) would be located within the PMF flood extent.	The acoustic shed and flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. However these impacts are unlikely to impact existing development.
Bexley Road East construction compound (C6)	The construction compound would be located completely outside of the 100 year ARI flood extent.	None anticipated due to its location outside of the 100 year ARI flood.
Arncliffe surface works		
Arncliffe construction compound (C7)	The construction compound would be located predominantly within the 20 year and 100 year ARI flood extents.	The majority of activities would be impacted by flooding although the stockpile and acoustic shed are outside of 20 year ARI. Flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. Design of these measures will give consideration to minimising adverse flooding impacts adjacent to existing development north of Marsh Street as far as practicable.
St Peters interchange and local roads upgrade		
Canal Road construction compound (C8)	The construction compound would be located completely outside of the 100 year ARI flood extent.	None anticipated due to its location outside of the 100 year ARI flood extent.
Campbell Road construction compound (C9)	The construction compound would be located completely outside of the 100 year ARI flood extent.	None anticipated due to its location outside of the 100 year ARI flood extent.
Landfill Closure construction compound (C10)	The construction compound would be located completely outside of the PMF flood extent.	None anticipated due to its location outside of the 100 year ARI flood extent.
Burrows Road construction compound (C11)	The construction compound would be located completely outside of the 100 year ARI flood extent.	None anticipated due to its location outside of the 100 year ARI flood extent.
Alexandra Bridge construction compound (C12)	The construction compound would be located partially within the 20 year ARI flood extent and completely within the 100 year ARI flood extent.	Potential minor impacts to activities on the immediate banks of Canal. No measureable impact on flood storage or conveyance anticipated during a flood event.

Project component	Existing flooding conditions	Potential impacts of activities for 20 year ARI event
Gardeners Bridge construction compound (C13)	The construction compound would be only marginally affected by the 20 year ARI flood extent. It would be partially within 100 year ARI flood extent.	None anticipated as the site would be only marginally within the 20 year ARI and 100 year ARI flood extent.
Sydney Park construction compound (C14)	The construction compound would be located completely above the PMF flood extent.	None anticipated as the site would be outside of the PMF extent.

18.3.2 Operation

During operation, flooding and drainage impacts could include the following:

- Impacts from the operational water treatment plant
- Localised flooding
- Mainstream flooding.

The main objective for the drainage design of the project is to provide the required flood immunity for the project and to minimise changes to the existing flood behaviour of land around operational infrastructure.

Operational water treatment plant

As the project tunnels would be drained, there would be ongoing groundwater inflow into the tunnels (refer to **Chapter 19** Groundwater). This would require the ongoing capture, treatment and discharge of groundwater during the operation of the project. Other sources of wastewater within the project tunnels would include stormwater entering the tunnels via the portals, deluge water, washdown water and hydrant water. The discharge of treated water from the operational water treatment plant has the potential to increase flow rates and volumes in watercourses.

Details of the operational water treatment plant are provided in **Chapter 16** (Soils and water quality) and **Chapter 24** (Construction resource use and waste minimisation).

The tunnel drainage system would flow to one sump at the tunnel low point, with a capacity of around 412 cubic metres before being pumped to the operational water treatment plant. The capacity of the sump has been designed to include 50 cubic metres (50,000 litres) of 'spare' capacity to capture accidental operational hydrocarbon or other spillage within the tunnel (for example, in the case of an accident resulting in release of fuel from vehicles). Groundwater leakage from the tunnel walls and floors would also be transferred to the tunnel sump. After being pumped to the operational water treatment plant, the water would be treated and discharged to the Cooks River. The discharge flow rate would be controlled to manage changes to flow rates and volumes.

Localised flooding and proposed drainage infrastructure

Potential localised flood-related impacts during operation include:

- Blockage or temporary diversions of drainage infrastructure, which may result in localised flooding
- Altered catchments from new and widened roads
- New and altered drainage infrastructure, which may not have sufficient capacity to accommodate increased inflow rates.

Existing drainage and surface water management infrastructure as identified in **Table 18-2** would continue to manage surface drainage and potential flooding. Additional upgrades would be carried out where parts of the drainage infrastructure would be impacted by the project and/ or would require relocation.

The drainage structures incorporated into the project would include existing drainage infrastructure around the interchanges, tie-in and integration works, and operational ancillary facilities which would be augmented to meet additional capacity requirements associated with increased impervious areas. Appropriate protection would be provided downstream of relevant drainage infrastructure to prevent adverse impacts on bed and bank stability, and to protect the existing water quality of downstream watercourses. These drainage systems would be designed and implemented to minimise potential impacts on receiving watercourse.

Table 18-4 provides an overview of the proposed drainage systems as part of the project.

Table 18-4 Project drainage systems

Project area	Project component	Proposed drainage upgrades
Western surface works and Bexley Road surface works	Western portals, tolling infrastructure, Kingsgrove and Bexley Road motorway operations complexes (MOC1 and MOC2)	New and / or upgraded drainage infrastructure to be provided as part of the western surface works and Bexley Road surface works includes: • New operational drainage infrastructure connecting existing stormwater infrastructure to a concrete channel at Kirrang Street • A new basin to capture and treat runoff, including one within the western surface works area, one at the surface near the southern extension caverns and one near the corner of Burrows Road and Campbell Road • New and upgraded culverts, including: – A new box culvert to connect existing stormwater pipes to a concrete channel at Kirrang Street, Beverly Hills (near the western end of the western surface works areas) underneath the existing shared pedestrian and cycle path – Extension of the two existing culverts at Kooemba Road, Beverly Hills (near the western end of the western surface works areas), by around 30 metres to accommodate the widening of the motorway at this point.
Arncliffe surface works	Arncliffe motorway operations complex (MOC3)	New and / or upgraded drainage infrastructure as part of the Arncliffe surface works would be confirmed during detailed design. New pipe connections would be installed where the existing transverse drainage requires upgrade and/ or relocation. This would include new and upgraded trunk and transverse drainage infrastructure upgrades. A new basin would also be established to capture and treat runoff at the surface near the southern extension caverns. Pavement drainage would be designed for the 10 year ARI flood, with pits spaced to limit flow width to shoulders where provided or one metre into the adjoining traffic lane where no shoulder is provided. The project would discharge into the existing Wolli Creek concrete lined channel via transverse drainage upgrades.
St Peters interchange	St Peters and Bedwin motorway operation complexes (MOC4 and MOC5)	New and / or upgraded drainage infrastructure to be provided as part of the St Peters interchange works includes: • A new basin to capture and treat runoff near the corner of Burrows Road and Campbell Road • Two water quality basins within the St Peters interchange to capture, store and treat surface water runoff • Upgrades to the existing detention basin in Camdenville Park to ensure downstream peak flow rates are not increased for events up to and including 100 year ARI flood. The required increase

Project area	Project component	Proposed drainage upgrades
		in storage capacity would be confirmed during detailed design • Installation of new hydrodynamic oil and grit separators within the western surface works area, St Peters interchange and local road upgrade surface works area to capture and treat surface water runoff at locations where construction of a surface water basin is impractical and/ or due to site location constraints restricting the construction of a basin • Upgrades to the existing drainage infrastructure that serves local surface roads (within the St Peters interchange and local road upgrade surface works areas), including connection to the existing piped drainage network and/ or provision of a new drainage discharge point at Alexandra Canal.
Local roads upgrades	Local road upgrades affected by flooding	New pipe connections would be installed where the existing transverse drainage requires upgrade and / or relocation. The upgrades and replacements of drainage infrastructure would respond to altered and increased catchments attributed to newly paved areas. Due to the urbanised nature and relatively flat topography of the area, the majority of new pipes would connect into existing networks prior to discharging as surface water. The intersection of Campbell Road and Burrows Road has been identified as having the potential to flood relatively frequently. A culvert would be constructed under Burrows Road to the south of Campbell Road to convey flows to Alexandra Canal. This would be in addition to other smaller transverse drainage pipes. The Munni Street Stormwater Channel would be crossed by a widened bridge structure to allow for the widening of Euston Road. The detailed design of the bridge and roadworks would give consideration to minimising flooding impacts on adjacent property whilst achieving the geometric design requirements for the road. This would be informed by flood analysis with the benefit of detailed survey information relating to existing stormwater infrastructure, ground levels and existing development. The project would include two new discharge outlets into Alexandra Canal: • An open channel discharging immediately to the south-west of the new Campbell Road bridge • A piped discharge outlet immediately to the south-east of new Campbell Road bridge.

Mainstream flooding

Potential mainstream flood-related impacts during operation include:

- An increase in runoff volumes, peak flows and / or time of concentration following rainfall events due to an increase in impermeable surfaces (ie operational infrastructure)
- An increased flood risk in adjacent areas due to the location of operational infrastructure, which has the potential to interrupt or divert existing flood routes and also reduce flood storage.

Mainstream flooding during operation was assessed by modelling the impacts of operational infrastructure and future climate change on flood behaviour. Model scenarios included:

- The 20 year ARI flood, 100 year ARI flood and PMF events
- The impact of a 10 per cent increase in rainfall intensity during a 100 year ARI flood
- The impact of a 0.4 metre rise in sea levels by 2015 on a 100 year ARI flood and PMF.

Potential mainstream flooding impacts are generally minor in nature and readily mitigated by managing specific detailed design aspects and site planning to suit identified flooding conditions and avoid the potential for off-site flooding impacts. A summary of the key flood assessment findings for each project area is provided below and mitigation measures that would be employed are outlined in **Section 18.4**.

Technical working paper: Flooding (**Appendix P**) provides additional details of flood modelling and includes figures showing the predicted impact for each of the modelling scenarios.

Impact of the project on flood behaviour

The impact of the project on existing flooding behaviour on the upper Wolli Creek floodplain for design floods of 20, 100 and 200 year ARI flood, as well as the PMF were modelled (refer to **Figure 18-4**). The key findings of this assessment are as follows:

- The widening of the M5 East Motorway would result in an increase in peak flood levels along the northern side of the M5 East Motorway for floods up to a 100 year ARI. However, the resulting impacts would be confined to the M5 East Motorway corridor and the Canterbury Golf Course
- The project would not increase peak flood levels in existing residential development areas for all floods up to the 100 year ARI flood
- The constriction imposed on flow by widening the M5 East Motorway would lead to an increase in peak PMF levels from around 0.45 metres to about 0.95 metres in the vicinity of the Canterbury Golf Course. The effects of the road widening on peak PMF levels would extend into seven residential properties that are located to the west of the Canterbury Golf Course in Elouera Street and Kirrang Street, Beverly Hills. Flooding in the seven properties would generally be of a ponding nature, with flow velocities shown to be less than about 0.1 metres per second during a PMF event. Inundation of previously flood free land would generally be confined to the landscaped portion of five of the seven properties.

However, floodwater would inundate land bordering the dwellings in Nos. 50 and 52 Elouera Street, Beverly Hills. While floor level survey would be required to determine whether the project would result in the above-floor inundation of these two dwellings, inspection of the LiDAR survey data shows that ground levels in the majority of No. 50 and in the south-west corner of No. 52 Elouera Street lie above the PMF level, indicating that evacuation would still be possible from the two properties by foot during an event of this magnitude. No measures are proposed to mitigate the impact of the project on these properties, as all properties would continue to lie above the residential flood planning level which in the Canterbury LGA is equal to the 100 year ARI event flood plus an allowance of 0.5 metres for freeboard

- The constriction imposed by the widening of the M5 East Motorway would lead to a reduction in peak PMF flood levels on the northern side of the M5 East Motorway in the vicinity of Beverly Grove Park and on the southern side of the M5 East Motorway in the vicinity of Tallawalla Street

The minor change in the distribution of flow in the drainage system would result in a minor increase in peak 100 year ARI flood levels in two industrial / commercial properties located on the

southern side of the M5 East Motorway opposite the outlet of two transverse drainage structures. The maximum increase in peak 100 year ARI flood levels for both properties would be about 20 millimetres

- The realignment of a transverse drainage structure along the M5 East Motorway between Wolli Creek and Garema Circuit would not result in a redistribution of flow in the drainage system for all floods up to the PMF
- The project would not result in more frequent inundations of property or the local road network over the full range of flood events
- The project would not increase the duration of flooding for all events up to the PMF
- The project would not impact existing evacuation routes.

Based on the above findings, the project would not impact the development potential of existing properties for residential, commercial and industrial purposes. However the modelled increase in peak PMF levels along the northern side of the M5 East Motorway, in the vicinity of Canterbury Golf Course, would constrain development in at least one residential property located at Elouera Street, Beverly Hills. The development would be constrained if, for example, the owner wished to augment the existing dwelling to incorporate a more sensitive land use such as child or aged-care facility (note that the existing land zoning is R3 medium density residential under the Canterbury LEP 2012 which permits child care centres and respite day care centres with development consent).

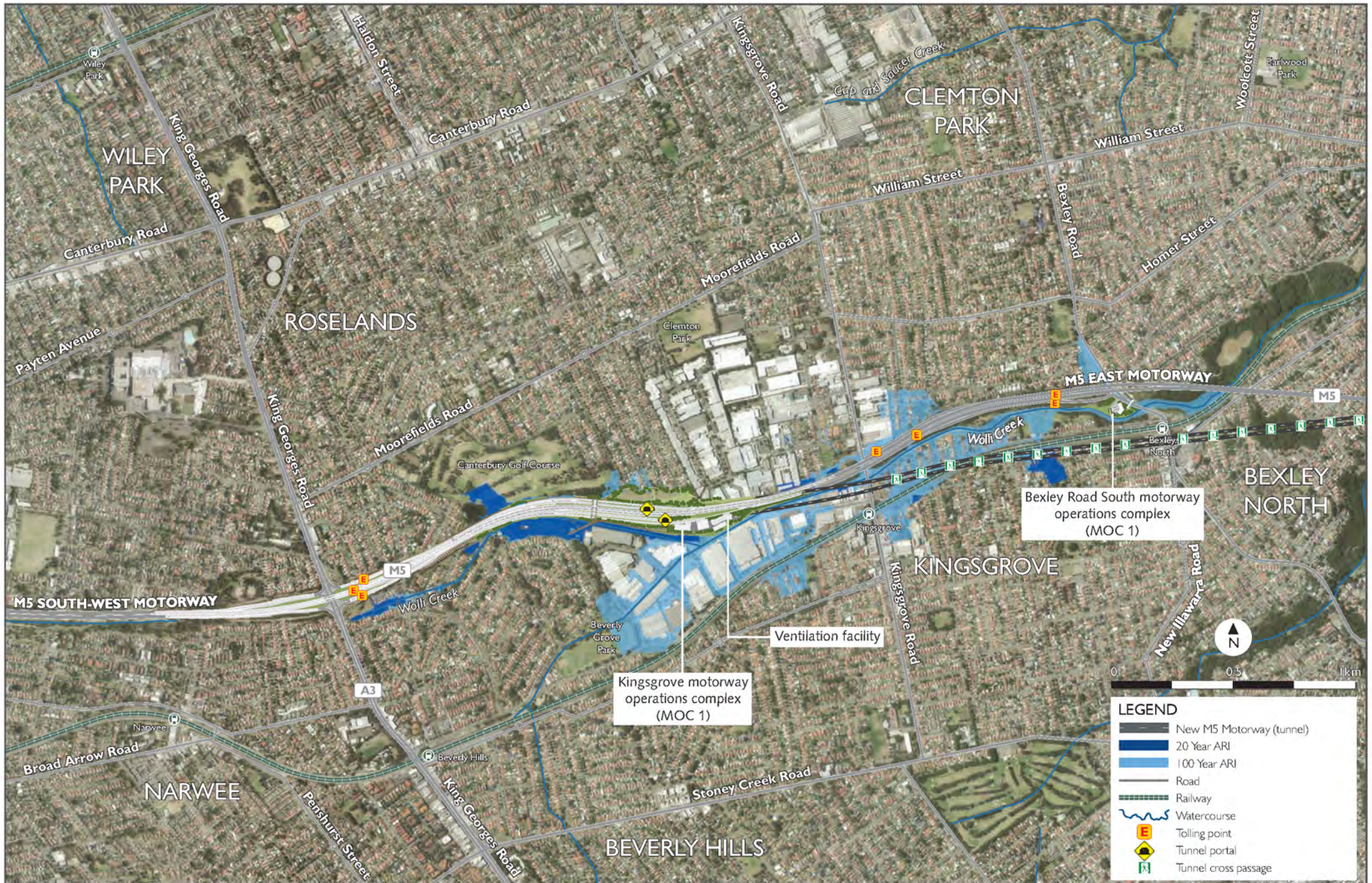


Figure 18-4 Impact of the project on flooding behaviour in the Upper Wolli Creek for the 20 year ARI and 100 year ARI

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The impacts of the project on existing flooding behaviour were modelled for the lower Cooks River floodplain and along Alexandra Canal for design floods of 20, 100 and 200 year ARI floods, as well as the PMF (refer to **Figure 18-5** and **Figure 18-6**). The key findings of this assessment are as follows:

The loss of about 12,000 cubic metres of floodplain storage associated with the construction of the Arncliffe motorway operations complex (MOC3) (based on a worst case disturbance footprint) would result in an increase in peak 100 year ARI flood levels in seven residential properties located on the northern (upstream) side of Marsh Street. The maximum increase in peak flood levels at these properties would be about 10 millimetres. A floor level survey would be required at the abovementioned properties to determine whether the project would result in the above-floor inundation of these properties due to flood levels. The potential impacts would be confirmed based on the detailed design of the Arncliffe motorway operations complex (MOC3).

- The construction of the two new road bridges across Alexandra Canal would generally not impact peak flood levels for events up to a 100 year ARI flood. However, the raising of the Campbell Road / Burrows Road intersection would impact local flooding patterns, leading to an increase in peak 100 year ARI flood levels by about 30 millimetres at two commercial / industrial properties, as well as in a recently upgraded section of TransGrid's Beaconsfield West Substation
- The loss of floodplain storage resulting from the construction of both the Arncliffe motorway operations complex (MOC3), the St Peters interchange and local road upgrades in combination with the constrictive effects imposed by the two new road bridges across Alexandra Canal would result in an increase in peak PMF flood levels across a large portion of the lower Cooks River floodplain. While increases in peak PMF levels would generally be in the range 10 to 50 millimetres, increases of greater than 100 millimetres would occur in an existing commercial / industrial development located on the western overbank of the Alexandra Canal immediately upstream of the Campbell Road bridge
- The resulting increase in peak PMF flood levels would not translate into a significant increase in the extent of flood prone land
- The flood risk at Sydney Airport would not be increased given the minor impact the project would have on flooding behaviour
- The project would not alter the distribution of flows on the lower Cooks River floodplain
- Peak flood levels would generally be increased in the range of 10 to 50 millimetres on the lower Cooks River floodplain, with greater increases to occur immediately upstream of the new Campbell Road bridge (generally in the range of 20 to 200 millimetres) and on the northern side of Marsh Street opposite the Arncliffe motorway operations control centre (MOC3)
- Additional pavement areas from the widening of Campbell Street and adjoining streets would cause a large increase in runoff within the catchment draining to Camdenville Park. The project would include improvements to the hydraulic standard of the drainage system servicing the roads that would be upgraded. This increase in runoff would be offset through provision of additional detention storage within and adjacent to Camdenville Park. This would limit increases in peak flow rates discharged to the downstream trunk drainage system. However the proposed drainage strategy would be determined during detailed design and would be based on not increasing flows into the Eastern Channel for all events up to and including the 100 year ARI flood. An option to achieve this would include the following key elements:
 - Enlargement of the existing detention basin through excavation to lower existing ground levels and the use of retaining walls adjacent to the upgraded sections of Bedwin Road and May Street. As this is a contaminated site, excavation would be planned accordingly. Based on preliminary analysis, the existing storage volume of around 6000 cubic metres would need to be increased to around 17,000 cubic metres to limit peak flow rates downstream of the basin to no greater than occurs under present day conditions for events up to and including the 100 year ARI flood. This required increase in capacity would be confirmed during detailed design
 - Upgrade of the existing discharge system and associated infrastructure including rising mains to suit the enlarged basin, to renew those assets while maintaining the existing pumping capacity

- Construction of supplementary underground detention storage along the south-western side of Bedwin Road, within the space created by realignment of this road. This would be hydraulically connected to the upgraded basin, with discharge via an outlet control structure to the existing box culvert beneath the rail line. The need for this supplementary storage would be confirmed during detailed design.
- The project would not result in more frequent inundation of property or the local road network over the full range of flood events
- The project would not increase the duration of flooding for all events up to the PMF
- The project would not impact existing evacuation routes.

Based on the above findings, the project could potentially increase the frequency and depth of above-floor inundation in a number of residential properties that are located along the northern (upstream) side of Marsh Street opposite the Arncliffe motorway operations complex.

Consultation with TransGrid in relation to the Beaconsfield West Substation has confirmed that a conservative design approach was adopted in the recent upgrade of the substation. This included positioning critical infrastructure above about six metres AHD, and setting all transformer switch bays and reactive plant at ground level (about two metres AHD). Further design development would be undertaken during detailed design in order to mitigate the impact of the project on flooding conditions in the TransGrid site. This would include further refinement of design of the relief drain, as well as the western approach to the new Campbell Street bridge.



Figure 18-5 Impact of the project on flooding behaviour in the Lower Cooks River floodplain for the 20 year ARI and 100 year ARI

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Figure 18-6 Impact of the project on flooding behaviour in the Alexandra Canal extent for the 20 year ARI and 100 year ARI

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Impact of flooding on the project

The Kingsgrove motorway operations complex (MOC1) would be located on land which lies above the extent of a PMF event, and would not be inundated during this event. The Burrows Road motorway operations complex (MOC5), which contains the Motorway Control Centre, would be located on land located above the 100 year ARI flood. However, it would be impacted during the PMF event.

Other motorway operation complexes would be located on land affected by a PMF flood event. Measures would be incorporated in the design of the Bexley Road South, Arncliffe and St Peters motorway operations complexes (MOC2, MOC3 and MOC4) to prevent the ingress of floodwater during a PMF event. For example, components critical to tunnel operations would be located on the first floor of the centre, which would lie above the peak PMF level. These measures would be further developed during the detailed design of the project.

The ventilation facilities at the Arncliffe and St Peters motorway operations complexes would also be designed to be above the PMF event.

Impact of a partial blockage of major hydraulic structures on flood behaviour

A partial blockage of major hydraulic structures located on the upper Wolli Creek floodplain would only have a minor impact on peak flood levels.

A partial blockage of the Southern Western Suburbs Outfall Sewer where it crosses the Cooks River would increase peak 100 year ARI flood levels adjacent to the Arncliffe motorway operations complex (MOC3). A partial blockage of major hydraulic structures located downstream of the Campbell Road bridge would also increase peak PMF levels adjacent to the St Peters interchange.

Impact of future climate change on flood behaviour

While climate change induced sea level rise would not impact the St Peters interchange for events up to the 100 year ARI flood, it would result in the more frequent inundation of Kogarah Golf Course in the vicinity of the Arncliffe motorway operations complex (MOC3). 100 year ARI flood levels would also be increased in the vicinity of the Arncliffe motorway operations complex MOC3 by about 0.49 metres and 0.84 metres in the case of a 0.4 metre and 0.9 metre rise in sea level, respectively.

A rise in sea level of 0.4 metres would result in an increase in peak PMF levels of about 0.13 metres in the vicinity of the St Peters interchange (including the Burrows Road and St Peters motorway operations complexes (MOC4 and MOC5) and about 0.14 metres in the vicinity of the Arncliffe motorway operations complex (MOC3). A sea level rise of 0.9 metres would result in an increase in peak PMF levels of about 0.29 metres in the vicinity of the Burrows Road and St Peters motorway operations complexes (MOC4 and MOC5), as well as the St Peters interchange and about 0.32 metres in the vicinity of the Arncliffe motorway operations complex (MOC3).

18.4 Environmental management measures

Environmental management measures relating to flooding for the construction and operation of the project are provided in **Table 18-5**.

The application of standard mitigation measures and refinements during detailed design are expected to be sufficient to mitigate potential mainstream flooding impacts during construction. Potential impacts on drainage and flooding during operation of the project are expected to be manageable through design of the project.

Table 18-5 Environmental management measures – flooding and drainage

Impact	No.	Environmental management measure	Timing
Construction			
Flood Management Strategy	FD01	A Flood Management Strategy would be prepared by a suitable qualified and experienced person in consultation with directly affected landowners, DPI-Water, OEH and the relevant local councils. It would include but not be limited to: • Identification of flood risks to the project and adjoining areas, including consideration of local drainage catchment assessments and climate change implications on rainfall, drainage and tidal characteristics • Design and mitigation measures to protect proposed operations and not worsen existing flooding characteristics during construction and operation, including soil erosion and scouring • Drainage system upgrades • Preparation of a flood / emergency management plan.	Pre-construction
Flood Management Strategy	FD02	The Flood Management Strategy would be peer reviewed and confirmed as meeting the requirements of this management measure by a suitably qualified and experienced independent hydrological engineer. It would be submitted to the Secretary of DP&E and the relevant local councils prior to construction works commencing in the vicinity of flood prone land and overland flow paths for the waterways and catchments in the vicinity of the project area, or as otherwise agreed by the Secretary of DP&E.	Pre-construction
Flooding design	FD03	The 100 year ARI flood level is to be adopted in the assessment of measures which are required to mitigate any adverse impacts attributable to the project. Changes in flood behaviour under PMF conditions would also be assessed in order to identify impacts on critical infrastructure and significant changes in flood hazards as a result of the project.	Detailed design
Hydraulic assessment	FD04	A detailed hydraulic assessment into the impacts the project would have on flooding behaviour and relevant mitigation measures would be undertaken.	Detailed design
Flooding design	FD05	Works within the floodplain would be designed to minimise adverse impacts on surrounding developments for flooding up to the 100 year ARI flood. Assessment would also be undertaken of the impacts during flooding in excess of the 100 year ARI flood up to the PMF in the context of impacts to critical infrastructure and flood hazards.	Detailed design
Survey	FD06	A floor level survey would be undertaken in affected areas to determine whether the project would increase floor damages in adjacent developments (ie in properties where there is a potential for increases in peak flood levels for events up to the 100 year ARI flood).	Detailed design

Impact	No.	Environmental management measure	Timing
Flood management	FD07	Flood management plans would be developed as part of the CEMP prior to construction to guide the detailed design of temporary ancillary facilities, including construction compounds, to minimise the potential impacts of flooding on the project.	Pre-construction
Flooding in existing residential development	FD08	Around 8,000 cubic metres of the projected 12,000 cubic metres of lost floodplain storage due to the operation of the Arncliffe motorway operations complex (MOC3) would be required to be recaptured. Floor level surveys would be undertaken to determine whether the project would result in the above-floor inundation of the following potentially affected properties. Further design development would be undertaken during detailed design to confirm the extent of works required to mitigate the impact of the project on flooding conditions at these existing residential developments.	Detailed design / construction
Flooding in existing commercial / industrial development	FD09	Detailed design would aim to reduce the impact of the project on flooding conditions for the following two potentially affected properties. This would include consideration of whether the project would result in above-floor inundation of these properties.	Detailed design / construction
Flooding in existing commercial / industrial development	FD10	The potential to reduce impacts of the project on flooding for the properties located on the western overbank of the Alexandra Canal would be considered during detailed design. This would also include consideration of whether the project would result in above-floor inundation of these properties.	Detailed design / construction
Flooding in TransGrid's Beaconsfield West substation	FD11	Further design development would be undertaken to mitigate the impact of the project on flooding conditions in the TransGrid site. This would include further refinement of design of the relief drain, as well as the western approach to the Campbell Road bridge.	Detailed design / construction
Hydrology and flooding	FD12	Existing transverse drainage structures would be left in place during construction where transverse drainage structures are to be upgraded or replaced. If this is not feasible, temporary drainage would be adopted.	Detailed design / pre-construction
Hydrology and flooding	FD13	Detailed flood modelling to understand the effects of likely rainfall events would be undertaken. Construction layouts would be finalised accordingly.	Pre-construction

Impact	No.	Environmental management measure	Timing
Hydrology and flooding	FD14	Tunnel dive shafts would be protected against flooding either through locating openings outside of flood prone areas or constructing temporary bunding and / or appropriate temporary drainage. Stockpiles would be located outside the 20 year ARI flood extent where possible. Where construction compounds are located in the 20 year ARI flood extent, a contingency plan to manage flooding would be prepared and implemented.	Detailed design / pre-construction
Hydrology and flooding	FD15	Further detailed assessment of flooding impacts for proposed construction compounds and relevant management measures would be undertaken during detailed design. Contingency plans to manage flooding would be prepared and implemented for high risk temporary facilities proposed including fuel storages, water treatment plants and substations, as well as for the following construction compounds (located either wholly or partially within the 20 year ARI flood extent): • Kingsgrove South construction compound (C2) • Commercial Road construction compound (C3) • Bexley Road North construction compound (C4) • Bexley Road South construction compound (C5) • Arncliffe construction compound (C7) • Alexandra Canal bridge construction compound (C12) • Gardeners Road bridge construction compound (C13). For these sites, suitable procedures for flood warning, emergency management, site evacuation and planning would be developed.	Detailed design / pre-construction
Hydrology and flooding	FD16	The following measures would be implemented to manage flooding risks on construction sites: • Temporary bunding around parts of the site that would be adversely affected by floodwaters • Temporary drains / detention areas within the site • Use of carparks to provide detention • Elevation of site buildings where necessary to get floor levels above expected flood levels • Use of erosion and sediment fences around noise barriers to provide bunding to some parts of the sites while directing overland flows through less sensitive parts of sites, particularly at Kingsgrove and Arncliffe.	Detailed design / pre-construction
Hydrology and flooding	FD17	A drainage strategy would be determined during detailed design to manage the increased runoff within the catchment draining into Camdenville Park. This drainage strategy would be based on not increasing flows into the Eastern Channel for all events up to and including the 100 year ARI flood.	Detailed design / construction

Impact	No.	Environmental management measure	Timing
Potential impacts of future climate change on flooding	FD18	A more detailed assessment would be undertaken during detailed design to determine the climate change related flood risks to the project and to scope requirements for any management measures. The assessment would be undertaken in accordance with the <i>Practical Considerations of Climate Change – Floodplain Risk Management Guideline</i> (DECC, 2007)	Detailed design
Operation			
Bridges	OpFD01	Bridge crossings over the Alexandra canal would incorporate a suitable freeboard between the underside of the bridge structure and the peak 100 year ARI flood level.	Detailed design / operation
Flooding design	OPFD02	The project and associated arrangements would be designed to limit increases in peak discharges into the downstream drainage systems in accordance with local council requirements.	Detailed design
Drainage and localised flooding	OpFD03	The control and mitigation of potential localised flooding and drainage impacts during operation would include: • Drainage systems that are of insufficient capacity would be modified or upgraded to cater for increased flows • Where new drains connect with existing drainage networks a survey and condition assessment would be undertaken to inform detailed design • The efficiency of transverse drainage upgrades would be taken into account during detailed design • The effects a partial blockage of major hydraulic structures on flooding behaviour would be considered when determining finished road level and flood wall heights.	Detailed design / operation
Tunnel portals and ancillary facilities	OpFD04	Tunnel entries and associated flood protection barriers would be located above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater). The same hydrological 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.	Detailed design / operations
Tunnel design	OpFD05	A suitable freeboard would be incorporated into the design of openings into the new road tunnels (eg at the location of the tunnel portals and ventilation shafts). These designs would take into account the impacts of a partial blockage of major hydraulic structures as well as climate change induced sea level rise on PMF event levels.	Detailed design / operation

Impact	No.	Environmental management measure	Timing
Emergency response facilities	OpFD06	Emergency response facilities, including the motorway control centre, tunnel fire water tank and pump buildings and associated electrical substations would be locate above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater).	Detailed design / operations