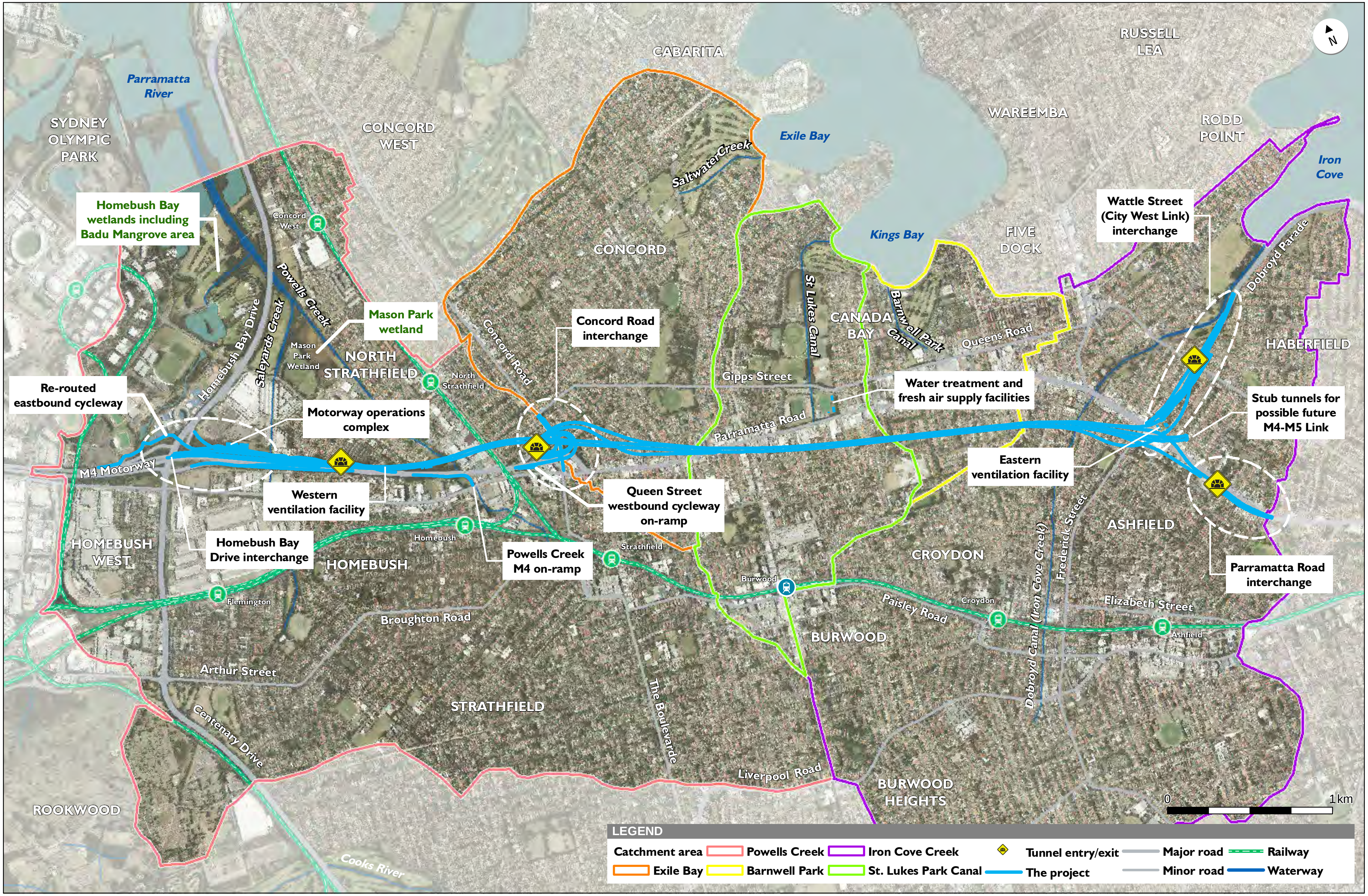

Figure 15.2 Waterways and catchment plan

The waterway referred to as St Lukes Park Canal is an unnamed channel that flows through St Lukes Park, Concord. It is a concrete-lined channel that originates at Parramatta Road. The channel flows adjacent to Concord Oval, between St Lukes Park and Cintra Park, before discharging into Canada Bay north of the western arm of Barnwell Park Golf Club. The project is about 1.4 kilometres upstream of the Parramatta River estuary at this waterway. St Lukes Park Canal is piped at the point where it is crossed by the mainline tunnels. Adjacent to Cintra Park, the riparian corridor comprises grassland with scattered trees.

Another unnamed channel is referred to as Barnwell Park Canal. This waterway is a concrete channel discharging into Kings Bay, just south of Canada Bay. While the open channel does not cross the project alignment, this channel is of relevance as the tunnel meets the surface at the intersection of William Street and Kings Road at Five Dock (within the zone of downstream influence of the project), from where it flows north alongside the Barnwell Park Golf Course to Kings Bay. The project is about 2.1 kilometres upstream of the Parramatta River estuary at this waterway.

Dobroyd Canal (also known as Iron Cove Creek) drains part of the inner-west suburbs of Ashfield, Burwood, Haberfield, Croydon, Drummoyne and Canterbury. This waterway is of importance to the project as the canal crosses the project footprint and then runs parallel to the Wattle Street interchange before discharging into Iron Cove. The project is about 1.6 kilometres upstream of the Parramatta River estuary where it crosses this waterway. Dobroyd Canal (Iron Cove Creek) has a highly urbanised riparian corridor at the point where it is crossed by the mainline tunnels. At Reg Coady Reserve, adjacent to the Wattle Street and Walker Avenue civil site, the riparian corridor comprises grassland with scattered trees.

Riparian connectivity along creek lines that cross the project footprint is minimal due to surrounding residential and industrial areas, with often very little, if any, vegetation present along the edges of the canals to provide wildlife linkages (refer to **Chapter 20** (Biodiversity)).

15.2.3 Sensitive receiving environments

A ‘sensitive receiving environment’ is defined as one that has a high conservation or community value or supports ecosystems or human uses of water that are particularly sensitive to pollution or degradation of water quality.

A sensitive receiving environment of note in the vicinity of the project footprint is the Homebush Bay wetlands area at the downstream end of the Powells Creek channel. This area includes the Badu Mangrove area, which is identified as a Nationally Important Wetland in the Australian Government Protected Areas register. Just upstream of this area is the Mason Park wetland, located between the M4 and Homebush Bay Drive. Mason Park is important habitat for migratory wetland birds listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (EBPC Act) and wetland birds listed under the *Threatened Species Conservation Act 1995* (NSW) (TSC Act). It also contains Coastal Saltmarsh, which is listed as a vulnerable community under the EPBC Act and an endangered ecological community under the TSC Act. The Mason Park wetland is not fully hydrologically connected to Powells Creek, with the base water level in the wetland positioned above the base level of Powells Creek. Limited tidal flushing occurs at high tide via an existing drop-board weir (see **Chapter 20** (Biodiversity)).

The Parramatta River estuary is the final receiving environment for stormwater runoff from the project area, before joining Sydney Harbour. Water quality within the Parramatta River estuary is generally considered to be poor. Urbanisation and surrounding industrial land uses have led to elevated levels of nutrients, gross pollutants and sediment contamination. There has also been extensive alteration to the estuarine foreshore and limited tidal flushing in some areas.

Sensitive receiving environments in the vicinity of the project footprint are shown in **Figure 15.2**.

15.2.4 Water quality

Existing water quality

The water quality in the waterways relevant to the project is largely influenced by stormwater, aquatic weeds and erosion, which are attributable to the catchment in which these creeks reside. Sewer overflows, particularly during high rainfall events, also influence water quality in these catchments, providing additional sources of nitrogen, phosphorus, suspended solids and faecal coliforms.

High pollutant loads including cadmium, copper and zinc have been recorded in Powells Creek (WestConnex Delivery Authority (WDA) 2013). Records show that Dobroyd Canal (Iron Cove Creek) contains high levels of heavy metals, predominantly from cars and runoff from roads (cited in Cardno Lawson Treloar 2008).

A water quality monitoring program has been established to determine the current baseline for water quality in the waterways that may potentially be impacted by the project. The results of the initial two rounds of pre-construction baseline surface water quality sampling conducted in June and July 2015 indicate that:

- Generally the existing nutrient loading in the monitored waterways exceeded the ANZECC Guidelines
- Petroleum hydrocarbons were detected at one site at Barnwell Park Canal, downstream of the project, in June 2015 and at one site at Dobroyd Canal, downstream of the project, in July 2015
- Concentrations of heavy metals copper and zinc exceeded the ANZECC Guidelines at all sites in July 2015. In June 2015, in about half the locations sampled, the concentrations of these heavy metals exceeded the ANZECC Guidelines limits. No traces of heavy metals were detected at the other sites in June 2015
- Suspended solid readings generally decreased slightly in July 2015 compared with the results from June 2015
- Between June and July 2015, a general increase in pH levels was noted (however two locations decreased in pH slightly)
- Turbidity levels at all locations were generally within ANZECC Guidelines.

Water and sediment quality within the Parramatta River estuary is generally poor, largely due to polluted stormwater runoff. There are only limited areas of the Parramatta River estuary that are considered suitable for primary and secondary contact recreational activities. There are a large number of sources of pollutants from urban areas in the estuary catchment, such as:

- Nutrients, eg from fertilisers and cleaning products
- Heavy metals, eg from some industrial sites and roads
- Organochlorine and organophosphate pesticides
- Polycyclic aromatic hydrocarbons associated with heavy industry/combustion
- Phenols used in industrial chemical synthesis
- Sewage from sewer overflows.

Water quality data collected by Sydney Water from the Parramatta River estuary includes monitoring of the following parameters:

- Dissolved oxygen
- pH
- Nitrogen (total nitrogen and biological available forms: ammonia, nitrates/nitrites)
- Phosphorous (total phosphorous and biologically available filterable reactive phosphorous)
- Chlorophyll a
- Faecal coliforms and enterococci.

An analysis of the data in the Sydney Harbour Catchment Water Quality Improvement Plan (cited in Cardno 2012) indicates that average concentrations of these water quality parameters exceed the ANZECC (2000a) aquatic ecosystem health guidelines for south-east Australian estuaries. The exception is for pH, for which the average values are in the acceptable range. Particular hotspots include near Duck River and the Silverwater Road bridge across the Parramatta River, upstream of the project.

Ongoing erosion and sedimentation is a natural process in the Parramatta River estuary catchments. The increased urbanisation of the catchments results in an increased mobilisation of these sediments during rainfall events. Historical accounts suggest very high rates of sedimentation during the early development of the catchment but more recent analysis of sediment cores suggests a rate of sedimentation of between 1.5 and 3.5 millimetres a year over the last 150 to 200 years, which is generally on par with other similar estuaries types of a less disturbed nature in NSW (Geoscience Australia 2012, cited in Cardno 2012).

The construction of canals, weirs and similar features has probably reduced the amount of sediment that can reach the estuary from the lower catchment. However, erosion and sedimentation may continue to occur from the upper catchment or from natural creek lines. Sediments introduced to the waterway can impact negatively on local water quality and sensitive receiving environments.

Existing drainage network and water quality treatment

The stormwater drainage network controls stormwater flows throughout the project area. This network of drains and underground pipes manages stormwater flows from the roads and impervious areas of the catchments before discharging into the Parramatta River estuary. Water quality improvement devices have been incorporated into the stormwater system at a number of locations within the wider project area. Existing water quality treatment measures that have been identified include:

- Gross pollutant traps
  - Three units around Iron Cove
  - Two units at Gipps Street, Concord
  - Nine units within the Canada Bay local government area
- Litter booms
  - One in Saleyards Creek
  - One in Dobroyd Canal
- Onshore litter collection and water-based litter collection for the Parramatta River estuary.

There are no known sediment or water quality treatment basins in the project footprint.

15.3 Assessment of construction impacts

15.3.1 Construction impacts on soils

Soil landscapes and geology

Construction of the project would involve disturbance and exposure of underlying soils which may lead to erosion and sedimentation and potential impacts on water quality. Potential risks to soils from the construction of the project include:

- Removal of riparian vegetation, which has the potential to reduce soil stability leading to soil and waterway bank erosion
- Exposure of soils during earthworks, leading to soil erosion and off-site movement of eroded sediments by wind and/or stormwater to receiving waterways
- Disturbance of contaminated land, leading to the mobilisation of contaminated soils (refer **Chapter 16** (Contamination))
- Direct disturbance of waterway beds and banks during works in or near the riparian zones
- Settlement of soft soils.

Other impacts on soils include compaction and mixing of soils from construction vehicles, stockpiling activities and transportation.

As discussed in **Chapter 6** (Construction work), about 2.4 million bank cubic metres of material would be excavated for the project. In line with the spoil management strategy (refer to **Chapter 6** (Construction work)), where possible, spoil would be reused within the project. Where this is not possible, beneficial reuse of spoil outside the project for environmental and community works and then for site levelling, development or rehabilitation would be selected before disposal is considered as an option.

Salinity

Some construction activities may contribute to the process of urban salinity. In particular, the building of embankments, filling and compacting surfaces associated with surface works near the Homebush Bay Drive interchange and in the M4 road reserve could restrict groundwater flow and result in a concentration of salt in one area. Cutting into slopes for the tunnel dives and cut-and-cover tunnel could result in saline soils or groundwater being exposed and intercepted. In addition, the inappropriate positioning, grading and construction of drains associated with surface road works could result in surface and groundwater mixing and the formation of stagnant pools that evaporate, leaving salt encrusted ground.

15.3.2 Construction impacts on water quality

Impact on waterways and riparian zones

Construction activities have the potential to impact directly on waterways and riparian zones. While the canals are concrete-lined, disturbance of the land around the canals could result in compaction and erosion. Proposed works in riparian areas and removal of vegetation have the potential to reduce soil stability, which can result in erosion and loss of soils, reducing the viability of revegetation. The construction of temporary works platforms, access tracks and use of heavy machinery on the channel edge may degrade the structural integrity of the canal edge, thereby increasing concrete and related material deposits in the waterway and reducing the viability of revegetation. The degraded canal wall could also increase the sedimentation in the watercourse from soil being washed through cracks in the canal wall. The following waterways may be subject to these impacts:

- Permanent impacts on the riparian zone of Saleyards Creek could arise from construction activities at the Homebush Bay Drive civil site (C1) located on either side of the creek. The location of activities is shown on **Figure 6.9** in **Chapter 6** (Construction work).
- Powells Creek riparian corridor could be permanently affected by construction activities from the Underwood Road civil and tunnel site (C3) and Powells Creek civil site (C4) located on the western side of the creek. The location of activities is shown on **Figure 6.12** in **Chapter 6** (Construction work).
- St Lukes Park Canal could be temporarily affected by the Cintra Park tunnel site (C6), which is adjacent to the waterway. The location of activities is shown on **Figure 6.14** in **Chapter 6** (Construction work).
- The project is in tunnel as it crosses under Dobroyd Canal (Iron Cove Creek) the alignment then turns to a north−south alignment where it connects to Wattle Street on the surface. The Wattle Street and Walker Avenue civil site (C9) is directly adjacent to Dobroyd Canal (Iron Cove Creek) and could temporarily affect this waterway during the construction phase. the location of activities is shown on **Figure 6.17** in **Chapter 6** (Construction work).

The permanent widening of the M4 at Saleyards Creek would further increase the existing gap in the planted riparian vegetation. Some planted vegetation in the riparian corridor would be permanently removed from adjacent to Saleyards Creek where the M4 crossing is located and from the Powells Creek civil site. There would be very limited clearing of planted trees from the Cintra Park civil site adjacent to St Lukes Park canal and from Reg Coady Reserve adjacent to Iron Cove Creek Canal. Revegetation would be undertaken where possible, on completion of the construction works. No planted vegetation would be removed from Barnwell Park Canal. As discussed in **Chapter 20** (Biodiversity) the limited removal of planted vegetation at these locations would have a negligible impact on the ecological value of riparian corridors, given that this vegetation is planted above the concrete sides of the canals and does not contribute to the health of water quality of the creeks. The permanent loss of small areas of vegetation at Saleyards Creek and Powells Creek would not impact the riparian corridor connectivity along the watercourses.

Water quality

Water quality impacts from surface works

Water quality impacts during surface works could result from general civil works and handling of spoil associated with the construction of the tunnel, surface road changes and ancillary facilities. These would have the potential to result in sediment transport and sedimentation, and potential contamination of downstream watercourses.

The greatest risk to water quality from erosion and sedimentation would be when these activities occur near waterways (such as Saleyards Creek and St Lukes Park Canal), on steep slopes or on land subject to overland flow or flooding. Runoff during storm events from stockpiles and areas of open cut that have not been appropriately stabilised or contained can also lead to sediment loading. These activities have the potential to increase sedimentation from runoff in downstream waterways and to contaminate waterways from chemical or hydrocarbon spills in the construction zone.

The earthworks and construction of the above ground sections of the project would also require the removal of existing vegetation, which would disturb and expose the soils close to overland flowpaths and waterways. The existing waterways are highly modified with low aesthetic and water quality value. The removal of vegetation associated with the construction works is expected to be in small areas only; therefore the potential impact of sediment and erosion deposition on downstream waterways caused by vegetation removal would not be significant. Similarly, the disturbance and movement of materials and soil due to demolition and the construction of buildings, ramps and road widening/realignment would be localised and would not be likely to result in mass sedimentation in the downstream waterways.

Uncontrolled impacts on receiving waterways are unacceptable and appropriate containment and stabilisation practices, in accordance with the Blue Book (NSW Government 2004), would be implemented as part of the project to mitigate impacts. While there are potential surface water impacts during the construction of the project, most construction-related risks, such as earthworks, spills, and location of stockpiles and equipment, can be managed with standard controls and methodologies (refer to **section 15.5**).

Water quality impacts from construction ancillary facilities

Construction ancillary facilities would be required at 10 locations. Activities that may be required within each site include vegetation removal and earthworks to establish the site, demolition of existing buildings, stockpiles, access and egress of vehicles to and from the site and public roads (including vehicle washes) and chemicals/fuel stored on site. Impacts on water quality from these activities could include:

- Erosion and sedimentation from open cuts/exposed soils and stockpiles being transported by stormwater runoff and entering into waterways
- Leakage/spills of hydrocarbons or other chemicals from machinery entering waterways or the stormwater pipe network
- Vehicles entering and exiting surface construction ancillary facilities, transferring soil to adjacent roads, with these soils then washed into the stormwater pipe network and ultimately adjacent waterways.

Construction ancillary facilities may affect the following waterways:

- Saleyards Creek: Homebush Bay Drive civil site (C1) and Pomeroy Street civil site (C2)
- Powells Creek: Underwood Road civil and tunnel site (C3), Powells Creek civil site (C4), and Concord Road civil and tunnel site (C5)
- St Lukes Park Canal: Cintra Park tunnel site (C6)
- Dobroyd Canal (Iron Cove Creek): Northcote Street tunnel site (C7), Eastern ventilation facility site (C8), Wattle Street and Walker Avenue civil site (C9), and Parramatta Road civil site (C10).

Water quality impacts from demolition works

The typical impacts on surface water quality from demolition works would be through mobilised dust, litter and other building materials being deposited and picked up by surface water runoff, waterways or stormwater management infrastructure, thereby degrading the quality of the natural receiving environment. The transportation of building waste from the demolition sites could potentially have an impact on the quality of the waterways through accidental spills/material drops and deposition entering the stormwater network. Some materials that are typically found in building demolition, such as lead-based paints and chemicals, can be easily transported from the demolition site through off-site stormwater runoff. These pollutants can be ingested by aquatic fauna. Sources of pollutants that could affect water quality from building demolition works may include:

- General household waste and litter
- Asbestos, synthetic mineral fibres and other building materials
- Toxic or pollutant laden soils including fertilisers and pesticides
- Heavy metals
- Chemicals including hydrocarbons and fluids associated with demolition processes and machinery
- Dust and airborne pollutants.

These impacts are of relevance to those construction ancillary facilities directly adjacent to the identified waterways:

- Homebush Bay Drive civil site (C1) – Saleyards Creek
- Underwood Road civil and tunnel site (C3) – Powells Creek
- Cintra Park tunnel site (C6) – St Lukes Park Canal
- Wattle Street and Walker Avenue civil site (C9) – Dobroyd Canal (Iron Cove Creek).

Water quality impacts from tunnel works

Water could enter the tunnel in the following ways:

- Water used for heat and dust suppression activities
- Water used for washdown of cut faces for shotcreting and concrete works activities
- Natural groundwater seepage
- Rainfall runoff from tunnel portals and ventilation shafts.

A high proportion of the water discharged from the tunnel would be associated with groundwater infiltration (see **Chapter 18** (Groundwater)). The quality of this groundwater is likely to be variable and potentially affected by contamination or acid sulfate soils.

The use of chemicals in the treatment and curing process of concrete, as well as the concrete dust itself, could also increase the alkalinity of this water. It is also likely that ammonia and nitrate concentrations would be elevated by blasting residues during construction; however, the likely levels and potential impact of these concentrations are expected to be negligible. Saline inflow would not be expected to develop during the construction phase.

Water discharged from the tunnel construction has the potential to result in contamination of downstream waterways and receiving environments. This water would require the settling of sediments, the use of flocculation for finer sediments and pH in the project treatment ponds prior to discharge.

As described in **section 6.10.3** of **Chapter 6** (Construction work), construction water treatment plants would be provided to treat tunnel groundwater and dirty construction water prior to discharge at the following locations:

- Underwood Road civil and tunnel site (C3), discharging to a concrete stormwater canal that forms a tributary of Powells Creek
- Concord Road civil and tunnel site (C5), discharging to a stormwater pipe under Concord Road that ultimately discharges to Canada Bay
- Cintra Park tunnel site (C6), discharging to St Lukes Park canal located along the eastern side of Concord Oval
- Northcote Street tunnel site (C7), discharging to a stormwater pipe under Parramatta Road that connects to Dobroyd Canal (Iron Cove Creek)
- Eastern Road ventilation facility site (C8), discharging to a stormwater pipe that connects into Dobroyd Canal (Iron Cove Creek).

Where practicable, wastewater from water treatment plants would be reused during construction.

Water quality impacts from spills

The potential impacts of the operation of machinery, with the attendant potential for hydrocarbon spills, are expected to be unlikely and of minor significance. However, in the unlikely event of a larger spill, the impacts could be significant for sensitive receiving environments downstream. Appropriate management measures are provided in **section 15.5**.

15.4 Assessment of operational impacts

15.4.1 Operational impacts to soils

Soil landscapes and geology

Following construction of the project, there is a period within the operational phase during which recently disturbed soils would be susceptible to erosion from stormwater runoff. Areas where this could be an issue are in the vicinity of Saleyards Creek and Dobroyd Canal (Iron Cove Creek) at the Homebush Bay Drive, Concord Road and Wattle Street interchanges, and at the former construction ancillary facilities. Stabilisation or soil improvement following construction may be required to prevent further erosion or to mitigate soil damage from compaction or loss of topsoil during the construction phase.

The modification of overland flowpaths and the realignment of these can also cause an increase in scour of surface soil, banks or bed material and resultant sedimentation in areas that were not previously subject to concentrated stormwater runoff, such as downstream waterways.

The potential for sediment transport and sedimentation issues is influenced by factors such as severity of storm events, the slope and footprint of the disturbed area and the management controls implemented on site. Key scenarios/area types where soil erosion could potentially occur during the operational phase of the project comprise:

- Cut batters
- Fill embankments.

These areas are expected to be susceptible to erosion, particularly during the early operational phase during which time there is settling of topsoil and vegetation is still establishing itself. The erosion of these areas during rainfall events would lead to the loss of topsoil required for vegetation establishment and would cause sediment loads to enter into the waterways. This would contribute to the degradation of the soil environment and could expose the underlying geology.

15.4.2 Operational impacts to water quality

Impact to waterways and riparian zones

Riparian zones and areas in the vicinity of the waterways may require rehabilitation in the form of revegetation, stabilisation or soil improvement following construction. Ongoing erosion or soil damage from compaction or loss of topsoil would have the potential to result in continuing reduction of quality in the riparian environment. Changes in flow volumes and velocities from new impervious surfaces could lead to scour and erosion impacts in local waterways.

While the major waterways are predominantly concrete-lined channels, there are sections of the canal banks and riparian areas that have small pockets of vegetation and could be directly affected by the operation of the project. This would include a reduction in existing vegetative cover, a reduction in bank stability and an increase in exposed soil surface adjacent to the canals and subsequent erosion. This has the potential to negatively impact the bankside environment.

The predominant riparian corridors that would potentially be permanently affected include Saleyards Creek where it is crossed by the project and Powells Creek near the Powells Creek M4 westbound on-ramp. This area of the creek would be impacted by overshadowing from the M4 and the proposed on-ramp. The additional area of riparian corridor that is potentially affected by the project is small and the riparian corridors are highly modified urban environments, with only pockets of vegetation ie grass and trees. The small areas of riparian vegetation disturbed by the project would be re-established following construction. Given the lack of native species and the presence of the concrete canal, removal of this vegetation would have negligible impact on the riparian connectivity.

The Wattle Street interchange in the vicinity of Dobroyd Canal (Iron Cove Creek) could impact on the waterway by increasing impermeable areas, leading to increased runoff. It is expected that these impacts would be relatively minor, as the surface component of the project directly adjacent to Dobroyd Canal (Iron Cove Creek) would not differ greatly from the current urban land use.

Water quality

Surface water quality impacts

A small increase the amount of impervious ground in the surface water catchment areas would have potential for a minor additional adverse impact on the hydrological regime by increasing runoff volumes and peak flows. Potential risks to water quality associated with the operation of the project would include:

- Contamination of waterways associated with mobilisation of pollutants in stormwater runoff
- Reduction of water quality and degradation of natural habitats in sensitive receiving environments from discharge of tunnel drainage water
- Contamination of waterways as a result of spills.

At the interchange locations there is a need to convert sections of once pervious areas (such as lawns, public parks and vegetated areas) alongside the existing carriageways into impervious (sealed) surfaces. The increase in impervious or paved areas could lead to an increase in stormwater runoff and therefore the mobilisation of any stormwater pollutants that would otherwise be filtered out by pervious surfaces prior to discharge into waterways downstream. The increase in impervious surface area also causes an increase in the volume and velocity of flows, which can scour surface soil and increase sediment loading in downstream waterways.

Operational impacts of the project on the quality of stormwater runoff would be consistent with a major roadway that is traversed by light and heavy vehicles. Contamination of the waterways can be caused through stormwater runoff containing typical pollutants such as oils and greases, petrochemicals and heavy metals as a result of vehicle leaks. Atmospheric deposition and maintenance activities during operation may also result in herbicides, fertilisers, nutrients and eroded material being transferred to surface waters. Contamination of waterways by these pollutants would result in habitat degradation and negatively impact on the health of aquatic flora and fauna species.

The project would be a major element of Sydney's road infrastructure. The potential impacts on water quality from spills during the operation of the project would therefore be directly related to the potential spill of vehicle oils, lubricants, hydraulic fluids and other accidental spills, including chemicals in transit through leakage or as the result of a crash. Any such spill has the potential to pollute the downstream waterways via the stormwater and therefore cause degradation of water quality and detrimental effects for the riparian and Parramatta River estuary receiving environments.

Given the presence of significant road infrastructure in the project area, any impacts resulting from the project would be in addition to those impacts already existing.

Water quality impacts from the tunnels

The proposed design and construction of the project incorporates tunnelled sections, cut-and-cover sections and dive structures. The project would therefore have impacts on the movement and collection of stormwater across and in the vicinity of the road alignment.

During large storm events, or when road drainage may become blocked, there is the potential for stormwater to run down the roads and collect in the tunnel. This runoff would carry any pollutants or sediments from the roadway, and any other runoff from within the tunnel. This, along with any groundwater ingress, would be captured and discharged from the tunnel by means of a pumping system to a water treatment facility, which is described in **Chapter 5** (Project description). The runoff could contain concentrations of pollutants that would ultimately be discharged into the receiving waterways downstream, which would have potential negative impacts on the water quality and natural habitats in these receiving waters.

Given the depth of the tunnel and predicted long-term groundwater levels, there is also potential for lateral inflow of saline water from existing unlined tidal drains at the western and eastern ends of the tunnel as well as the potential for drawing up deeper saline groundwater. Such saline inflow may not develop immediately and may take several years to impact on inflow water quality; however, it is likely to develop over the design life of the tunnel. Groundwater inflows would flow to a sump with a dedicated groundwater chamber, from which it would be pumped to the water treatment facility at Cintra Park. All runoff captured by the tunnel drainage system would flow to the sump containing a hydrocarbon chamber and stormwater/deluge water chamber where it would be treated separately from groundwater. It would then be pumped to a water quality basin located at Cintra Park, before discharge to the local stormwater system. The tunnel drainage system, including a water treatment facility located at Cintra Park, has been designed to accommodate the capture, removal, treatment and discharge of groundwater and other water entering the tunnels.

The assessment of groundwater chemistry presented in Chapter 18 (Groundwater) suggests that there are inherent aspects of the existing groundwater quality, particularly with regard to salinity, pH, metals, sulfate and nitrate, which may require management at the surface treatment plant to prevent impacts to surface water quality. Discharges from the water treatment plant would be directed to St Lukes Park Canal. While this canal is tidally affected, surface water quality monitoring indicates that the downstream location in St Lukes Park Canal has salinity characteristics indicative of freshwater. Salinity would either be treated before discharge into St Lukes Park Canal or the discharge of untreated saline groundwater may be managed by strategic placement of discharge points in downstream areas that are more influenced by saline conditions. A description of the water treatment facility is provided in **section 5.8.3** of **Chapter 5** (Project description), and further details of groundwater quality are provided in **Chapter 18** (Groundwater).

The washing of the tunnels as part of ongoing maintenance would mobilise fine particulates and pollutants from the tunnel internal surfaces into the stormwater drainage system, and ultimately the receiving waterways, if appropriate treatment measures are not employed. The potential impacts on downstream waterways would be the degradation of water quality and the natural habitats in these receiving waters.

In addition to the impacts of stormwater, groundwater inflow and tunnel washing, the collection and surface discharge of fire suppressant and pollutant spills in the tunnel could have a potential impact on water quality in the adjacent waterways if appropriate treatment measures are not implemented. The tunnel drainage system would capture and convey stormwater and groundwater captured within the tunnel to the water treatment facility, where it would be treated and discharged.

15.5 Management of impacts

Most construction related risks, such as earthworks, spills, and location of stockpiles and equipment, can be managed with standard controls and methodologies. Monitoring of discharged water would be required throughout construction to confirm that the discharged water quality meets the required standards of the receiving environment and the project environment protection licence.

The potential surface water impacts associated with tunnel construction and associated activities would be managed by other non-standard construction mitigation measures, including installation and commission of construction water treatment plants.

15.5.1 Project design features that manage impacts

During construction, water from the tunnelling process would be captured and treated at six water treatment plants located along the project footprint. Erosion, sediment and pollution control measures would be implemented to manage surface sections of the construction works. The project includes temporary water quality and spill containment basins at construction ancillary facilities and along the project alignment. The number, location and size of these basins would be confirmed during detailed design.

The project also incorporates appropriate operational surface water management and drainage design measures in order to adequately manage potential ongoing operational impacts to surrounding watercourses. This would include the capture, treatment and discharge of groundwater inflow into the tunnels, provision for spill containment within the tunnels and the augmentation of existing drainage infrastructure along the project footprint. This infrastructure would work together to form a treatment train whereby the larger pollutants are primarily managed by the gross pollutant traps and grassed channels, and the finer pollutants would be managed by the water treatment facility and basins.

The criteria for discharge from the surface carriageways during operation to surface water would be based on Part N of the Strathfield Consolidated Development Control Plan 2005, which provides clear targets for water quality.

15.5.2 Environmental management measures

Environmental management measures to minimise impacts to soils and water quality during construction and operation of the project are provided in **Table 15.4**.

Table 15.4 Environmental management measures – soil and water quality

Impact	No.	Environmental management measure	Responsibility	Timing
Construction				
Managing soil and water in general	SW1	A soil and water quality management plan will be prepared in consultation with the New South Wales Environment Protection Agency and NSW Office of Water and in accordance with: • Blue Book requirements • RTA *Code of Practice for Water Management* (RTA 1999).	Construction contractor	Pre-construction
	SW2	Work method statements will be prepared for waterway works with particular emphasis on the early implementation of erosion and scour protection requirements.	Construction contractor	Pre-construction
	SW3	A qualified soil conservationist will develop the initial project erosion and sediment control plans and advise on appropriate controls, implementation and monitoring and management processes.	Construction contractor	Pre-construction and construction
	SW4	Tool box talks or similar inductions will be carried out to inform employees of erosion and sedimentation control plans.	Construction contractor	Pre-construction and construction

Impact	No.	Environmental management measure	Responsibility	Timing
	SW5	A surface water quality monitoring program for the pre-construction, construction and operation will be undertaken in accordance with the ANZECC Guidelines and RTA Guideline. The program will be periodically reviewed so that it provides appropriate information relevant to the project implementation phase.	Construction contractor	Pre-construction and construction
Erosion risk	SW6	Measures will be implemented to minimise the risk of erosion and sedimentation. These measures may include: • Disturbed areas will be minimised and revegetated or stabilised as soon as practical. • Erosion control measures such as sediment fences, check dams, temporary ground stabilising, diversion berm or site regrading will be installed as appropriate. • Where practical, clean water will be diverted away from works or disturbed areas. • Measures will be employed to control ground stability and limit run-off lengths and velocities within the construction ancillary facilities. • Wheel wash or rumble grid systems will be installed, where practical, at compound heavy vehicle exit points to minimise the transfer of soil from construction areas to roadways. • Erosion and sedimentation controls will be regularly inspected to maintain performance to the design criteria and design specifications. Controls are to be upgraded or altered if these objectives are found to not be satisfied.	Construction contractor	Pre-construction and construction

Impact	No.	Environmental management measure	Responsibility	Timing
Scour protection	SW7	Measures will be implemented to minimise the risk of scour of waterways. These measures may include: • Permanent scour protection measures required for the operational phase will be installed early, where practical. • Work platforms or access tracks required in the vicinity of waterways will be constructed of large clean rock material wrapped or underlain with geofabric.	Construction contractor	Construction
Stockpile management	SW8	Measures will be implemented to manage stockpiles. These measures may include: • Stockpiles will to be located outside of overland flowpaths, riparian corridors and finished and contoured so as to minimise loss of material in flood or rainfall events. • Stockpiles left exposed and undisturbed for longer than 28 days will be stabilised by compaction then either: – Sprayed with suitable tackifier – Covering with anchored fabrics – Seeded with sterile grass.	Construction contractor	Construction
Pollution control	SW9	Measures will be implemented to minimise the risk of spills. These measures may include: • Spill containment will be included at locations where there is direct discharge of stormwater to receiving waterways. • Appropriately bunded areas will be provided for storage of hazardous materials such as oils, chemicals and fuels. • Adequate controls around stockpile areas and excavation works will be installed to minimise the risk of contaminants being washed into waterways or stormwater systems. • Maintenance of containment/spill infrastructure and clean-up procedures for on-site spills will be undertaken. • Spilt materials and/or any contaminated materials will be disposed of appropriately.	Construction contractor	Construction

Impact	No.	Environmental management measure	Responsibility	Timing
Rehabilitation of disturbed and riparian zones	SW10	Disturbed areas, including riparian environments, will be rehabilitated as soon as practical. Measures will include revegetation (using native species from the relevant local vegetation communities) and stabilisation.	Construction contractor	Construction
Operation				
Operational water quality	OpSW1	Measures to prevent runoff, stormwater or spillage being directed onto other roadways outside of the project footprint will be implemented.	Construction contractor	Operation
	OpSW2	Water quality monitoring will continue from SW5 for at least 12 months post-construction or until any affected waterways are certified by an independent expert as being rehabilitated to an acceptable condition as required by any condition of approval.	Construction contractor	Operation

16 Contamination

This chapter outlines the potential contamination impacts associated with the M4 East project (the project). A detailed soil and land contamination assessment has been undertaken for the project and is included in **Appendix P**.

The Secretary of the NSW Department of Planning and Environment has issued a set of environmental assessment requirements for the project; these are referred to as Secretary's Environmental Assessment Requirements (SEARs). **Table 16.1** sets out these requirements as they relate to soil and land contamination, and identifies where they have been addressed in this environmental impact statement (EIS).

Table 16.1 Secretary's Environmental Assessment Requirements – contamination

Secretary's Environmental Assessment Requirement	Where addressed in the EIS
Identifying potential impacts of the development on acid sulphate soils in accordance with the relevant guidelines and a description of the mitigation measures proposed to minimise potential impacts	**Section 16.4.2** (impacts) and **section 16.6** (mitigation)
A contaminated lands assessment in accordance with relevant guidelines	**Chapter 16** (this chapter) and **Appendix P**.

16.1 Assessment methodology

The framework for the assessment has been developed in accordance with guidelines "made or approved" by the NSW Environment Protection Authority (EPA) under Section 105 of the *Contaminated Land Management Act 1997* (NSW) (CLM Act). These guidelines include the following:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000a)
- *National Environment Protection (Assessment of Site Contamination) Measure 1999* (ASC NEPM)
- *Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites* (NSW Office of Environment and Heritage (OEH) 2011)
- *Contaminated Sites: Guidelines on the Duty to Report Contamination under the CLM Act 1997* (Department of Environment and Climate Change 2009b)
- *Sampling Design Guidelines* (EPA 1995)
- *Contaminated Sites: Guidelines for the Assessment and Management of Groundwater Contamination* (Department of Environment and Conservation (DEC) 2007)
- *Contaminated Sites: Guidelines for NSW Site Auditor Scheme (2nd Edition)* (DEC 2006b)

Additional guidelines referred to in this report are:

- *Acid Sulfate Soil Assessment Guidelines* (Stone et al 1998)
- Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Technical Report No. 10: *Health screening levels for petroleum hydrocarbons in soil and groundwater* (Friebel and Nadebaum 2011).
- *Waste Classification Guidelines, Part 1: Classifying Waste* (EPA 2014).

16.1.1 Desktop review

The following sources of information about existing contamination issues within the project footprint were reviewed:

- Current and historical aerial photographs to determine what current and past land uses may have resulted in contamination

- Historical title deeds to determine past uses of commercial properties and therefore the potential for contamination
- NSW Roads and Maritime Services (Roads and Maritime) spill database to determine if any spills have occurred in the vicinity of the project that could result in contamination
- Geological, soils, acid sulfate and hydrogeological maps and data
- EPA regulatory searches such as the Contaminated Land: Record of Notices (contaminated land record), list of NSW contaminated sites notified to the EPA, and the environment protection licences (EPL) public register
- Relevant council information such as regulatory information and policies relating to the management of contaminated sites, and planning certificates under Section 149 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act)
- Available previous site investigation reports for areas located along the project.

16.1.2 Site inspection

Site inspections were undertaken on 27 February, 4 March and 11 September 2014 and 15 July 2015. These inspections considered the following:

- Land use immediately adjacent to the construction and operational footprints
- Potential sources of contamination that could pose a constraint or require management as part of the project
- Targeted areas of potential concern identified during the information review described in **section 16.1.1**
- The nature of the project, particularly in relation to the construction of the tunnels, widening activities and construction of on- and off-ramps and the need to manage any potential for contamination in these areas during construction work.

The site inspection included all areas affected by the project, including areas that would be used during construction only. However, the inspection did not include detailed investigations of residential and commercial properties to be acquired as part of the project.

16.1.3 Site investigations

Targeted contamination and acid sulfate soil investigations were undertaken between 22 September and 3 November 2014. These investigations involved the following:

- 33 soil boreholes were extended to a maximum of between 0.5 and 7.5 metres below ground level
- 25 boreholes were extended to a maximum depth of between 4.5 and 26 metres below ground level, to allow collection of soil samples and installation of groundwater monitoring wells.

These borehole locations were selected based on the desktop assessment undertaken for the project. Areas identified as ‘moderate’ and ‘high’ risk of contamination were targeted as part of the targeted investigations.

Each borehole was assigned a unique identifying number (eg BH1301) which is used throughout this chapter. The location of these boreholes is shown in **Figure 16.1** to **Figure 16.7**. Sampling of all groundwater wells and selected soil and all groundwater samples were analysed by a National Association of Testing Authorities (NATA) accredited laboratory for a range of contaminants of potential concern.

16.1.4 Preliminary conceptual site model

Based on information collected during the desktop review and site inspection, a conceptual model was developed to identify any areas of known contamination or potential areas of contamination. The model identifies potential sources of contamination, any potential for contaminants to migrate into the project footprint (referred to as pathways) and any potential impacts on the community.

Figure 16.1 Contamination assessment sections and potential contamination - Map 1

Figure 16.2 Contamination assessment sections and potential contamination - Map 2

Figure 16.3 Contamination assessment sections and potential contamination - Map 3

Figure 16.4 Contamination assessment sections and potential contamination - Map 4

Figure 16.5 Contamination assessment sections and potential contamination - Map 5

Figure 16.6 Contamination assessment sections and potential contamination - Map 6

Figure 16.7 Contamination assessment sections and potential contamination - Map 7

16.1.5 Study area

The project footprint was divided geographically into seven sections that were used to describe the existing environment. These seven sections are as follows:

- Section 1: West of Homebush Bay Drive at Homebush to Pomeroy Street at Homebush
- Section 2: Pomeroy Street to Ismay Avenue at Homebush
- Section 3: Ismay Avenue at Homebush to Carrington Lane at North Strathfield
- Section 4: Carrington Lane at North Strathfield to Broughton Street including Cintra Park Reserve at Burwood/Concord
- Section 5: Broughton Street at Burwood/Concord to Dobroyd Canal (Iron Cove Creek) at Croydon/Five Dock/Haberfield
- Section 6: Dobroyd Canal (Iron Cove Creek) at Croydon/Five Dock/Haberfield to Bland Street including Wattle Street at Haberfield/Ashfield
- Section 7: Bland Street at Haberfield/Ashfield to Orpington Street at Haberfield/Ashfield.

The extent of the seven sections is shown in **Figure 16.1** to **Figure 16.7**.

16.2 Assessment criteria

The investigation levels used to evaluate measured chemical concentrations in soil and groundwater samples were developed based on the following guidelines:

- ASC NEPM
- Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Technical Report No. 10: *Health screening levels for petroleum hydrocarbons in soil and groundwater* (Friebel and Nadebaum 2011)
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000a).

These levels are summarised in **Table 16.2**. It should be noted that, as the investigations were not targeting residential properties, the results of investigations were not compared to residential criteria.

Table 16.2 Overview of adopted guidelines

Guideline	Justification
Soils	
Health investigation level/Health screening level – C (ASC NEPM)	The recreational criteria have been selected based on current or potential future land use.
Health investigation level/Health screening level – D (ASC NEPM)	The commercial/industrial criteria have been selected based on current and potential future land use.
Intrusive maintenance workers (Friebel and Nadebaum 2011)	Guidelines for intrusive maintenance workers have also been adopted.
Groundwater	
Management limits (ASC NEPM)	Management limits have been used for parkland and public open space land use for both coarse and fine soils.
Health Screening Level - D – vapour intrusion (ASC NEPM)	The commercial and/or industrial criteria have been selected based current and potential future site use. The public open space criteria have not been included as all screening criteria are non-limiting.
Groundwater investigation levels – Fresh water and marine water (ASC NEPM)	Fresh and marine water criteria have been selected for the groundwater investigation levels, because as some of the receiving surface waters, surrounding the project footprint include Powells Creek (freshwater), Dobroyd Canal (Iron Cove Creek) (freshwater), Hen and Chicken Bay (marine) and Iron Cove (marine).

Guideline	Justification
Groundwater investigation levels – Drinking Water (ASC NEPM)	Groundwater is not likely to be abstracted for potable use in the study area, given the quality and availability of reticulated town supply. However, incidental ingestions may occur during construction.
Low reliability trigger values (ANZECC 2000a)	Where there is no NEPM groundwater investigation level (Marine or Fresh) for analytes, the ANZECC low reliability trigger values were adopted.

16.3 Existing environment

The following sections outline the existing environment in relation to potential and known contamination within each section of the project. The location of potential contamination is shown in **Figure 16.1** to **Figure 16.7**.

16.3.1 Section 1: West of Homebush Bay Drive to Pomeroy Street

EPA regulatory registers

No contaminated sites listed on the contaminated land record are located within 500 metres of the project in Section 1. However three contaminated sites were recorded as having been notified to the EPA as follows:

- Caltex service station at 334-336 Parramatta Road at Homebush, about 300 metres south-west of the project (currently under assessment)
- Ausgrid's Mason Park Substation at 1 Underwood Road at Homebush just north of the project near Homebush Bay Drive (regulation under the CLM Act not required)
- Sydney Olympic Park (former State Sports Centre Landfill) at Homebush, located to the north of the proposed bike path (contamination formerly regulated under the CLM Act however, the site has since been remediated).

A current EPL applies to the Ausgrid Depot located about 150 metres north of the project in Section 2 on Pomeroy Street, and is within 500 metres of Section 1. This licence relates to Hazardous, Industrial or Group A Waste Generation or Storage.

Potential sources of contamination

The following potential sources of contamination have been identified:

- Ausgrid's Mason Park Substation to the north of the M4 on the eastern side of Homebush Bay Drive at Homebush
- Former recycling centre on existing open space located on the eastern side of Homebush Bay Drive at Homebush
- Fill material in the vicinity of the proposed on- and off-ramps between Homebush Bay Drive and the M4
- Light industry such as car yards, particularly along Parramatta Road, including one car yard which has a visible fuel bowser and mechanical workshop.

Historical title deeds and Section 149 certificates

Historical title deeds and Section 149 certificates were obtained for the Ausgrid substation. The historical deeds did not reveal any additional potential contamination sources resulting from past land uses. The Section 149 certificates did not identify any known contamination on the Ausgrid substation site.

Roads and Maritime spills incidents record

Four spills have occurred on the nearby road network between 2009 and 2014. These occurred in the following locations and involved the following materials:

- Homebush Bay Drive (50 metres west of the M4) – produce/fruit boxes on side of road
- M4 (100 metres east of Homebush Bay Drive) – dirt at end of off-ramp
- Parramatta Road, Silverwater Road and Henley Marine Drive Five Dock – oil spill
- Homebush Bay Drive (near M4 off-ramp westbound) – truck fire.

Acid sulfate soils

The majority of this section is not mapped as having acid sulfate soil potential (Department of Land and Water Conservation 1997a). However, areas in the vicinity of Verley Drive and Bedford Road in Homebush, as well as west of Homebush Bay Drive, are identified as disturbed terrain which would potentially contain acid sulfate soils due to past filling activities.

Testing within Section 1 of the project (refer to Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) included testing for acid sulfate soils at six locations (at different depth profiles). Testing identified that the likelihood of widespread acid sulfate soils is low.

Potential and known contamination

Soil

Evidence of potential soil contamination was identified in BH1301 (trace bricks), BH1310 (bricks and asbestos) and BH1312 (bitumen layer). Photo-ionisation detector measurements, which measure the concentration of volatile organic compounds and other gases within the soil, were generally low in all samples (ie less than 0.1 to 1.2 parts per million).

Results (located in Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) identified that asbestos materials were identified in a soil sample at BH1310 and within fragment samples at BH1310 and BH1308. The locations of these boreholes and potential areas of contamination are shown in **Figure 16.1**.

Groundwater

Groundwater testing at BH1309 and BH1310 (refer Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) found that the following contaminants were present at levels above the adopted screening criteria:

- Copper and zinc exceeded the screening criteria in BH1310
- Nickel exceeded the screening criteria in BH1309.

The observed concentrations were only marginally above the adopted criteria, and are likely to be indicative of background metal concentrations in groundwater.

In situ waste classification

Based on the investigations to date, it is likely that excavated fill material would be classified as ‘general solid waste’. In the vicinity of BH1308 and BH1310 fill would be classified as ‘general solid waste with asbestos’ due to the presence of asbestos in these areas.

The underlying natural soils would be classified as general solid waste; however, these are likely to satisfy the criteria for virgin excavated natural material (VENM).

16.3.2 Section 2: Pomeroy Street to Ismay Avenue

EPA regulatory registers

No contaminated sites listed on the contaminated land record are located within 500 metres of the project in this section. However, one contaminated site was recorded as having been notified to the EPA. This site is the Ausgrid Mason Park Substation at 1 Underwood Road at Homebush, which is located directly north of the project in Section 1 near Homebush Bay Drive, and is within 500 metres of Section 2. It was deemed this site did not require regulation under the CLM Act.

A current EPL applies to the Ausgrid Depot located about 150 metres north of the project on Pomeroy Street. This licence relates to Hazardous, Industrial or Group A Waste Generation or Storage.

Potential sources of contamination

Due to the predominantly residential nature of this section of the project, no specific potential contamination sources have been identified. There is, however, potential for asbestos contamination due to past illegal dumping in open space areas, or older residential dwellings located in the project footprint which may contain asbestos materials.

Several car yards are located along Parramatta Road to the south of the project. Detailed site walkovers on private property were not undertaken as part of this assessment and would be required to determine the potential for contamination on these sites.

Historical title deeds and Section 149 certificates

No historical title deeds or Section 149 certificates were obtained as no commercial properties are to be acquired in this section of the project.

Roads and Maritime spills incidents record

No spill incidents have been recorded in this section of the project.

Acid sulfate soils

Acid sulfate soil mapping (Department of Land and Water Conservation 1997a) does not identify any land within Section 2 as containing known occurrences of acid sulfate soils.

Potential and known contamination

No intrusive investigations were undertaken in this section, as the desktop review did not identify any moderate to high potential for contamination.

16.3.3 Section 3: Ismay Avenue to Carrington Lane

EPA regulatory registers

No contaminated sites listed on the contaminated land record are located within 500 metres of the project in Section 3. Two contaminated sites located within Section 2 and within 500 metres of Section 3 were recorded as having been notified to the EPA as follows:

- Former Caltex service station at 92a Concord Road at Concord, about 150 metres north of the Concord Road interchange, but adjacent to road works near Patterson Street (currently under assessment)
- Budget service station at 143 Concord Road at Concord, about 450 metres north of the Concord Road interchange (regulation under the CLM Act not required).

The above sites are not located within the project footprint.

A current EPL applies to the Main North Rail Line for construction of the North Strathfield Rail Underpass which is nearing completion. This EPL is for land-based extractive activities and railway systems activities. A previous EPL was issued for agricultural produce processing, however this land has since been redeveloped for residential housing.

Potential sources of contamination

Potential sources of contamination in this section of the project include car washing facilities, commercial properties within the Bakehouse Quarter (site of the former Arnotts Biscuits factory), and a mechanic workshop. The Main North Rail Line and the Ausgrid substation located on the corner of Bakehouse Lane and George Street are also potential sources of contamination.

Past investigations at Arnotts Reserve have identified that contamination is present within the shallow soils (JBS Environmental (JBS) 2013). Contaminants found during these investigations include benzo(a)pyrene, lead and asbestos. Asbestos has been reported by JBS as being located within the fill across the site and that the majority of the site consists of bonded asbestos. Strathfield Council will soon undertake remediation of Arnotts Reserve and this would be complete before construction starts. Any contamination present at Arnotts Reserve would be remediated as part of these works.

There is no evidence of widespread contamination within this section; however, localised contamination may be present in the vicinity of mechanics, car washes and commercial properties, and in some old residential dwellings to be acquired and demolished, which may contain asbestos materials.

Historical title deeds and Section 149 certificates

Historical title deeds were obtained for the one commercial property to be acquired in this section of the project. The historical deeds did not reveal any additional potential contamination sources resulting from past land uses. No Section 149 certificate was obtained, as the land that is to be acquired is located west of Powells Creek and, based on historical photographs, has never been developed. This land is currently open space but is not accessible to the public.

Roads and Maritime spills incidents record

No spill incidents have been recorded in this section of the project.

Acid sulfate soils

Acid sulfate soil mapping (Department of Land and Water Conservation 1997a) does not identify any land within Section 3 as containing known occurrences of acid sulfate soils.

Potential and known contamination

Soil

Evidence of potential soil contamination was identified in BH1313, consisting of bricks, bitumen and roof tile fragments. Photo-ionisation detector measurements for all samples were generally low (ie less than 0.1 to 0.8 parts per million).

Results (located in Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) identified that contamination within BH1313 was below the selected screening criteria.

Past investigations at Arnotts Reserve have identified that contamination is present within the shallow soils (JBS 2013). Contaminants found during these investigations include benzo(a)pyrene, lead and asbestos. Concentrations for benzo(a)pyrene within the reserve were found to be up to three times the commercial/industrial criteria, indicating there may be unacceptable risk to construction workers from shallow contamination. These contaminants were from investigations undertaken on the northern side of the existing M4 and are therefore not located within the project footprint. No contaminants on site are considered to be volatile, and therefore there are no likely pathways for inhalation of vapours.

Groundwater

Groundwater testing at BH1314 (located in Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) found that cadmium, copper, nickel and zinc levels were above the adopted screening criteria. The observed concentrations are only marginally above the adopted criteria, and are likely to be indicative of background metal concentrations in groundwater. The locations of these boreholes and potential areas of contamination are shown in **Figure 16.2**.

In situ waste classification

Based on the investigations, it is likely that excavated fill material would be classified as general solid waste. Land within Arnotts Reserve would, however, be likely to trigger more stringent waste classifications than general solid waste due to the elevated concentrations of lead and polycyclic aromatic hydrocarbons (PAHs) and the presence of asbestos noted in the JBS (2013) investigations.

The underlying natural soils would be classified as general solid waste. However, these are likely to satisfy the criteria for VENM.

16.3.4 Section 4: Carrington Lane to Broughton Street

EPA regulatory registers

There are no contaminated sites listed on the contaminated land record within 500 metres of this section of the project. Three contaminated sites were recorded as having been notified to the EPA:

- Former Caltex service station at 92a Concord Road at Concord, about 150 metres north of the Concord Road interchange, but adjacent to road works near Patterson Street (currently under assessment)
- Caltex service station at 87-89 Parramatta Road at Concord, about 50 metres south of the tunnel alignment and 385 metres to the east of the end of the M4
- Budget service station at 143 Concord Road at Concord, about 450 metres north of the Concord Road interchange (regulation under the CLM Act not required).

The above sites are not located within the project footprint.

An EPL was issued to a car dealership located at the corner of Parramatta Road and Concord Road at Concord, directly adjacent to the project footprint. This licence related to Hazardous, Industrial or Group A Waste Generation or Storage, specifically petroleum hydrocarbons. This licence has since been surrendered.

Potential sources of contamination

Potential sources of contamination in this section of the project include a service station, car washes, car yards, a dry cleaner and a substation on the corner of Lloyd George Avenue and Ada Street. Older residential properties to be acquired along Concord Road would also potentially contain asbestos, given their age and structure.

Historical title deeds and Section 149 certificates

Historical title deeds and Section 149 certificates were obtained for the one commercial lot to be acquired within this section. The historical deeds did not reveal any additional potential contamination sources resulting from past land uses. The Section 149 certificate did not identify any known contamination on the commercial property to be acquired.

Roads and Maritime spills incidents record

A single spill has been recorded in this section of the project in 2004, on the westbound M4 carriageway under the Concord Road overbridge. This spill involved concrete.

Acid sulfate soils

Acid sulfate soil mapping (Department of Land and Water Conservation 1997a) does not identify any land within Section 4 as containing known occurrences of acid sulfate soils.

Potential and known contamination

Soil

Evidence of potential soil contamination was identified in BH1320, with a slight hydrocarbon odour detected. Elevated photo-ionisation detector measurements were found in BH1320 (as high as 281 parts per million) while other samples in this section were generally low (ie less than 0.1 to 1.7 parts per million).

Results (located in Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) identified that fill material at BH1317 contained the following contaminants at levels that exceed the screening criteria:

- Carcinogenic PAHs exceeding both the recreational and commercial/industrial criteria
- Total PAHs above the recreational guidelines
- Total recoverable hydrocarbons C16-C34 (which are semi-volatile compounds) above the management limit for recreational soils. This level is a screening level for aesthetic issues rather than health issues. This sample does not exceed any other criteria and is located below a hard surface, and therefore is not considered significant.

Groundwater

Groundwater testing at four boreholes (BH1316. BH1317, BH132 and BH1326) (refer to Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) resulted in the following readings above the adopted screening criteria:

- Cadmium exceeded the screening criteria in BH1317 and BH1320
- Copper exceeded the screening criteria in BH1316, BH1317, BH1320 and BH1326
- Nickel exceeded the screening criteria in BH1316, BH1317, BH1320 and BH1326
- Zinc exceeded the screening criteria BH1316, BH1317, BH1320 and BH1326.

The observed concentrations are relatively minor exceedances of the adopted criteria, and are likely to be indicative of background metal concentrations in groundwater.

In situ waste classification

Based on the investigations to date, it is likely that excavated fill material would be classified as general solid waste, with the exception of material at or near BH1317. Soils at or near BH1317 would potentially require classification and off-site disposal as hazardous solid waste, due to potential contaminants identified in this location. The locations of these boreholes and potential areas of contamination are shown in **Figure 16.3**. This area is outside the project footprint and would not be disturbed during construction.

The underlying natural soils would be classified as general solid waste; however, these are likely to satisfy the criteria for VENM.

16.3.5 Section 5: Broughton Street to Dobroyd Canal (Iron Cove Creek)

EPA regulatory registers

A search of the contaminated land record identified one site within 500 metres of the project in Section 5. This site is the Sydney Bus Depot (listed as State Transit Authority) located at the corner of Parramatta Road and Shaftesbury Road on the southern side of Parramatta Road opposite Cintra Park. This site was also notified to the EPA. This site was previously contaminated with petroleum hydrocarbons, which resulted in both soil and groundwater contamination. The site has been audited by a NSW EPA Auditor and has been indicated as suitable for use as a commercial/industrial site. The notification is categorised as ‘former’, as the EPA has determined that the contamination is no longer significant enough to warrant regulation. No other sites were recorded as having been notified to the EPA within this section of the project.

Three EPLs have been issued to sites within 500 metres of the project in Section 5:

- Sydney Buses Bus Depot at the corner of Parramatta Road and Shaftsbury Road at Burwood. This licence was in relation to Hazardous, Industrial or Group A Waste Generation or Storage specifically petroleum hydrocarbons, but is longer in force
- Visy Packaging at 53-75 Queens Road at Five Dock. This licence was in relation to Hazardous, Industrial or Group A Waste Generation or Storage. It was surrendered in March 2001
- Cheltenham Road Park development (Burwood Council), at 34 Cheltenham Road at Croydon to the south of the project. This licence related to waste disposal and was surrendered in July 2004. A Notice of Clean-up Action, dated 9 September 2003, was issued by the EPA in relation to landfill gas and high methane levels detected in monitoring wells on this site.

Potential sources of contamination

Potential sources of contamination in Section 5 of the project include service stations, car washes, mechanical workshops, car yards and an Ausgrid substation on Parramatta Road near Great North Road. Cheltenham Road Park to the south of the project is a former brick pit which has been backfilled with clean and hard fill material and some other waste materials. There is no data for this site to confirm the presence of any contamination on site or migrating off site.

The Sydney Buses Bus Deport is located on Parramatta Road at Shaftsbury Road (opposite Cintra Park and above the mainline tunnels). Based on a review of available information residual contamination in groundwater is not considered likely to pose a significant risk.

Historical title deeds and Section 149 certificates

No historical title deeds or Section 149 certificates were obtained as no commercial properties are to be acquired in this section of the project.

Roads and Maritime spills incidents record

Two spills have occurred on the nearby road network between 2011 and 2012. These occurred in the following locations and involved the following materials:

- Parramatta Road near Wattle Street at Haberfield/Ashfield – oil spill reported but nothing found on site
- Parramatta Road near Dobroyd Avenue at Haberfield – oil spill.

Acid sulfate soils

The majority of Section 5 of the project is not mapped has having acid sulfate soil potential. An area within the project footprint at Concord Oval is identified as disturbed terrain, which would potentially contain acid sulfate soils due to past filling activities (Department of Land and Water Conservation 1997a).

Testing undertaken within this section of the project (refer to Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) included testing for acid sulfate soils at four locations (at different depth profiles at each location). Testing identified that the likelihood of widespread acid sulfate soils is low.

Potential and known contamination

Soil

Evidence of potential soil contamination was identified in BH1333 (trace plastic and sandstone fragments and trace hydrocarbon odour), BH1336 (trace sandstone, blue metal and roadbase gravels and hydrocarbon odour), BH1341 (trace asphalt gravels), BH1344 (asphalt odour) and BH1353 (slight hydrocarbon odour). Photo-ionisation detector measurements in most samples in this section were generally low (ie less than 0.1 to 1.1 parts per million); however, elevated measurements were found in BH1333, where a reading of 65.7 parts per million was recorded.

Results (located in Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) identified that fill material at BH1353 exceeded the recreational screening criterion for carcinogenic PAHs for benzo(a)pyrene toxicity equivalent quotient (TEQ).

Groundwater

Groundwater testing at four boreholes (BH1331. BH1333, BH1336 and BH1344) (refer to Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) found that the following contaminants exceeded the adopted screening criteria:

- Copper exceeded the screening criteria in BH1336 (residual)
- Nickel exceeded the screening criteria in BH1333 and BH1397
- Zinc exceeded the screening criteria in all monitoring well locations
- Phenanthrene exceeded the screening criteria in BH1344
- BH1344 reported several anomalies of contaminants of potential concern above detection, and it is unlikely that the source is from the local commercial business surrounding the monitoring well. A possible source is trace contamination from drilling.

The observed concentrations are considered likely to be indicative of background metal concentrations in groundwater within the bedrock. The locations of these boreholes and potential areas of contamination are shown in **Figure 16.4** and **Figure 16.5**.

In situ waste classification

Based on the investigations to date, it is likely that excavated fill material would be classified as general solid waste. The underlying natural soils would be classified as general solid waste, however, these are likely to satisfy the criteria for VENM.

16.3.6 Section 6: Dobroyd Canal (Iron Cove Creek) to Bland Street (including Wattle Street)

EPA regulatory registers

A search of the contaminated land record, contaminated sites notified to EPA register, and the EPL register did not identify any sites within 500 metres of this section of the project.

Potential sources of contamination

The surrounding land use in Section 6 of the project footprint includes service stations and car yards. Numerous residential properties around Wattle Street would be acquired for the project. Based on the age and the structure of these properties there is potential for asbestos containing materials to be present in the building fabric.

Historical title deeds and Section 149 certificates

Historical title deeds and Section 149 certificates were obtained for all commercial lots to be acquired within this section. Historical deeds indicated that a former laundry/dry cleaner was present at 225-227 Parramatta Road at Ashfield. The Section 149 certificates obtained did not identify any known contamination on the commercial properties to be acquired.

Roads and Maritime spills incidents record

No spill incidents have been recorded in this section of the project.

Acid sulfate soils

The majority of Section 6 is not mapped as having acid sulfate soil potential. The area along Wattle Street (between Ramsay Street and Waratah Street) is identified as disturbed terrain which would potentially contain acid sulfate soils due to past filling activities (Department of Land and Water Conservation 1997a).

No acid sulfate soil testing was completed in this section of the project as minimal excavation works are proposed in areas of disturbed terrain, and the likelihood of encountering acid sulfate soils in this section was considered low.

Potential and known contamination

Soil

There was no evidence of potential soil contamination within the samples for this section of the project. Photo-ionisation detector measurements in most samples in this section were generally low (ie less than 0.1 to 1.4 parts per million).

Results (located in Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) identified that fill material at BH1371 exceeded the recreational screening criterion for carcinogenic PAHs for benzo(a)pyrene TEQ.

Historical deeds identified a former laundry/dry cleaner at 225-227 Parramatta Road at Haberfield. The presence of this past land use indicates the potential for chlorinated solvents to be present within the soil and groundwater.

Groundwater

Groundwater testing at two boreholes (BH1365 and BH1369) (refer to Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) found that the following contaminants were present at levels above the adopted screening criteria:

- Copper exceeded the screening criteria in BH1369
- Nickel exceeded the screening criteria in BH1365 and BH1369
- Zinc exceeded the screening criteria in BH1365 and BH1369.

The observed concentrations are considered likely to be indicative of background metal concentrations in groundwater within the shale. The locations of these boreholes and potential areas of contamination are shown in **Figure 16.6** and **Figure 16.7**.

In situ waste classification

Based on the investigations to date, it is likely that excavated fill material would be classified as general solid waste. The underlying natural soils would be classified as general solid waste, however, these are likely to satisfy the criteria for VENM.

16.3.7 Section 7: Bland Street to Orpington Street

EPA regulatory registers

A search of the contaminated land record, contaminated sites notified to EPA register, and the EPL register did not identify any site within 500 metres of this section of the project.

Potential sources of contamination

The surrounding land use in this section of the project footprint includes service stations and car yards. The former Brescia Furniture showroom site is located at the corner of Parramatta Road and Bland Street. This site was subject to a fire which destroyed much of the development. The site therefore has the potential to contain contamination from hydrocarbons, firefighting residues and asbestos.

Historical title deeds and Section 149 certificates

Historical title deeds and Section 149 certificates were obtained for all commercial lots to be acquired within this section. Historical deeds indicated that a former petrol station was present at 186 Parramatta Road, Ashfield. There is potential for hydrocarbon contamination in the soil and groundwater. The Section 149 certificates did not identify any known contamination on the commercial properties to be acquired.

Roads and Maritime spills incidents record

No spill incidents have been recorded in this section of the project.

Acid sulfate soils

Acid sulfate soil mapping (Department of Land and Water Conservation 1997b) does not identify any land within this section as containing known occurrences of acid sulfate soils.

Potential and known contamination

Soil

Evidence of potential soil contamination was identified in BH1374, consisting of bitumen gravel and slag gravels. Photo-ionisation detector measurements in most samples in this section were generally low (ie less than 0.1 to 1.4 parts per million).

Results (located in Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) identified that fill material at BH1373, BH1374, BH1378 and BH1381 exceeded the recreational criterion for carcinogenic PAH as benzo(a)pyrene TEQ.

Groundwater

Groundwater testing at two boreholes (BH1373 and BH1379) (refer to Appendix C of the Soil and Land Contamination Assessment in **Appendix P**) found that the following contaminants were present at levels above the adopted screening criteria:

- Copper exceeded the screening criteria in BH1373 and BH1379
- Nickel exceeded the screening criteria in BH1373
- Zinc exceeded the screening criteria in BH1373 and BH1379.

The observed concentrations are considered likely to be indicative of background metal concentrations in groundwater within the shale. The locations of these boreholes and potential areas of contamination are shown in **Figure 16.7**.

In situ waste classification

Based on the investigations to date, it is likely that excavated fill material would be classified as general solid waste. The underlying natural soils would be classified as general solid waste, however, these are likely to satisfy the criteria for VENM.

16.4 Assessment of construction impacts

16.4.1 Potential contamination pathways

There is the potential to encounter contamination during construction, which could result in impacts on:

- Human receptors such as construction workers, and nearby residents and commercial users
- Environmental receptors such as groundwater and surface water.

As outlined in **section 16.3**, there is potential for contamination to be present along the entire corridor based on existing or past land uses. In many locations, the potential for contamination is low, particularly in the vicinity of residential areas; however, in some areas the potential is considered to be moderate to high (refer to **Figure 16.1** to **Figure 16.7**). There is, however, a number of locations where testing has identified the presence of soil or groundwater contamination, being present either within or adjacent to the project footprint.

During the construction phase there are potential pathways for human exposure to contaminated soils and groundwater, via direct contact, inhalation of dust and vapours, or ingestion.

The following sections outline the potential pathways for contamination within the project footprint. The potential pathways outlined below would be minimised through the implementation of the mitigation measures described in **section 16.6**.

Section 1: West of Homebush Bay Drive to Pomeroy Street

Asbestos has been identified within fill materials and at the surface in the vicinity of BH1308 and BH1310 (shown on **Figure 16.1)**. The key potential exposure pathways would include:

- Inhalation of asbestos contaminated soil and/or dust
- Inhalation of asbestos fibres from dumped materials.

Excavation works required for the project could potentially result in human exposure, in particular for construction workers, through potential inhalation of contaminated dust, or potential contact with soils and groundwater.

Section 2: Pomeroy Street to Ismay Avenue

No specific contamination issues were identified within Section 2 of the project footprint. Potential contamination pathways would therefore be limited to human exposure to dust, vapours, soils or groundwater that may be identified as contaminated during further investigations or during construction. Construction workers would be most at risk to any potential pathways, particularly during the demolition of old dwellings required for acquisition, should additional investigations identify the presence of asbestos.

Section 3: Ismay Avenue to Carrington Lane

Land within Arnotts Reserve has been identified as containing lead, benzo(a)pyrene and asbestos within shallow fill. Due to the presence of these contaminants, the key potential exposure pathways would include:

- Inhalation of asbestos contaminated soil/dust
- Direct contact with contaminated soil (including incidental ingestion)
- Inhalation of contaminated soil/dust.

Excavation works required for the project would potentially result in human exposure, in particular for construction workers, to contaminated dust, soils (particularly those containing asbestos) and groundwater.

These impacts are considered to be minimal, as Strathfield Council is planning to remediate the site prior to the start of construction.

Section 4: Carrington Lane to Broughton Street

Potential pathways within Section 4 of the project footprint related to the presence of benzo(a)pyrene and total PAH contaminants which exceed the human health screening levels in the vicinity of BH1317 (shown on **Figure 16.3**). Due to the presence of the above contaminants the key potential exposure pathways would include:

- Direct contact with contaminated soil (including incidental ingestion)
- Inhalation of contaminated soil/dust.

No excavation works are planned at or around this area. However, it is noted that, if excavation works are required for the project in this area, this could result in human exposure, in particular for construction workers, to contaminated dust, soils and groundwater.

Benzo(a)pyrene and the majority of PAHs are of low volatility and solubility, and pathways of vapour intrusion and leaching to groundwater are not considered to be significant.

The Caltex service station located on Parramatta Road at Coles Street near the end of the M4 has an inferred groundwater flow towards the north east (ie towards the project). Investigations have found there is potential for hydrocarbons in the shallow groundwater, however, no significant contamination has been identified deeper groundwater. As a result, it is not considered that contamination from this source would affect construction of the project.

Section 5: Broughton Street to Dobroyd Canal (Iron Cove Creek)

Fill material in the vicinity of BH1353 has been identified as exceeding the human health criteria for benzo(a)pyrene. Due to the presence of this contamination, the key potential exposure pathways would include:

- Direct contact with contaminated soil (including incidental ingestion)
- Inhalation of contaminated soil/dust.

Excavation works required for the project could result in human exposure, in particular for construction workers, to contaminated dust, soils (particularly those containing asbestos) and groundwater.

Benzo(a)pyrene and the majority of PAHs are of low volatility and solubility, and pathways of vapour intrusion and leaching to groundwater are not considered to be significant.

As outlined in **section 16.3.5**, no intrusive investigations have been undertaken for the former brick pit site on Cheltenham Road to the south of the project footprint (including by others). During the detailed investigations phase for the project, the alignment of the mainline tunnels was proposed to be further to the north along Parramatta Road. The potential for latent contamination in soils or groundwater, or the potential for the vapour intrusion pathway to exist at the site cannot be discounted.

Petroleum hydrocarbon contamination was not detected at elevated concentrations within this section of the project; however, odours were noted during field investigations. Detailed investigations of properties thought to be the source of odours were not undertaken as part of this assessment. For this reason, the potential for contaminated soils or groundwater, and therefore potentially vapour intrusion pathways, to be present cannot be discounted.

Section 6: Dobroyd Canal (Iron Cove Creek) to Bland Street

Potential pathways within this section related to the presence of benzo(a)pyrene, which exceeds the human health screening criteria at BH1371 (shown on **Figure 16.7**). Due to the presence of this contamination, the key potential exposure pathways would include:

- Direct contact with contaminated soil (including incidental ingestion)
- Inhalation of contaminated soil/dust.

Excavation works required for the project could result in human exposure, in particular for construction workers, to contaminated dust, soils (particularly those containing asbestos) and groundwater.

Benzo(a)pyrene and the majority of PAHs are of low volatility and solubility, and pathways of vapour intrusion and leaching to groundwater are not considered to be significant.

This section of the project footprint contains two petrol station sites. Investigations at BH1386 were conducted adjacent to one of these petrol stations and did not identify any evidence of gross hydrocarbon contamination, with the likelihood of a significant vapour intrusion pathway from contamination at this location being low. No investigations were undertaken near the other petrol station or the former laundry/dry cleaner, as access to this property or a nearby property was not available. The potential for localised latent contamination at these sites therefore remains. This service station is located within the project footprint and therefore there are potential pathways for human exposure to latent contamination due to direct contact, inhalation of dust and vapours or ingestion.

Section 7: Bland Street to Orpington Street

Potential pathways within this section of the project related to the presence of benzo(a)pyrene, which exceeds the human health screening criteria at BH1373, BH1374, BH1378 and BH1381 (shown on **Figure 16.7**). Due to the presence of this contamination, the key potential exposure pathways would include:

- Direct contact with contaminated soil (including incidental ingestion)
- Inhalation of contaminated soil/dust.

Excavation works required for the project could result in human exposure, in particular for construction workers, to contaminated dust, soils (particularly those containing asbestos) and groundwater.

Benzo(a)pyrene and the majority of PAHs are of low volatility and solubility, and pathways of vapour intrusion and leaching to groundwater are not considered to be significant.

BH1378 and BH1379 are located adjacent to a service station; these boreholes did not identify any gross hydrocarbon contamination, with the likelihood of a significant vapour intrusion pathway from contamination at this location being low. The former service station identified through historical title deeds has the potential for localised latent contamination.

16.4.2 Acid sulfate soil impacts

As outlined in **section 16.3**, acid sulfate soils are only considered to be potentially present within Sections 1, 5 and 6 of the project footprint, where Department of Land and Water Conservation mapping (1997a and 1997b) shows disturbed terrain in these sections. Testing undertaken within Sections 1 and 5 indicates that the potential for acid sulfate soils within these sections is considered to be low. No testing was undertaken in Section 6, as the area of disturbed terrain would not be affected by the project. Further investigations in this area would be undertaken during detailed design.

If acid sulfate soils were to be encountered during construction, they have the potential to result in the following impacts:

- Weakening of concrete and steel infrastructure, resulting in increased maintenance and replacement costs
- Damage to aquatic environments due to release of sulfuric acid generated from oxidised acid sulfate soils during construction
- Mobilisation of aluminium, iron and manganese from soils as a result of increased acidity from disturbance of acid sulfate soils.

If acid sulfate soils were encountered, they would be managed in accordance with the *Acid Sulfate Soil Manual* (Acid Sulfate Soil Management Advisory Committee 1998).

16.4.3 Contamination resulting from the project

The project has the potential to result in contamination of both soils and groundwater as a result of accidents or spills of fuels, oil and chemicals during the construction. Such impacts are considered to be minimised with the implementation of mitigation measures outlined in **section 16.6**. **Chapter 25** (Hazards and risk) provides further details regarding dangerous goods and hazardous substances.

16.5 Assessment of operational impacts

While the contamination identified in **section 16.4.1** would remain (other than those sources that would be removed as part of the project in the form of spoil), post-construction human health exposure, in the context of the project use as a roadway and tunnel, is likely to be low. Most potential direct contact pathways would be broken by the presence of hard surfaces such as the road.

The tunnel design would largely be unlined, with only areas of high groundwater inflows to be ‘lined’ with a waterproof membrane. Groundwater ingress would therefore be expected to occur at a maximum of one litre per second per kilometre. Groundwater would be separated from surface water and collected in a sump at the low point in the tunnel. The groundwater seepage would then be transferred to a water treatment facility at Cintra Park for treatment and discharge to the stormwater canal in St Lukes Park. During construction, samples of the groundwater would be taken to check for key chemicals of potential concern, and to understand the groundwater quality and treatment requirements prior to discharge.

The vapour intrusion pathway was not identified during intrusive investigations, with no contamination sources identified in the deep groundwater in the vicinity of the proposed tunnels. The tunnel design incorporates a ventilation system (for traffic exhaust) which is considered suitable for mitigating against any vapour intrusion from a latent groundwater source. Therefore risk from this pathway is considered to be low.

During operation, the project has the potential to result in the contamination of soils and groundwater as a result of accidents and spills of fuels, oils, chemicals and other potential contaminants. Such accidents and spills would generally be associated with vehicle accidents resulting in spills into the tunnel or along the road. Drainage infrastructure to be installed as part of the project (refer to **section 5.8.3** in **Chapter 5** (Project description) would include spill containment facilities where direct discharge of stormwater from surface areas to receiving watercourses would occur. This infrastructure would have the capacity to prevent soil or groundwater contamination resulting from spills, by collecting, treating or removing spill materials from site.

Acid sulfate soil impacts during operation are considered to be unlikely, as acid sulfate soils are unlikely to be disturbed.

16.6 Management of impacts

Measures to avoid, minimise or manage contamination impacts as a result of the project are detailed in **Table 16.3**.

Table 16.3 Environmental management measures – contamination

Impact	No.	Environmental management measure	Responsibility	Timing
Construction				
Confirmation of contamination	C1	Further intrusive investigation will be undertaken within the Powells Creek construction ancillary facility (at Arnotts Reserve) to obtain a statistically complete dataset. The investigation will include sampling of soils likely to be disturbed during construction, analysed for benzo(a)pyrene, lead and asbestos.	Construction contractor	Pre-construction
	C2	Further site investigations will be undertaken in the vicinity of BH1344 to confirm the presence and determine the nature of contaminant of potential concern in this area.	Construction contractor	Pre-construction
	C3	Hazardous materials assessments will be undertaken for buildings proposed for demolition to manage potential risk of exposure to site workers during these works. Management strategies will be developed from these assessments and will be included Safe Work Method Statements and/or Waste Management Plan.	Construction contractor	Pre-construction
	C4	Further site investigations will be undertaken to assess the level and extent of asbestos in publicly accessible areas beside the M4 in Section 1 of the project footprint.	Construction contractor	Pre-construction
	C5	Targeted site investigations will be undertaken at the former laundry/dry cleaners at 225-227 Parramatta Road, Ashfield and the former service station located at 186 Parramatta Road, to confirm the presence of any latent contamination.	Construction contractor	Pre-construction

Impact	No.	Environmental management measure	Responsibility	Timing
Management of contamination	C6	Procedures to manage unexpected contamination finds and hazardous materials identified during site preparation and/or construction works will be prepared. The procedures will include details for the management of the following identified contaminants: • PAHs and benzo(a)pyrene TEQ • Latent contamination.	Construction contractor	Construction
	C7	Potentially contaminated areas directly affected by the project will be investigated and managed in accordance with the requirements of the *Contaminated Land Management Act 1997* (NSW) and *Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites* (OEH 2011).	Construction contractor	Construction
Contaminated groundwater	C8	Where passive dewatering of the aquifer system is required, additional contamination sampling (of groundwater and seepage quality) would be completed to assess the potential management and disposal options. A baseline groundwater monitoring plan would be implemented to gather water quality data to inform management and disposal options of groundwater seepage during construction.	Construction contractor	Construction
Management of potentially contaminated waste	C9	Any excavated soil contaminated with benzo(a)pyrene will be managed to prevent spreading potentially contaminated soil on final ground surfaces where the general public could be exposed post construction.	Construction contractor	Construction
Waste classification	C10	Further waste classification will be undertaken during construction to allow appropriate soil management and disposal, in particular for areas that were not accessible during this assessment (including private properties). Details of sampling and analysis protocols will be included in the Spoil Management Plan (refer to **Chapter 23** (Resource Use and Waste)).	Construction contractor	Construction

Impact	No.	Environmental management measure	Responsibility	Timing
Asbestos	C11	Asbestos handling and management will be undertaken in accordance with an Asbestos Management Plan and relevant State legislation, government policies and Australian Standards. The plan will include • Protocols and procedures for entering and safe working in areas with surface asbestos (eg Sections 1 and 3) with respect to asbestos containing materials (fibrous and cement-bound) • Appropriate remediation/ management strategies.	Construction contractor	Pre-construction
Acid sulfate soils	C13	Confirmatory testing of areas identified as disturbed terrain (eg such as near, to Bedford Road and Verley Drive (Section 1), Concord Oval (Section 5), and Wattle Street (Section 6)) and stockpiled spoil during construction will be carried out in areas where potential acid sulfate soils have been mapped, to confirm their presence or absence, and to obtain a specific liming rate for stockpiles (if required).	Construction contractor	Construction
	C14	If acid sulfate soils are encountered, they will be managed in accordance with the *Acid Sulfate Soil Manual* (Acid Sulfate Soil Management Advisory Committee, 1998).	Construction contractor	Construction
Demolition	C15	Demolition works will be undertaken in accordance with Australian and NSW WorkCover Standards.	Construction contractor	Construction
	C16	Appropriate mitigation measures including stockpiling and management of potentially contaminated material will be undertaken at building demolition sites to prevent movement of material into receiving waters.	Construction contractor	Construction
Operation				
Contamination during operation	OpC1	Procedures to address spills, leaks and tunnel washing will be developed and implemented during operation of the project.	Construction contractor	Operation

17 Flooding and drainage

This chapter outlines the potential flooding and drainage impacts associated with the M4 East project (the project). A detailed flooding assessment has been undertaken for the project and is included in **Appendix Q**.

The Secretary of the NSW Department of Planning and Environment has issued a set of environmental assessment requirements for the project; these are referred to as Secretary's Environmental Assessment Requirements (SEARs). **Table 17.1** sets out these requirements as they relate to flooding and drainage, and identifies where they have been addressed in this EIS.

Table 17.1 Secretary's Environmental Assessment Requirements – flooding and drainage

SEARs	
Soil and Water	
Requirement	**Section where addressed in EIS**
Identification of potential impacts of the project on existing flood regimes, consistent with the Floodplain Development Manual (Department of Natural Resources, 2005), including impacts to existing receivers and infrastructure and the future development potential of affected land, and demonstrating consideration of the changes to rainfall frequency and/or intensity as a result of climate change on the project. The assessment shall demonstrate due consideration of flood risks in the project design.	Impacts of the project on existing flood regimes are addressed in **sections 17.3** and **17.4**. Impacts on existing receivers and infrastructure are addressed in **sections 17.3** and **17.4**. Consideration of changes to rainfall frequency and/or intensity as a result of climate change is addressed in **section 17.4.2**. Consideration of flood risks in the project design is considered in **sections 17.4** and **17.5**.

17.1 Assessment methodology

17.1.1 Methodology overview

The purpose of this assessment is to identify potential surface water impacts associated with the construction and operation of the project in terms of:

- Flood impacts on the surrounding environment, including changes in peak flows in the receiving drainage lines
- Flood risks to the project works.

The findings of the flood and drainage study were used to develop a strategy to mitigate the flood and drainage related impacts of the project. Baseline flooding behaviour conditions were established and the nature and extent of potential impacts associated with the proposed works were then assessed. The potential impacts of constructing and operating the project were considered as part of the assessment.

The approach to the assessment involved:

- Developing computer based hydrologic models using the DRAINS software to generate discharge hydrographs for input to the hydraulic models
- Developing computer based hydraulic models (using TUFLOW software) to convert the discharge hydrographs into peak flood levels, depths of inundation and flow velocities
- Defining flood behaviour under present day conditions

- Assessing the impact of the project on flooding behaviour and also the flood risks associated with constructing and operating the project
- Assessment of the impact the project will have on the development potential of land adjacent to the project corridor
- Identifying measures that aim to:
  - Mitigate the impacts of the project on flood behaviour
  - Achieve the required level of flood protection for the project.

17.1.2 Policy and guidance

Assessment of flood risks to the project and impacts on the surrounding environment, and development of appropriate flood standards and mitigation measures, have been carried out in accordance with the NSW *Floodplain development manual* (Department of Infrastructure, Planning and Natural Resources (DIPNR) 2005) and industry guidelines. Policies and guidelines that have been considered as part of this assessment include:

- *Floodplain Development Manual* (DIPNR 2005), incorporating the Flood Prone Land Policy
- Section 117(2) of Local Planning Direction 4.3 − Flood prone land
- Planning circular PS 07-003 − New guideline and changes to section 117 direction and Environmental Planning and Assessment (EP&A) Regulation on flood prone land
- Guideline on development controls on low flood risk areas (NSW Department of Planning and NSW Department of Natural Resources 2008)
- Stormwater management code (Strathfield Council 1994)
- *Australian rainfall and runoff* (Institute of Engineers Australia (IEAust) 1998)
- The estimation of probable maximum precipitation in Australia: generalised short-duration method (Bureau of Meteorology (BoM) 2003)
- Floodplain risk management guideline – practical considerations of climate change (Department of Environment, Climate Change and Water (DECCW) 2008)
- Derivation of the NSW Government’s sea level rise planning benchmarks technical note (DECCW 2009)
- Specification for the management of stormwater (City of Canada Bay 2009d)
- Flood risk management guide: incorporating sea level rise benchmarks in flood risk assessments (DECCW 2010)
- Australian rainfall and runoff revision projects – Project 11 – blockage of hydraulic structures (IEAust 2013)
- Stormwater management policy (Ashfield Council 2013).

17.1.3 Study area and analysis

All project activities would lie within the following catchments which form part of the larger Parramatta River catchment. These catchments, as shown on **Figure 15.2** in **Chapter 15** (Soil and water quality), form the study area for this flooding and drainage assessment:

- Powells Creek – Homebush Bay Drive at Homebush to Concord Road at North Strathfield
- Exile Bay – Concord Road to Park Road at Concord
- St Lukes Park Canal –Park Road to Royce Avenue in Concord, Burwood and Croydon
- Barnwell Park – Royce Avenue to Scott Street at Croydon
- Dobroyd Canal (Iron Cove Creek) – Scott Street at Croydon to Orpington Street at Ashfield.

The hydrologic standards were developed in accordance with the NSW *Floodplain Development Manual* (DIPNR 2005) and are based on matching the level of protection to the risk and consequence of flooding. A 100 year average recurrence interval (ARI) flood standard has been adopted to assess measures that are required to mitigate adverse impacts attributable to the project. Flooding behaviour in the vicinity of the project was defined for a range of events with average recurrence intervals of five to 200 years. Changes in flood behaviour under probable maximum flood conditions are also assessed to identify impacts on critical infrastructure and significant changes in flood hazard as a result of the project.

The assessment of drainage and flood mitigation requirements was based on flows resulting from the current level of development within the catchments which drain across the project corridor (denoted as 'present day' (2015) conditions). The assessment considers the changes in flood levels resulting from the project, climate change and sea level rises. The assessment considers the impact from the ten 10 construction ancillary facilities as well as other areas of proposed surface works. Note that the Underwood Road civil and tunnel site construction ancillary facility C3 , which comprises both civil and tunnelling sites, has been spilt into two for the purpose of the following assessment, whereby construction ancillary facility C3a comprises the civil site, while C3b comprises the tunnelling site.

17.2 Existing environment

17.2.1 Catchment descriptions

Five catchments contribute runoff to the existing drainage systems and waterways that are located along the project; these are referenced on **Figure 15.2** and are described below. These catchments form part of the Parramatta River catchment. A number of surface waterways and drainage networks traverse the catchments and are referenced on **Figure 17.1** to **Figure 17.3** as XD01 to XD11.

Powells Creek catchment – Homebush Bay Drive to Concord Road

The Powells Creek catchment (refer to **Figure 17.1**) includes land within the suburbs of Homebush, Enfield, Strathfield, Burwood, North Strathfield and Liberty Grove, as well as part of Sydney Olympic Park. It predominantly comprises low to medium density residential development, with higher density residential and commercial development located near the Main Western Line, Parramatta Road and the existing M4, which run east−west across of middle reaches of the catchment.

The main and tributary arms of Powells Creek have been highly modified. The main arm of the creek consists of a series of pipe and box culvert systems from its headwaters to a location immediately upstream of the Main Western Line at Strathfield. At this location, the culvert system discharges into a concrete-lined open channel, which continues under Parramatta Road and the existing M4. The concrete channel (XD03) is six metres wide by 1.5 metres deep where it crosses under the existing M4 elevated bridge structure. The bridge is about 10 metres above the level of the floodplain.

Downstream of the existing M4, the concrete-lined channel continues to a location just upstream of Homebush Bay Drive in Homebush, where it discharges into a mangrove-lined channel which runs through Powells Creek Reserve and the Badu Wetlands to its outlet into the Parramatta River.

Two tributaries to Powells Creek cross the existing M4 to the west of the main arm. The larger of these tributaries (XD02) runs under the existing M4 immediately east of Underwood Road, via a single 2.6 metre wide by 1.3 metre high box culvert. The smaller tributary (XD01) runs along the rear of properties in Powell Street in Homebush and under the M4 in a 0.6 metre diameter pipe. Both of these tributaries join Powell Creek downstream of Allen Street in Homebush.

Saleyards Creek (XD01a) is the largest tributary of Powells Creek and joins the main arm immediately upstream of Homebush Bay Drive. Saleyards Creek is a nine metre wide by 1.5 metre high concrete-lined open channel where it flows beneath the existing M4. The existing M4 is a single span bridge structure at this crossing point.

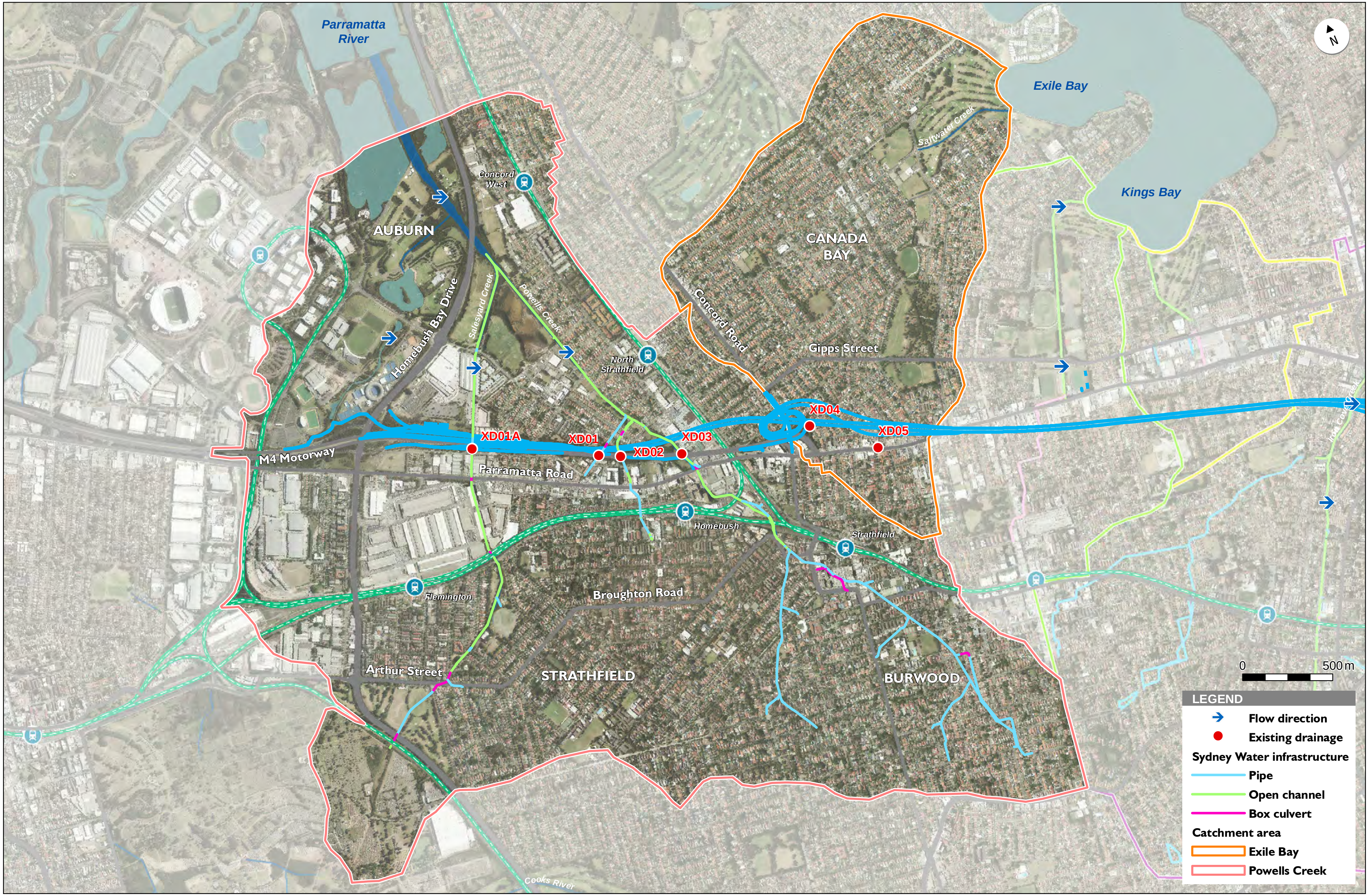

Figure 17.1 Existing drainage layout - Powells Creek and Exile Bay catchments

Figure 17.2 Existing drainage layout - Saint Lukes Park Canal catchment

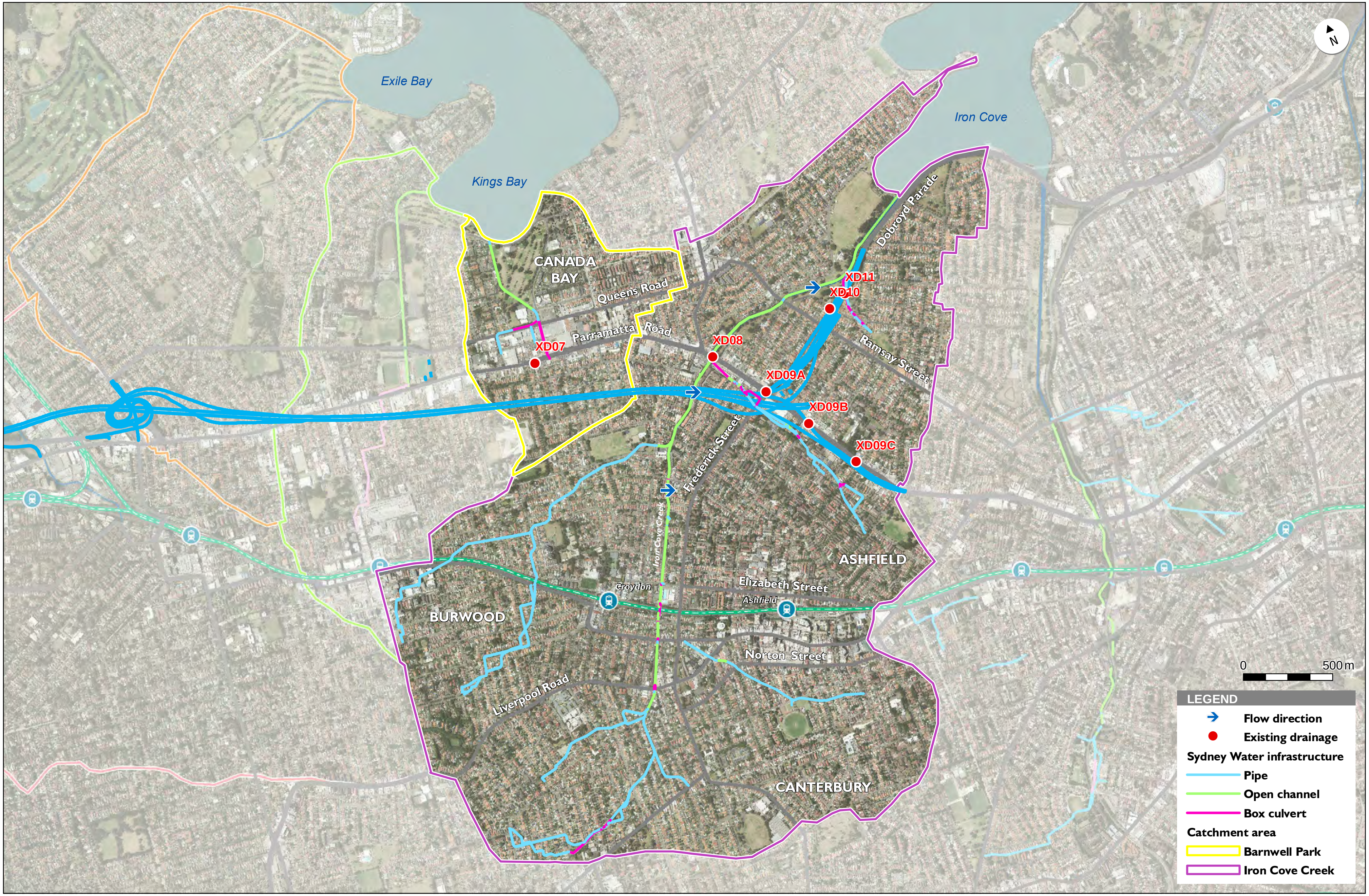

Figure 17.3 Existing drainage layout - Barnwell Park and Iron Cove Creek catchments

Exile Bay catchment – Concord Road to Park Road

The Exile Bay catchment (refer to **Figure 17.1**) includes land within the suburbs of Strathfield, Burwood and Concord. Parramatta Road runs east−west across the upper reach of the catchment. The catchment comprises mainly low and medium density residential development, with higher density residential and commercial development located generally along the Parramatta Road corridor. A significant portion of the catchment north (downstream) of Parramatta Road comprises open space (Goddard Park, Queen Elizabeth Park and the Massey Park golf course).

Two existing drainage lines cross the project within the Exile Bay catchment. Cross drainage structure XD04 drains a catchment of 3.7 hectares and is a 0.45 metre diameter pipe where it crosses the project footprint immediately east of Concord Road. It then runs along Ada Street in Concord via a single 1.2 metre wide by 0.6 metre high pipe before joining the second drainage structure (XD05) north (downstream) of Parramatta Road. Cross drainage structure XD5 is a 1.05 metre diameter pipe where it crosses the low point in Parramatta Road at Coles Street in Concord. It then continues north via a series of pipes to Ian Parade in Concord. Downstream of Ian Parade the drainage system discharges into a concrete-lined open channel which continues north to its outlet into Exile Bay.

St Lukes Park Canal catchment – Park Road to Royce Avenue

The St Lukes Park Canal catchment (refer to **Figure 17.2**) includes land in the suburbs of Burwood, Croydon and Concord. The Main Western Rail Line runs east−west across the upper reach of the catchment and Parramatta Road runs east−west across the middle reach of the catchment. The catchment predominantly comprises low to medium density residential development, with higher density residential and commercial development located in the Burwood town centre, as well as along the Parramatta Road corridor. A significant portion of the catchment north (downstream) of Parramatta Road comprises open space (Concord Oval, St Lukes Park, Cintra Park and Barnwell Park).

The catchment upstream of Parramatta Road in Concord is drained via a series of street drainage systems comprising pipes and box culvert sections. These systems convey flows across Parramatta Road by a 3.6 metre wide by 1.37 metre high box culvert and a 2.6 metre wide by 1.37 metre high box culvert (XD06), which then discharges into an open channel that runs between Concord Oval and the Cintra Hockey Complex. This open channel continues between Cintra Park and St Lukes Park and along the western edge of Barnwell Park to its outlet into Canada Bay.

Barnwell Park Canal catchment – Royce Avenue to Scott Street

The Barnwell Park Canal catchment (refer to **Figure 17.3**) drains in a northerly direction into Canada Bay. The catchment includes land in the suburbs of Croydon, Five Dock and Canada Bay. Parramatta Road runs east−west across the middle reach of the catchment. The area upstream of Parramatta Road predominantly comprises low to medium density residential development. Between Parramatta Road and Queens Road there is a mixture of commercial and industrial development. Barnwell Park Golf Course is located in the lower reaches of the catchment, adjacent to Canada Bay.

The catchment upstream of Parramatta Road in Five Dock is drained via a system of pits and pipes to the low point in Parramatta Road immediately west of Short Street in Croydon. From the low point in Parramatta Road, the drainage system discharges into two 1.2 metre wide by 0.9 metre high box culverts (XD07). The drainage line then runs along William Street in Five Dock, via a series of box culverts, before discharging into a concrete-lined open channel that runs through Barnwell Park Golf Course, under Lyons Road West in Five Dock and into Canada Bay.

Dobroyd Canal (Iron Cove Creek) catchment – Scott Street to Orpington Street

The Dobroyd Canal (Iron Cove Creek) catchment (refer to **Figure 17.3**) drains in a north-easterly direction, from its headwaters in Burwood Heights to its outlet in Iron Cove. The catchment includes land in the suburbs of Burwood Heights, Burwood, Ashfield, Ashbury, Croydon, Five Dock and Haberfield. The main land use type within the catchment is low to medium density residential development interspersed with local parks. Higher density residential, commercial and industrial development exists along the Main Western Rail Line, Parramatta Road and Wattle Street, as well as near the Burwood town centre. Algie Park in Haberfield acts as a stormwater detention basin. A significant portion of the catchment north (downstream) of Parramatta Road comprises open space (Timbrell Park).

The main arm of Dobroyd Canal (Iron Cove Creek) comprises a concrete-lined open channel that extends from Liverpool Road in Ashfield, through to its outlet at Iron Cove. Where it crosses Parramatta Road the channel is 15 metres wide by 1.8 metres deep (XD08). The channel dimensions increase to 21.6 metres wide by 2.6 metres deep at its outlet into Iron Cove.

A tributary to Dobroyd Canal (Iron Cove Creek) runs in a north-westerly direction and joins the main arm of Dobroyd Canal (Iron Cove Creek) immediately upstream of Parramatta Road. This tributary is drained via a series of pipes and box culverts, and comprises a 2.4 metre wide by 2.1 metre high box culvert where it discharges into Dobroyd Canal (Iron Cove Creek).

Runoff from the catchments that lie to the east of Parramatta Road in the suburb of Haberfield between Walker Avenue and Chandos Street are controlled by pavement drainage systems draining across Parramatta Road at Walker Street (XD09a), Alt Street and Bland Streets (XD09b) and Chandos Street (XD09c).

There are two drainage lines that cross the project at Dobroyd Parade discharging into Dobroyd Canal (Iron Cove Creek) north of Dobroyd Parade. A 375 millimetre pipe (XD10) crosses Dobroyd Parade at Martin Street in Haberfield. Between Martin Street and Waratah Street a 2.6 metre wide by 1.4 metres high box culvert and a 1.05 metre diameter pipe (XD11) cross Dobroyd Parade. This pipe discharges into two 0.9 metre pipes immediately downstream of Dobroyd Parade.

17.2.2 Environmental conditions

The project area has generally high rainfall in summer and autumn, and low rainfall in winter and spring. Average monthly rainfall ranges from approximately 80 to 140 millimetres in the months of summer to autumn, to approximately 60 to 110 millimetres in the months of winter to spring. The average annual rainfall is 884 millimetres. Average monthly evaporation in the project area ranges from 60 millimetres in the winter months to 200 millimetres in the summer months.

The project corridor traverses relatively flat or gently undulating terrain within the lower reaches of the Parramatta River catchment, with ground slopes of six per cent or less. Elevations are highest at the eastern end of the project corridor along the ridge that separates the Dobroyd Canal (Iron Cove Creek) catchment and Hawthorne Canal catchment, where ground levels are about 30 metres Australian height datum (AHD). The lowest lying areas are where the project corridor crosses the watercourses of Saleyards Creek, Powells Creek, St Lukes Park Canal and Dobroyd Canal (Iron Cove Creek), where ground levels are below five metres AHD.

17.2.3 Present day flooding conditions

The stormwater drainage systems that control runoff from the catchments have limited capacity. As a result, during periods of heavy rainfall the project footprint is presently affected by both:

- Main stream flooding, when normally dry land is inundated when water overflows the natural or artificial banks of a creek, channel or estuary
- Major overland flow, when land on an overland flow path is inundated during the 100 year ARI storm event to a depth of equal to or greater than 150 millimetres.

Table 17.2 summarises the main stream flooding and major overland flow patterns (collectively referred to as 'flooding') at key locations along the project corridor. The 100 year ARI flooding patterns along the modelled reaches of Powells Creek, St Lukes Park Canal and Dobroyd Canal (Iron Cove Creek) are shown in **Figures 4.9** to **4.12** in the flooding and drainage assessment in **Appendix Q**. Probable maximum flood events are shown along the same modelled reaches in **Figures 4.13** to **4.16** in the flooding and drainage assessment in **Appendix Q**,

Table 17.2 Probable maximum flood and 100 year average recurrence interval flood

Location	100 year average recurrence interval flood (ARI) – present day conditions	Probable maximum flood (PMF) – present day conditions
M4 bridge at Saleyards Creek (XD01a) in Homebush	The hydraulic standard is in excess of 100 year ARI. The clearance between the 100 year ARI flood level and the underside of the bridge is approximately one metre.	The existing M4 at Saleyards Creek would be overtopped during a PMF event with depths of inundation reaching 1.5 metres.
Powells Creek tributaries XD01 and XD02 in Homebush	The existing Underwood Road underpass operates as an overland flow path during a 100 year ARI event and conveys flows in excess of the capacity of cross drainage structures. Overland flow along Underwood Road is typically between 0.4 and 0.7 metres deep, but would reach 0.9 metres in three locations.	Overland flow from the tributaries travels along Underwood Road, where flow depths in excess of two metres would be experienced upstream of the existing M4, reducing to 1.5 metres on the downstream side.
Powells Creek at Parramatta Road, Homebush	Flow along Powells Creek immediately downstream of Parramatta Road (XD03) is generally confined to the main channel. Further downstream at the existing M4, flow extends onto the overbank areas either side of the main channel, inundating the area to a maximum depth of 0.8 metres during a 100 year ARI event.	Parramatta Road at Powells Creek is overtopped during a PMF event with depths of inundation reaching 1.5 metres over a width of approximately 200 metres. A similar width of flow continues downstream along Powells Creek to the existing M4.
Stormwater drainage line (XD04), near Concord Road in the suburb of Concord	Flows in excess of the capacity the drainage line would travel overland along the local depression between Sydney Street and Alexandra Street, east of Concord Road. During a 100 year ARI event overland flow would be typically less than 0.2 metres deep, but would reach 0.4 metres at three locations.	Overland flow along the drainage line is typically less than 0.4 metres deep but would reach 0.9 metres deep at three locations.
St Lukes Park Canal around Cintra Park and Concord Oval in the suburb of Concord	An overland flow path occurs along the eastern side of the Cintra Hockey Complex during a 100 year ARI event. Overland flow would typically be less than 0.3 metres deep but would reach 0.5 metres deep at two locations.	Overland flow would occur along the eastern side of the Cintra Hockey Complex where flows up to 0.8 metres deep would be experienced in a PMF.
Dobroyd Canal (Iron Cove Creek) catchment - Parramatta Road, between Chandos Street and Wattle Street, Haberfield	Parramatta Road would operate as an overland flow path during a 100 year ARI event. Overland flow along Parramatta Road at this section would be typically less than 0.15 metres deep, but would reach 0.3 metres deep in three locations.	Overland flow would typically be less than 0.3 metres deep, but would exceed 0.5 metres deep in five locations. Overland flow along this section of Parramatta Road is the result of local catchment runoff, rather than main stream or major overland flooding.
Dobroyd Parade at its intersection with Waratah Street in Haberfield	Dobroyd Parade would be inundated to a depth of up to 0.6 metres during a 100 year ARI event.	Flow across Dobroyd Parade occurs to a depth of two metres.

17.3 Assessment of construction impacts

17.3.1 Flood risk to the project

The 10 construction ancillary facilities as well as other areas of proposed surface works have the potential to be affected by either main stream flooding or major overland flow which may:

- Cause damage to the project works
- Cause delays in construction programming
- Pose a safety risk to construction workers
- Adversely affect the downstream waterways by transporting sediments and construction materials in floodwaters
- Alter the characteristics of flooding in adjacent development.

Table 17.3 summarises the results of the modelled flood behaviour on the surface works and construction ancillary facilities.

Table 17.3 Summary of assessed flood risk at proposed construction ancillary facilities and other surface works

Site	Flood level affecting the site	Description of flood behaviour
M4 -Homebush Bay Drive to Underwood Road and Homebush Bay Drive Civil Site (C1)	5 year ARI	Surface earthworks associated with the Homebush Bay Drive interchange would be located outside the 100 year ARI extent. Flow along Saleyards Creek would inundate an area along the eastern boundary of site C1 during storms in excess of five year ARI. If a 100 year ARI event occurs during construction, floodwater would inundate an area along the eastern boundary of C1 about 8.0 m wide and 0.6 m deep.
Pomeroy Street civil site (C2)	Not affected	The site is not located in flood prone land.
Homebush Bay Drive interchange and Underwood Road civil site (C3a)	Less than five year ARI	Flows in excess of the capacity of cross drainage structures XD01 and XD02 would travel overland along Underwood Road and and across the proposed cut and cover tunnel section at the interchange. More than half of the site would be inundated during a five year ARI event. A portion of C3a would also be inundated by flows surcharging the open channel that runs between the outlet to cross drainage structure XD02 and Ismay Avenue in Homebush. If a 100 year ARI event occurs during construction, overland flow along Underwood Road and through the site would typically be between 0.4 and 0.7 m deep.
Underwood Road tunnel site (C3b)	200 year ARI	The site would be located outside the extent of main stream flooding from Powells Creek for all events up to 200 year ARI. If a PMF event occurred during construction, floodwaters up to 0.8 m deep would inundate the northern third of the site.
Powells Creek civil site (C4) incorporating Powells Creek on-ramp	Less than five year ARI	Powells Creek flows in a northerly direction through the eastern portion of the site via a concrete-lined channel. Surface earthworks associated with the Powells Creek on ramp would be located outside the 100 year ARI extent. While flow on the western overbank of Powells Creek would reach a maximum depth of about 0.8 m within C4 during a 100 year ARI event, the extent of the affected area would be confined to the immediate overbank area of the creek.

Site	Flood level affecting the site	Description of flood behaviour
Concord Road interchange, M4 – Sydney Street to Parramatta Road and Concord Road civil and tunnel site (C5)	Less than five year ARI	Surface earthworks associated with the interchange would be located in an area which is affected by flow which surcharges the stormwater drainage system in the M4 and ponds at the low point east of the Concord Road overbridge. The cut-and-cover tunnel section at the Concord Road interchange would not be affected by mainstream flooding or major overland flow. However, the cut-and-cover tunnel section would be affected by local catchment runoff draining west along Sydney Street. C5 would be affected by overland flow from the stormwater drainage line XD04 that travels along the local depression east of Concord Road. If a 100 year ARI event occurred during construction, overland flow through C5 would be typically less than 0.2 m deep, but may reach a maximum depth of about 0.4 m at three locations. C5 would also be affected by local stormwater runoff that would inundate the drainage system in the existing M4 and ponds at the low point west of the Concord Road overbridge.
Cintra Park tunnel site (C6) incorporating Cintra Park fresh air supply and water treatment facility	Less than five year ARI	The site extends across St Lukes Park Canal, which is a concrete-lined channel where it runs between Parramatta Road and Gipps Street. An overland flow path also operates along the eastern portion of the site during storms in excess of a five year ARI event. If a 100 year ARI event occurred during construction, overland flow would typically be less than 0.3 m deep, reaching a maximum depth of about 0.5 m at two locations.
Northcote Street tunnel site (C7)	Not affected	The site is not affected by main stream flooding or major overland flow as it fronts onto Parramatta Road, which operates as an overland flow path during storms that inundate the stormwater drainage system. Depths of overland flow along this section of Parramatta Road are typically less than 0.15 m for all storms up to 100 year ARI. The site is affected by local catchment runoff draining west along Northcote Street.
Eastern ventilation facility site (C8)	Not affected	The site is not affected by main stream flooding or major overland flow as it fronts onto Parramatta Road, which operates as an overland flow path during storms that inundate the stormwater drainage system. Overland flow along this section of Parramatta Road is less than 0.25 m deep for all storms up to 100 year ARI.
Wattle Street interchange and Wattle Street and Walker Avenue civil site (C9)	Less than five year ARI	Surface earthworks north of the Dobroyd Parade tunnel dive structure and the northern end of site C9 would be affected by flow in Dobroyd Parade which would occur due to a combination of surcharge of the stormwater drainage system and Dobroyd Canal (Iron Cove Creek). During a 100 year ARI storm event, Dobroyd Parade would be inundated to a maximum depth of about 0.6 m at its intersection with Waratah Street. The cut and cover tunnel section at the Wattle Street tunnel site structure and C9 would be affected by local catchment runoff draining north along Allum Street.

Site	Flood level affecting the site	Description of flood behaviour
Parramatta Road interchange and Parramatta Road civil site (C10)	Less than five year ARI	Stormwater drainage line XD09c runs in a westerly direction along Chandos Street. Flows in excess of the capacity of stormwater drainage line XD09c collect at the low point in Parramatta Road north of Chandos Street before travelling north along Parramatta Road and west along Chandos Street during storms more frequent that the 5 year ARI event. . Overland flow from stormwater drainage line XD09c crosses the area of proposed surface earthworks in Parramatta Road as well as the location of the cut-and-cover section of tunnel within site C10.

Construction ancillary facilities

The 10 construction ancillary facilities may be affected by flooding during the construction period. The activities within each site are described in **Chapter 6** (Construction work) and the locations are shown on **Figure 6.1** of that chapter. **Table 17.3** summarises the likely level of flooding that may affect each site and the potential changes in flooding behaviour resulting from the establishment of the sites. Flooding behaviour is shown in Figures 5.1 to 5.7 in the flooding and drainage assessment in **Appendix Q**.

Stockpiles located on the floodplain have the potential to obstruct floodwater and alter flooding patterns. Inundation of stockpile areas by floodwater can also lead to significant quantities of material being washed into the receiving drainage lines and waterways. Spoil material is proposed to be stockpiled at five sites (C1, C3a, C3b, C5 and C10). While all five are affected by main stream and/or overland flooding, site C3a (Underwood Road civil site in Homebush) is at greatest risk of being flooded during the construction phase of the project.

A range of offices, staff amenities, workshops and parking areas are proposed at all 10 construction ancillary facilities. Where these are located on the floodplain, particularly in areas of high hazard, there is a potential safety risk to construction personnel. The sites would be organised to locate amenities in low hazard areas with safe evacuation routes to mitigate this hazard.

Tunnel construction

Floodwater entering the tunnel excavations could pose a significant risk to safety, cause damage to machinery and result in delays in the project timetable. There is the potential for local catchment runoff to enter the tunnel excavations. The tunnel entries would be protected from flooding by physical barriers that would be designed so as not to increase flooding conditions in buildings adjacent to the project.

The flood standard adopted at each tunnel opening during construction would be developed taking into consideration the duration of construction, the magnitude of inflows and the potential risks to the project works and personnel.

Cut-and-cover tunnel construction

Floodwater entering the open excavations could pose a significant risk to safety, cause damage to machinery and delays to the project timetable.

The cut-and-cover section of tunnel at the Homebush Bay Drive interchange crosses Underwood Road, which operates as an overland flow path during storms more frequent than the five year ARI. Construction of the cut-and-cover section would be staged to maintain the existing overland flow path. Barriers would also be provided to prevent overland flow from entering the open excavation.

The cut-and-cover section of tunnel at the Parramatta Road interchange is located across an existing overland flow path that operates during storms more frequent than the five year ARI. To construct the cut-and-cover section, the existing stormwater drainage line that crosses Parramatta Road at Chandos Street would be converted to a siphoned arrangement to direct overland flows along Parramatta Road and Bland Street. This mitigation measure would be further developed during detailed design and construction planning.

Diversion of flow around the open excavations at the Homebush Bay Drive and Parramatta Road interchanges has the potential to adversely affect flooding conditions in adjacent development (see **section 17.3.2** for assessment of impacts).

The cut-and-cover sections of tunnel at the Concord Road and Wattle Street interchanges are located outside the extent of the probable maximum flood. As a result, the risk of flooding can be addressed through local stormwater management at these sites.

Surface earthworks

Surface works at the Homebush Bay Drive interchange and construction of the Powells Creek M4 westbound on-ramp are located outside the 100 year ARI flood extent. As a result, the flood risks associated with constructing these surface earthworks is low and would be addressed through local stormwater management of the construction ancillary facility.

Surface earthworks at the Concord Road interchange are located in an area that is affected by flow which surcharges the stormwater drainage system in the existing M4 and collects at the low point west of the Concord Road overbridge.

Surface earthworks at the Wattle Street and Parramatta Road interchanges intersect overland flow paths that operate during storms more frequent than the five year ARI.

Concentrated flow that discharges onto the road corridor within areas of surface earthworks has the potential to scour disturbed surfaces and transport sediment and construction materials into the receiving waterways.

Bridge construction

There is potential for temporary bridge works to reduce the available waterway area beneath the two new bridges over Saleyards Creek at the Homebush Bay Drive interchange. The increase in waterway area created by the new longer bridges is likely to exceed the loss of waterway areas caused by the temporary works. The longer spans would therefore mitigate any impact these works would have had on flooding behaviour. It is also likely that the superstructure would comprise precast members (rather than cast in-situ), which would further act to minimise the impact of the temporary works on the available waterway area.

All groundworks, access tracks and other temporary works associated with the Powells Creek on-ramp would be located outside the concrete channel. Temporary crossings over the channel would be required for access to construct the bridge structure.

17.3.2 Potential impacts of construction activities on flooding behaviour

Construction activities have the potential to exacerbate flooding conditions when compared to both present day and post-construction conditions. This arises from the need to locate temporary infrastructure on the floodplain within the operational project footprint, which would be removed after construction is complete.

Activities at the 10 construction ancillary facilities as well as other areas of surface works have been modelled to assess the potential impacts of construction activities on flooding behaviour during a 100 year ARI flood event. Further investigation would need to be undertaken during detailed design as layouts and staging diagrams are developed. The key findings of the investigation are summarised in **Table 17.4** and shown in Figures 5.8 to 5.21 the flooding and drainage assessment in **Appendix Q**.

The investigation found that construction activities have the potential to exacerbate flooding conditions in adjacent development at a number of locations along the project corridor. While the greatest impacts are associated with construction ancillary facilities C3a and C10, adverse flooding conditions arising in adjacent development are also associated with construction ancillary facilities C1, C4, C5, C6 and C9. There is also the potential for all 10 construction ancillary facilities to affect local catchment runoff; local stormwater management controls would be implemented to manage this impact.

Table 17.4 Summary of impacts of construction ancillary facilities and works areas on flooding behaviour outside the project footprint – 100 year ARI (ARI) Flood

Site	PPFL* (mAHD)	Modelled construction activity	Potential impacts on flooding behaviour
M4 - Homebush Bay Drive to Underwood Road and Homebush Bay Drive Civil Site (C1)	3.4	The footprint of site C1 was raised above the 100 year ARI flood level to represent a complete blockage to flow. No changes were made to the dimensions of the existing bridge over Saleyards Creek.	Peak 100 year ARI flood levels would be increased by up to 20 mm within industrial development that is located upstream of the existing M4.
Pomeroy Street civil site (C2)	N/A	No hydraulic assessment has been carried out for these construction works because C2 is not affected by main stream flooding or major overland flow for events up to the PMF.	No impacts on main stream flooding or major overland flow during a 100 year ARI event.
Homebush Bay Drive interchange and Underwood Road civil site (C3a)	5.2	The footprint of construction ancillary facility 3a was raised above the 100 year ARI flood level and the width of Underwood Road was reduced to 10 m to reflect the temporary traffic arrangements during construction of the cut-and-cover tunnel section. The area of cut-and-cover construction either side of Underwood Road was blocked off to overland flow by raising ground elevations above the 100 year ARI flood level.	Narrowing Underwood Road to construct the cut-and-cover section of tunnel, combined with the obstruction caused by construction ancillary facility C3a, would divert additional overland flow north into existing residential development located along Underwood Road and Ismay Avenue. There is the potential for peak 100 year ARI flood levels to be increased by a maximum of 460 mm at these locations. There would also be an increase in peak flood levels of up to 220 mm in existing residential development along Underwood Road and Powell Street south of the existing M4.
Underwood Road tunnel site (C3b)	N/A	No initial hydraulic assessment has been carried out for this site because the Underwood Road tunnel site is unaffected by either main stream flooding or major overland flow for all storms up to 200 year ARI.	No impacts on main stream flooding or major overland flow during a 100 year ARI event.

Site	PPFL* (mAHD)	Modelled construction activity	Potential impacts on flooding behaviour
Powells Creek civil site (C4) incorporating Powells Creek on-ramp	4.8	The footprint of the proposed access road west of the Powells Creek bridge was raised to the level of Parramatta Road. The two proposed access road crossings over the concrete channel were added to the model as bridge structures. These bridge decks were assumed to be 1 m thick, with the underside of the structure set at the top of the concrete channel.	The proposed construction works would increase peak flood levels by about 180 mm within Powells Creek and in the commercial property on its eastern overbank, north of Parramatta Road.
Concord Road interchange, M4 – Sydney Street to Parramatta Road and Concord Road civil and tunnel site (C5)	28.3	The footprint of construction ancillary facility C5 was raised above the 100 year ARI flood level to represent a complete blockage to flow. Existing stormwater drainage line XD04 was realigned between Sydney Street and Alexander Street to run along the eastern boundary of the site. A temporary diversion channel and bund was also modelled along the eastern side of construction ancillary facility C5.	The obstruction to overland flow caused by the construction ancillary facility has the potential to increase peak flood levels by up to 50 mm in a single residential property which is located on the southern side of Alexandra Street adjacent to the civil site.
Cintra Park tunnel site (C6) incorporating Cintra Park fresh air supply and water treatment facility	5.4	The footprint of construction ancillary facility C6 was raised above the 100 year ARI flood level to represent a complete blockage to flow, with the exception of a 16 m wide corridor that was maintained along the alignment of St Lukes Park Canal, where it crosses the site.	The obstruction of the existing overland flow path that currently runs along the eastern side of the Cintra Hockey Complex would have a minor impact on flooding behaviour external to the site. Additional flow would be diverted along Parramatta Road and Saint Lukes Park Canal. Peak flood levels in the eastbound lanes of Parramatta Road would be increased in the range of 0 mm to 100 mm.
Northcote Street tunnel site (C7)	N/A	No hydraulic assessment has been undertaken because construction ancillary facility C7 is not affected by either main stream flooding or major overland flow for events up to the PMF.	No impacts on main stream flooding or major overland flow during a 100 year ARI event.

Site	PPFL* (mAHD)	Modelled construction activity	Potential impacts on flooding behaviour
Eastern ventilation facility site (C8)	N/A	No hydraulic assessment has been undertaken because construction ancillary facility C8 is not affected by either main stream flooding or major overland flow for events up to the PMF.	No impacts on main stream flooding or major overland flow during a 100 year ARI event.
Wattle Street interchange and Wattle Street and Walker Avenue civil site (C9)	3.1	The footprint of the proposed haul road along the southern side of Reg Coady Reserve was raised to the level of Dobroyd Parade.	The proposed haul road has the potential to cause localised increases of up to 200 mm in the depth of inundation in Dobroyd Parade at Martin Street. Increases in the range of 10 mm to 20 mm would extend into the Sydney Water pump station on the corner of Dobroyd Parade and Martin Street.
Parramatta Road interchange and Parramatta Road civil site (C10)	-	The footprint of construction ancillary facility C10 was raised above the 100 year ARI flood level to represent a complete blockage to flow. This facility includes the extent of the cut-and-cover section of tunnel at the Parramatta Road (Chandos Street) tunnel portals. The existing stormwater drainage line XD09c was maintained across the construction ancillary facility to reflect the temporary siphon arrangement proposed during construction.	The construction ancillary facility would obstruct overland flow that travels west across Parramatta Road at Chandos Street. Depths of overland flow along Parramatta Road between Chandos Street and Bland Street would increase by up to 120 mm. There would be a slight increase in the extent of inundation within development located at the corner of Parramatta Road and Chandos Street. Flood levels within properties along Bland Street and Parramatta Road north of Bland Street would be increased by up to120 mm.

*Preliminary peak flood level

17.4 Assessment of operational impacts

17.4.1 Flood risk to the project and impact on flooding behaviour

The project has the potential to be flooded during operation. This may damage infrastructure, impact on the safe operation of the tunnels and pose a safety risk to road users and motorway operations staff. **Table 17.5** summarises the following:

- Modelled peak level of the 100 year ARI flood and probable maximum flood
- Recommended flood protection level for project infrastructure which is based on the *Floodplain development manual* (DIPNR 2005) and Roads and Maritime Services standards
- Potential impact of flood behaviour.

Project design measures would need to be developed to manage flood risks remaining after the recommended flood protection levels have been implemented. These are discussed in **section 17.5**.

The extent of flooding is shown in Figures 6.1 to 6.24 in **Appendix Q**. Surface road works at the four interchanges would be designed to maintain the existing hydrologic standard and limit increases in flood depths that would otherwise lead to an increase in flood hazard.

The project also has the potential to exacerbate flooding and drainage conditions in adjacent development. **Table 17.6** provides a summary of the key findings from the flood impact assessment. The extent of flooding is shown in Figures 6.1 to 6.24 in **Appendix Q**. The assessment has identified a number of properties where floor level survey would be required to confirm whether the project would increase the risk of flood damage in affected properties (refer **section 17.5**).

Table 17.5 Summary of operational flood impacts on the project

Location	Project details	Peak flood level (m AHD)		Recommended level of flood protection (whichever is greater)	Assessed impact of flooding
		100 year ARI	PMF		
Homebush Bay Drive interchange	Motorway operations complex	3.4	4.4	PMF or 100 year ARI plus 0.5 m	The maintenance facility and motorway control centre are located outside the PMF extent, and therefore more than 1 m above the 100 year ARI flood level.
	Bridge over Saleyards Creek	3.6	6.3	100 year ARI plus 0.5 m	The concept bridge arrangement provides a minimum clearance of 0.7 m to the 100 year ARI flood level.
	Tunnel dive structure	5.1	6.1	PMF or 100 year ARI plus 0.5 m	The tunnel dive structure is located outside the PMF extent, and therefore more than 1 m above the 100 year ARI flood level.
	Underwood Road distribution substation and western ventilation facility	5.1	6.1	PMF or 100 year ARI plus 0.5 m	The buildings would be affected by overland flow that travels north along Underwood Road and inundates the eastern edge of the site during a 100 year ARI event.
	Ismay Avenue substation, fire pump room	5.1	6.1	PMF or 100 year ARI plus 0.5 m	The buildings are located outside the PMF extent, and therefore more than 1 m above the 100 year ARI flood level.
Powells Creek M4 westbound on-ramp	Bridge over Powells Creek	4.6	6.4	100 year ARI plus 0.5 m	The on-ramp would be located outside the 100 year ARI flood extent.
Concord Road interchange	Tunnel dive structure	28.4	28.5	PMF or 100 year ARI plus 0.5 m	On- and off-ramps at the entry to the tunnel dive structure cross an existing overland flow path that occurs as a result of surcharge of stormwater drainage line XD04.
	Distribution substation	N/A	N/A	PMF or 100 year ARI plus 0.5 m	The buildings would not be affected by main stream flooding or major overland flow.
Cintra Park facility	Water treatment plant, water quality basin and supporting facilities	5.4	6.1	PMF or 100 year ARI plus 0.5 m	The facility would be affected by overland flow that overtops Parramatta Road and inundates the southern end of the site during a 100 year ARI event.

Location	Project details	Peak flood level (m AHD)		Recommended level of flood protection (whichever is greater)	Assessed impact of flooding
		100 year ARI	PMF		
	Fresh air supply facility	5.4	6.1	PMF or 100 year ARI plus 0.5 m	The fresh air supply facility would be affected by overland flow that overtops Parramatta Road and inundates the southern end of the site during a PMF event.
Parramatta Road interchange	Tunnel dive structure	20.2	20.4	PMF or 100 year ARI plus 0.5 m	The tunnel dive structure crosses an existing overland flow path that occurs as a result of surcharge of stormwater drainage line XD09c during storms more frequent than five year ARI.
	Ancillary facilities: fire water tank and pump, ventilation facility	N/A	N/A	PMF or 100 year ARI plus 0.5 m	The facility would not be affected by main stream flooding or major overland flow.
Wattle Street (City West Link) interchange	M4 East tunnel dive structure	2.8	4.1	PMF or 100 year ARI plus 0.5 m	The tunnel dive structure is located on the fringe of the PMF extent as shown on **Figure 6.24** in **Appendix Q**.
	M4−M5 Link tunnels dive structure	N/A	N/A	PMF or 100 year ARI plus 0.5 m	The M4−M5 Link tunnels dive structure would not be affected by main stream flooding or major overland flow. However, local catchment runoff presently drains in a northerly direction along Allum Street and across the proposed location of the tunnel dive structure.

Table 17.6 Summary of operational project impacts on flooding behaviour

Assessed preferred design arrangement	Impacts on flooding behaviour
Homebush Bay Drive interchange: • Realignment of the existing M4 • New bridges over Saleyards Creek • Cycleway overpass and on- and- off ramps.	A minor reduction in peak 100 year ARI flood levels upstream of the M4 of 0.02 m or less. An increase in peak PMF levels upstream of the M4, to a maximum of 0.3 m. The new 13 m span plank bridge over Saleyards Creek provides 0.3 m less freeboard (distance from the waterline) to the 100 year ARI flood level compared to the existing 9.4 m span bridge. However, freeboard is still in excess of 0.5 m and the longer span results in an increase in total waterway area.
Homebush Bay Drive interchange: • Realignment of cross drainage structures XD01 and XD02 to accommodate the cut-and-cover tunnel • Western ventilation facility and distribution substation	An increase in peak 100 year ARI flood levels by a maximum of 0.02 m within two residential properties in Ismay Avenue, immediately north of the project corridor. An increase in peak PMF levels upstream and downstream of the existing M4 by a maximum of 0.03 m.
Powells Creek: • A new bridge structure over Powells Creek to accommodate the Powells Creek M4 westbound on-ramp.	The bridge would have a total span of 120 m and would be supported by a series of piers located outside the Powells Creek channel. The bridge abutment at Parramatta Road would be located outside the 100 year ARI extent and therefore would not affect flooding behaviour during this event. The bridge abutment at Parramatta Road would result in a minor increase (by a maximum of 0.02 m) in peak PMF levels in a commercial development on the corner of Powells Street and Parramatta Road. Similar increases in flood level would be experience along Parramatta Road.
Concord Road interchange: • Surface road works • Realignment of existing stormwater drainage line XD04	An increase in the extent of inundation during a 100 year ARI would affect a residential property in Sydney Street east of the project. An increase in peak 100 year ARI flood levels would affect three residential properties in Franklyn Street, south of Alexandra Street, by a maximum of 0.03 m. An increase in peak PMF levels would affect three residential properties in Franklyn Street and Alexandra Street by a maximum of 0.1 m. Similar increases would be experienced within the road corridor in Alexandra Street. Peak five year ARI overland flows along stormwater drainage line XD04, downstream of the interchange, would be increased from 0.4 m^3/s (present day) to 0.5 m^3/s (post-construction). As a result, peak flood levels would be increased between Alexandra Street and Lloyd George Avenue in Concord, which would potentially affect more than 10 residential properties.

Assessed preferred design arrangement	Impacts on flooding behaviour
Cintra Park: • Water treatment facility and water quality basin • Fresh air supply facility and distribution substation.	Changes in peak 100 year ARI flood levels in areas outside the project corridor would be less than 0.01 m. There would be localised increases in peak PMF flood levels in Parramatta Road and along St Lukes Park Canal by a maximum of 0.3 m. Increases in PMF levels within commercial development along Parramatta Road would be 0.02 m or less. The peak operational discharge from the tunnel drainage into St Lukes Park Canal is estimated to be 0.15 m^3/s. This compares to the peak 100 year ARI discharge in St Lukes Park Canal of 46.3 m^3/s. Based on this, the discharge of flow from the tunnel drainage directly to St Lukes Park Canal would not have a significant impact on flooding behaviour.
Wattle Street interchange: • Surface road works and tunnel dive structures • Upgrades to the drainage system in Dobroyd Parade to accommodate the surface road works at cross drainage structures XD10 and XD11.	The Wattle Street tunnel dive structure facility is not affected by major overland flow or mainstream flooding. However, local catchment runoff presently drains in a northerly direction along Allum Street and across the proposed location of the tunnel dive structure. Reduction in peak 100 year ARI flood levels along Dobroyd Canal (Iron Cove Creek) and Dobroyd Parade upstream (west) of Waratah Street in Haberfield, of up to 0.08 m but typically 0.02 m or less. Localised increases in peak PMF levels in the vicinity of Loudon Avenue, by a maximum of 0.04 m. An increase in the depth of inundation in Dobroyd Parade of between 0.1 and 0.3 m across the range of potential storm events.
Parramatta Road interchange: • Surface road works and tunnel dive structure • Realignment of stormwater drainage line XD09c along Parramatta Road to connect into the Sydney Water trunk drainage line in Bland Street • Underground onsite detention tank adjacent to Bland Street.	An increase in peak 100 year ARI flood level in Parramatta Road, north of Chandos Street in Haberfield, to a maximum of 0.32 m, resulting in an increase in the extent of inundation in the adjacent commercial property. An increase in peak 100 year ARI flood level on the corner of Parramatta Road and Bland Street by a maximum of 0.12 m. Similar increases would be experienced at three commercial properties in Parramatta Road, north of Bland Street, Haberfield. Localised increases in peak 100 year ARI flood levels along Bland Street, between Parramatta Road and Curt Street in Ashfield, by a maximum of 0.07 m. These increases in peak flood levels have the potential to impact one residential property in Bland Street. A reduction in peak 100 year ARI flows and flood levels along the Sydney Water trunk drainage line downstream (north) of Bland Street in Haberfield, due to the attenuating effect of the stormwater detention tank and the diversion of a portion of the catchment at the tunnel dive structure to the tunnel drainage system. An increase in peak PMF levels along Parramatta Road between Chandos Street and Walker Avenue in Haberfield, to a maximum of 0.48 m north of Chandos Street, but typically 0.05 m or less.

17.4.2 Potential impacts of future climate change

Climate change impacts on flood-producing rainfall events show a trend for larger scale storms and resulting increased rainfall depths. This has the potential to increase the frequency and magnitude of flows surcharging the tunnel drainage systems and entering the tunnels. The assessment of future climate change impacts has been based on the TUFLOW models established to define main stream flooding and major overland flow paths. The following guides have been used as a basis for examining climate change induced increases in rainfall intensities to inform the assessment:

- *Practical considerations of climate change* (DECC 2007)
- Sea level rise policy statement (NSW Government 2009)
- *Flood risk management guide: incorporating sea level rise benchmarks in flood risk assessments* (DECCW 2010).

Based on the above guidelines, the following scenarios were adopted as being representative of the likely lower and upper bound estimates of climate change impacts over the design life of the project:

- Scenario 1 – Based on an assumed 10 per cent increase in 2015 rainfall intensities, together with a rise in sea level of 0.4 metres
- Scenario 2 – Based on an assumed 30 per cent increase in 2015 rainfall intensities, together with a rise in sea level of 0.9 metres.

Peak flood levels at key locations along the project for present day (2015) conditions, as well as for the assessed climate change scenarios, are shown in **Table 17.7**.

Table 17.7 Summary of peak flood levels − 2015 and future climate conditions (1) (2)

Location	100 year ARI					PMF				
	2015 Conditions	Scenario 1		Scenario 2		2015 Conditions	Scenario 1		Scenario 2	
	Level (m AHD)	Level (m AHD)	Change (m)	Level (m AHD)	Change (m)	Level (m AHD)	Level (m AHD)	Change (m)	Level (m AHD)	Change (m)
Bridges over Saleyards Creek	3.57	3.68	+ 0.11	3.80	+ 0.23	6.26	6.26	0.00	6.26	0.00
Homebush Bay Drive interchange	5.06	5.10	+ 0.04	5.15	+ 0.09	6.03	6.05	+0.02	6.05	+0.02
Powells Creek on-ramp	4.57	4.69	+0.12	4.89	+0.32	6.43	6.43	0.00	6.43	0.00
Concord Road interchange	28.38	28.39	+ 0.01	28.40	+0.02	28.46	28.46	0.00	28.46	0.00
Cintra Park facilities	5.49	5.52	+0.03	5.55	+0.06	6.11	6.15	+0.04	6.15	+0.04
Parramatta Road interchange	20.14	20.18	+ 0.04	20.22	+ 0.08	20.39	20.39	0.00	20.39	0.00
Wattle Street interchange	2.78	2.87	+ 0.09	3.05	+0.27	4.12	4.12	0.00	4.15	+ 0.03

(1) Peak flood levels quoted to two decimal places for ease of comparison only. Adopted flood levels for design purposes would be rounded to the nearest 0.1 metres.

(2) These are peak flood levels for the particular flood event and make no allowance for freeboard.

Potential impacts of future climate change on flooding behaviour for a storm with an ARI of 100 years are as follows:

- **Existing M4 bridge at Saleyards Creek**: Peak 100 year ARI flood levels could potentially increase by between 0.11 metres and 0.23 metres under future climate conditions. Under the upper estimate there would still be about 0.5 metres of clearance to the proposed bridge structure.
- **Homebush Bay Drive interchange**: Peak 100 year ARI flood levels could potentially increase by between 0.04 and 0.09 metres under future climate conditions. Post-climate change 100 year ARI flood levels would be about 0.9 metres below the probable maximum flood level, which sets the minimum level of the tunnel portals and ancillary facilities
- **Powells Creek on-ramp**: Peak 100 year ARI flood levels could potentially increase by between 0.12 and 0.32 metres under future climate conditions. The reduction in freeboard due to the impact of climate change would need to be considered during detailed design
- **Concord Road interchange**: There could potentially be a minor increase in peak 100 year ARI flood levels, of between 0.01 metres and 0.02 metres under future climate conditions, which is well within the minimum 0.5 metres freeboard to be provided to the tunnel portals
- **Cintra Park water treatment facility**: There could potentially be a minor increase in peak 100 year ARI flood level of between 0.03 metres and 0.06 metres under future climate conditions. Post-climate change peak 100 year ARI flood levels would be approximately 0.5 metres below the probable maximum flood level, which sets the minimum level of the water treatment plant and tunnel ancillary facilities
- **Parramatta Road interchange**: There could potentially be a minor increase in peak 100 year ARI flood level of between 0.04 and 0.08 metres under future climate conditions, which is well within the minimum 0.5 metre freeboard to be provided to the flood protection barriers around the tunnel dive structure
- **Wattle Street interchange**: Peak 100 year ARI flood levels could potentially increase by between 0.13 metres and 0.30 metres under future climate conditions. Peak 100 year ARI flood levels would still be more than one metre below the probable maximum flood level which sets the minimum level of the tunnel portal.

The assessment found that peak probable maximum flood levels at the proposed Saleyards Creek bridge, Powells Creek M4 westbound on-ramp, Cintra Park fresh air supply facility and water treatment facility, and proposed interchanges are not sensitive to a rise in sea level of up to 0.9 metres.

This investigation has found that changes in the characteristics of flooding associated with future climate change would not significantly increase the flood risk to the project.

17.5 Management of impacts

17.5.1 Project design features that manage impacts

The project incorporates flood management and drainage design measures to manage potential flooding impacts on areas outside the project footprint. Flood protection of each project element would be in accordance with the *NSW Floodplain development manual* (DIPNR 2005) and current Roads and Maritime standards. In particular, tunnel portals, as well as ancillary facilities such as substations, ventilation buildings and emergency response facilities, would be located above the probable maximum flood level or the 100 year ARI flood level plus 0.5 metres (whichever is greater) to provide the required level of flood protection. A summary of measures to manage potential flood impacts is below.

- Tunnel portals and ancillary facilities
  - Tunnel entries and associated flood protection barriers would be located above the probable maximum flood level or the 100 year ARI flood level plus 0.5 metres (whichever is greater)

- The same hydrologic standard would be applied to tunnel ancillary facilities, such as tunnel ventilation and water treatment plants, where the ingress of floodwaters would also have the potential to flood the tunnels

- Emergency response facilities
  - Emergency response facilities, including the motorway operations complex, fire water tank and pump buildings and associated electrical substations, would be located above the probable maximum flood level or the 100 year ARI flood level plus 0.5 metres (whichever is greater)
- M4 realignment
  - A 100 year ARI level of flood immunity would be provided to the realigned section of the M4 between Homebush Bay Drive and Parramatta Road
- Bridge waterway crossings
  - Bridge crossings over waterways at Saleyards Creek and Powells Creek would be provided to a minimum clearance of 0.5 metres between the underside of the bridge structure and the 100 year ARI flood level
- Modifications to Parramatta Road, Concord Road, Dobroyd Parade and Wattle Street
  - Modifications to existing roads at their point of connection to the project would be configured to ensure that the existing level of flood immunity is maintained and flood depths and hazards are not increased.

17.5.2 Environmental management measures

Environmental management measures to minimise impacts from flooding during construction and operation of the project are provided in **Table 17.8**.

Table 17.8 **Environmental management measures – flooding**

Impact	No.	Environmental management measure	Responsibility	Timing
Construction				
Management of flood and stormwater – General	FD01	A flood management strategy will be prepared to manage flooding and stormwater related issues and will include: • The layout of construction ancillary facilities • Location of amenities buildings and equipment outside high flood hazard areas • Controlled diversion of overland flow either through or around work areas • Staging construction to limit the extent and duration of temporary works on the floodplain • Monitoring weather conditions • Ensuring construction equipment and materials are removed from floodplain areas at the completion of each work activity, or upon issuing of a weather warning of impending flood producing rain • Provision of temporary flood protection for properties identified as being at risk of adverse flood impacts during any stage of construction of the project • Development of flood emergency response procedures to remove temporary works during periods of heavy rainfall and staff evacuation plans. For site facilities located within the floodplain, the strategy will identify how risks to personal safety and damage to construction facilities will be managed.	Construction contractor	Pre-construction

Impact	No.	Environmental management measure	Responsibility	Timing
Flooding impacts on adjacent development	FD02	Adverse flood impacts on existing development will be managed through the FSM. This will include: • A detailed hydrologic and hydraulic assessment into flooding behaviour and mitigation measures required during detailed design • Design of works within the floodplain to minimise adverse impacts on surrounding development for flooding up to the 100 year ARI event. Assessment will also be made of impacts during flooding in excess of the 100 year ARI event up to the PMF, in the context of impacts on critical infrastructure and flood hazards • Floor level survey will be carried out at all properties at risk (where there is a potential increase in flood levels) to confirm whether construction activities will increase flood damages. Where flooding potential is confirmed, management measures for construction works and operational design will be incorporated.	Construction contractor	Pre-construction
Management of stormwater	FD03	Appropriate local stormwater measures will be provided, where required.	Construction contractor	Pre-construction and construction
Impacts of future climate change on flooding behaviour	FD04	The project will be designed to manage the potential impacts due to climate change in accordance with the *Practical Considerations of Climate Change – Floodplain Risk Management Guideline* (DECC 2007).	Construction contractor	Pre-construction
Homebush Bay Drive interchange	FD05	Refinement of XD02 realignment and reshaping of the overbank area will partially divert overland flow away from the affected properties.	Construction contractor	Pre-construction and construction
Homebush Bay Drive interchange – bridge over Saleyards Creek	FD06	The detailed design will exceed minimum clearance requirements. The longer spans of the new bridges will offset the increased hydraulic losses associated with their larger footprint and multiple bridges, when compared to the existing arrangement. Continuous walls will be provided between the abutments of the new bridges to provide a uniform waterway section. The eastbound cycleway bridge will be managed through provision of a waterway area consistent with that of the M4.	Construction contractor	Pre-construction and construction

Impact	No.	Environmental management measure	Responsibility	Timing
Homebush Bay Drive interchange – Underwood Road distribution substation and western ventilation facility	FD07	Openings to the buildings will be located to prevent the ingress of floodwaters in a PMF event, providing a freeboard allowance greater than 0.5 metres freeboard to the 100 year ARI flood level.	Construction contractor	Pre-construction and construction
Powells Creek on-ramp – bridge over Powells Creek	FD08	The bridge over Powells Creek will be designed to provide a minimum 0.5 m clearance between the underside of the bridge and the 100 year ARI flood level. The bridge abutment at Parramatta Road will be located to minimise impacts during a 100 year ARI event.	Construction contractor	Pre-construction and construction
Concord Road interchange – tunnel dive structure	FD09	A barrier wall and overland flow path will be provided along the eastern side of the on- and off-ramps to direct overland flow around the tunnel entry during a PMF event. The top of the barrier wall will be located a minimum 0.5 metres above the 100 year ARI flood level.	Construction contractor	Pre-construction and construction
Concord Road interchange – realignment of existing stormwater drainage line XD04	FD10	A grassed channel will be provided to divert overland flow from stormwater drainage line XD04 around the surface road works. The grassed channel will be sized to contain 100 year ARI flows within the project footprint and thus prevent an increase in the extent of inundation within residential properties in Sydney Street.	Construction contractor	Pre-construction and construction
Cintra Park facilities	FD11	Openings to the facility will be located to prevent the ingress of floodwater in a PMF event and to provide a freeboard greater than 0.5 metres to the 100 year ARI flood level.	Construction contractor	Pre-construction and construction
Cintra Park facilities	FD12	The size and layout of the overland flow path will be integrated with the layout of the water treatment facility.	Construction contractor	Pre-construction and construction
Parramatta Road interchange – tunnel dive structure	FD13	A barrier wall will be provided along the eastern side of the tunnel dive structure to direct overland flow around the tunnel entry during a PMF event. The top of the barrier wall will be located a minimum 0.5 m above the 100 year ARI flood level.	Construction contractor	Pre-construction and construction

Impact	No.	Environmental management measure	Responsibility	Timing
Parramatta Road interchange − realignment of stormwater drainage line XD09c	FD14	The diversion of stormwater drainage line XD09c and the overland flow path at Chandos Street will be designed to contain flows within the project footprint, preventing an increase in the extent of inundation within the adjacent commercial property. Refinement of the pit and pipe drainage system design will be undertaken to prevent an increases in flows and flood levels along Parramatta Road and Bland Street.	Contractor	Pre-construction and construction
Wattle Street interchange − dive structure	FD15	Road level and barriers at the entry to the tunnel portals will prevent ingress of floodwaters during a PMF event, providing a freeboard allowance greater than 0.5 metres freeboard to the peak 100 year ARI flood level. A drainage path will be provided to drain local catchment runoff from Allum Street around the tunnel dive structure during a PMF event.	Construction contractor	Pre-construction and construction
Changes to flooding behaviour – bridge construction	FD16	Temporary bridge works and access roads will be staged and removed as soon as practical after serving their primary purpose.	Construction contractor	Construction
Scour prevention	FD17	Measures will be implemented and maintained to intercept concentrated flow and divert it in a controlled manner to prevent scour of disturbed surfaces and transportation of sediment and construction materials.	Construction contractor	Construction
M4 Motorway - Homebush Bay Drive to Pomeroy Street and Homebush Bay Drive Civil Site (C1)	FD18	The resulting increase in peak flood levels will be managed by providing a setback (up to about 8.0 m) between the edge of the existing concrete channel and the construction site.	Construction contractor	Construction
Homebush Bay Drive interchange and Underwood Road civil site (C3a)	FD19	The width of the flow path where it crosses the cut-and-cover section of tunnel will be increased and ground levels lowered on the eastern side of Underwood Street. The overland flow path will be maintained so as not to increase depths of inundation in adjacent residential development.	Construction contractor	Construction

Impact	No.	Environmental management measure	Responsibility	Timing
Powells Creek civil site (C4) Incorporating Powells Creek on ramp	FD20	The location and dimensions of the temporary access crossings across the Powells Creek channel will be managed. Temporary flood protection measures at the allotment level will be implemented as required.	Construction contractor	Construction
Concord Road interchange, M4 Motorway – Sydney Street to Parramatta Road and Concord Road civil and tunnel site (C5)	FD21	The impacts on depths of overland flow in existing residential development are localised and will be addressed by providing an overland flow path through the site or around its perimeter to control flows that exceed the capacity of stormwater drainage line XD04.	Construction contractor	Construction
Cintra Park tunnel site (C6) Incorporating Cintra Park fresh air supply and water treatment facility	FD22	An overland flow path through the site will be provided.	Construction contractor	Construction
Wattle Street (City West Link) interchange and Wattle Street and Walker Avenue civil site (C9)	FD23	Bunding will be provided to direct overland flow along the haul road and around the Sydney Water pump station.	Construction contractor	Construction
Parramatta Road interchange and Parramatta Road civil site (C10)	FD24	An overland flow path will be provided along Parramatta Road between Chandos Street and Bland Street to control flows that exceed the capacity of stormwater drainage line XD09c. Subject to land access, the detention tank at Bland Street and upgrades to the drainage line along Parramatta Road and Bland Street will be built as part of enabling works or temporary storage on site C10 will be considered as an alternative measure. Temporary flood protection measures will be implemented at the allotment level, as required, to address residual flood impacts.	Construction contractor	Construction

Impact	No.	Environmental management measure	Responsibility	Timing
All tunnel structures	FD25	The flood standard adopted at each tunnel entry during construction will take account of the duration of construction, the magnitude of inflows and the potential risks to personal safety and the project works.	Construction contractor	Construction

18 Groundwater

This chapter outlines the potential groundwater impacts associated with the M4 East project (the project). A detailed groundwater assessment has been undertaken for the project and is included in **Appendix R**.

The Secretary of the NSW Department of Planning and Environment has issued a set of environmental assessment requirements for the project; these are referred to as Secretary's Environmental Assessment Requirements (SEARs). **Table 18.1** sets out these requirements as they relate to groundwater, and identifies where they have been addressed in this environmental impact statement (EIS).

Table 18.1 Secretary's Environmental Assessment Requirements – groundwater

Secretary's Environmental Assessment Requirement	Where addressed in the EIS
Soil and Water – including but not limited to: • Groundwater impacts as a result of the project (including ancillary facilities such as the tunnel control centre and any deluge systems), considering local impacts along the length of the tunnels and impacts on local and regional hydrology including consideration of any Water Sharing Plan and impacts on groundwater flow.	**Sections 18.3** and **18.4** (this chapter)
The assessment must consider:	
• extent of drawdown;	**Section 18.4.1**
• impacts to groundwater quality;	**Sections 18.3.2** and **18.4.6**
• volume of groundwater that will be taken (including inflows);	**Sections 18.3.1** and **18.4.3**
• discharge requirements;	**Section 18.4.8**
• location and details of groundwater management and	**Sections 18.4.8** and **18.5.1**
• implications for groundwater dependent surface flows, groundwater-dependent ecological communities, and groundwater users.	**Sections 18.4.2**, **18.4.4** and **18.4.5**
The assessment should include details of proposed surface and groundwater monitoring and be prepared having consideration to the requirements of the *NSW Aquifer Interference Policy*;	Surface and groundwater monitoring is addressed in **sections 18.1.2** and **18.5**. The requirements of the *NSW Aquifer Interference Policy* are addressed in **sections 18.1.3** and **18.4.9**.

18.1 Assessment methodology

18.1.1 Overview

A groundwater assessment has been undertaken in relation to the existing environment and to determine the potential impacts of the construction works and operation of the project. A summary of the groundwater assessment is provided in this chapter. The full report is included in **Appendix R**.

The assessment considers:

- The existing environment, which describes the current environment that the project would interact with, including the hydrogeological conditions and environmental values of the surrounding environment
- Impact assessment, which characterises the impacts to groundwater dependent systems associated with the tunnel on the surrounding environment using numerical modelling techniques

- Groundwater management, which characterises proposed management and monitoring measures required to mitigate impacts and manage tunnel inflows.

Desktop review

The key aspects of the project that may affect groundwater quality and quantity were identified through a desktop review. Relevant groundwater policy guidance documents were reviewed to identify relevant aspects and potential implications for the project. Overarching criteria for the groundwater impact assessment were then developed, including characterisation of key water quality criteria and key groundwater drawdown/flow criteria.

Conceptual groundwater model

A conceptual model was developed that characterised and identified the key features of the surrounding environment relating to groundwater. The area covered by the model is shown in **Appendix R**, Figure 6.1. The key features of the model include:

- Climate, rainfall and groundwater recharge
- Geological and hydrogeological characteristics such as the primary geological units and associated hydraulic properties and estimated groundwater elevations
- Condition of the existing system with regard to both water quality and yields. This included the development of a preliminary water balance for the project footprint
- Groundwater dependent surface water systems
- Groundwater dependent ecosystems including riparian vegetation that may be affected by drawdown
- Groundwater users
- Contaminated land (summarised from other assessments undertaken for the project)
- Acid sulfate soils (summarised from other assessments undertaken for the project)
- The sensitivity of the current system.

Characterisation of impacts on the surrounding environment

Impacts on the surrounding environment were assessed by:

- Characterising the key potential impacting activities and the magnitude of their impacts, primarily in qualitative terms
- Undertaking numerical groundwater modelling to
  - Estimate the range of potential inflows to the project footprint
  - Estimate the range of potential groundwater drawdown due to the project and the potential for reduced flows to surface water features and groundwater users
  - Assess changes in groundwater interaction with the nearby Parramatta River and tributaries
- Characterising the water quality of groundwater inflows along the tunnel, to inform treatment requirements for potential discharge to surface water
- Characterising the potential mobilisation of saline groundwater, contaminated groundwater and exposure of acid sulfate soils, and the associated impacts.

The expected water ingress was compared to water allocation and availability criteria and licensing requirements in the NSW water sharing plans administered by the NSW Department of Primary Industries – Water (DPI – Water).

Mitigation measures were then developed to minimise potential water quality impacts from various influences and to manage inflows and drawdowns.

The objectives, design and parameters of the numerical groundwater model are detailed in **Appendix R**. Acid sulfate soils and contamination are also discussed in **Chapter 16** (Contamination).

18.1.2 Ground and surface water monitoring

A baseline water quality monitoring program has recently commenced. Data obtained from this monitoring has been used to provide an overview of the existing water quality conditions along the alignment for the purposes of:

- Characterising existing impacts on groundwater quality created by the current urban environment surrounding the project
- Understanding the environmental value and beneficial use potential of the existing groundwater conditions
- Characterising the potential aggressiveness of the existing water quality to project infrastructure
- Obtaining a preliminary understanding of the treatment required for tunnel seepage to be suitable for disposal to surface water.

Groundwater

Groundwater quality sampling from 15 wells along the project corridor was completed between 4 and 6 November 2014 as part of the soil and land contamination assessment (refer to **Chapter 16** (Contamination) and **Appendix P**). The locations of these wells were selected to target sources of potentially contaminating land uses along the project corridor.

A baseline groundwater monitoring program has commenced, and is monitoring groundwater quality at 27 monitoring wells along the project corridor, as described in Appendix B of the groundwater impact assessment in **Appendix R**. The first baseline monitoring event was completed between 23 and 25 June 2015 and groundwater elevations were recorded immediately before sampling each well. The groundwater elevations presented in this assessment are relative to depth below the measuring point (top of the monitoring well casing), which is usually near to ground surface. As the wells have not yet been surveyed, groundwater contours have not been interpolated along the corridor.

Surface water

A baseline surface water monitoring program has commenced, and is monitoring surface water quality at a total of 10 locations on the five waterways that are crossed by the project (refer **Appendix R**). Where possible, this includes an upstream and downstream location on each waterway. In addition, monitoring is being conducted at two reference sites, one each to the east and west of the project area on Finlaysons Creek and Hawthorne Creek. These reference sites allow identification of water quality impacts unrelated to the project. The first surface water baseline monitoring event was completed on 29 June 2015.

18.1.3 Policy framework

The framework for the groundwater assessment has been developed in accordance with relevant Australian and NSW Government groundwater policy and guidelines (refer **Appendix R**). The NSW Aquifer Interference Policy (NSW Office of Water 2012a) requires that potential impacts on groundwater sources, including their users and groundwater dependent ecosystems, be considered. The policy clarifies the water licensing and approval requirements for aquifer interference activities in NSW. **Table 18.2** summarises the relevance of key policy and guidance documents to this assessment.

Table 18.2 Policy and guidance considered for the groundwater assessment

Policy/guidance	Relevance to project
NSW Aquifer Interference Policy (NSW Office of Water 2012a)	The impact limits in terms of drawdown magnitudes and offset distances have been considered in this assessment and inform the overall structure of the assessment.
Water Management Act 2000 (NSW) (WM Act)	Section 91F of the Act requires an aquifer interference approval when carrying out an aquifer interference activity. However, section 91F of the Act does not currently apply as at the time of writing, no proclamation under Section 88A had been made declaring that the WM Act applies in relation to aquifer interference approvals. The project would take groundwater as a consequence of the interception of the aquifer. Roads authorities are exempt from the requirement to obtain a water access licence under clause 2, Schedule 5 of the *Water Management (General) Regulation 2011* (NSW). Ongoing licensing arrangements for road infrastructure are currently under development by DPI – Water in consultation with NSW Roads and Maritime Services (Roads and Maritime). Roads and Maritime would continue to consult with DPI – Water in relation to licensing arrangements. Under section 90 of the WM Act, a water management work approval is required for a water supply work, a drainage work or a flood work. The project does not involve any of these and approval is therefore not required.
Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011	The Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources covers 13 groundwater sources. The project lies within the Sydney Basin Central groundwater source area, which is a porous rock aquifer. While the interference and extraction of groundwater covered by a water sharing plan requires a water access licence, roads authorities are exempt (as discussed above).
Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011	The estuarine systems within the Lower Parramatta River management area in which the project lies have low sensitivity to changing low and high inflow conditions of freshwater with a moderate impact from changes in groundwater inflow. The water sharing plan also indicates that the Lower Parramatta River management zone has low to moderate instream values relative to a hydrologic stress and dependence on extraction.
NSW State Groundwater Quantity Management Policy (NSW Office of Water n.d.)	The requirements of this policy are met by the general assessment requirements in the Aquifer Interference Policy.
NSW Groundwater Quality Protection Policy (Department of Land and Water Conservation (DLWC) 1998)	The requirements of this policy are considered through the identification of baseline conditions for the study area and assessment of potential changes to groundwater quality as a result of the project.
NSW State Groundwater Dependent Ecosystems Policy (DLWC 2012)	This policy requires the assessment of changes in water levels and flows near identified groundwater dependent ecosystems.
Risk assessment guidelines for groundwater dependent ecosystems (NSW Office of Water 2012b)	Volume 1 of the guidelines provides general guiding material, while Volumes 2 through 4 relate specifically to coastal aquifers.

Policy/guidance	Relevance to project
NSW Water Extraction Monitoring Policy (Department of Water and Energy 2007)	Under this policy, all groundwater extraction during construction and operation of the project would need to be monitored. Typically this would involve metering of all flows in and out of the tunnel and using the difference to identify the groundwater inflow contribution.
Australian Drinking Water Guidelines (National Health and Medical Research Council 2013)	Existing and potential groundwater quality has been compared against the guidelines, to identify the highest and best use of the groundwater, and to assess the risk to the public from incidental exposure to untreated groundwater intercepted by the tunnel.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000a)	The national guidelines provide default trigger values of various analytes that can be compared with sampled values from the project. From the assessment of these trigger values, site specific values have been recommended for the project.
National Environment Protection (Assessment of Site Contamination) Measure 1999	This measure provides adequate protection of human health and the environment, where site contamination has occurred, through the development of an efficient and effective national approach to the assessment of site contamination. This measure has been reviewed and considered as appropriate for this assessment.

18.2 Existing environment

18.2.1 Drainage, topography and geology

Drainage

The project is located within the lower Parramatta River catchment, which hosts a number of surface water tributaries (ie Duck Creek, Duck River, Haslams Creek, Hen and Chicken Bay, Iron Cove, Dobroyd Canal (Iron Cove Creek) and Hawthorne Canal) and several local channels, described in **Chapter 15** (Soil and water quality). To the south of the project, the land drains towards the Cooks River. To the north of the project the land drains towards the Parramatta River.

Topography

The topography surrounding the project footprint is characterised by a gentle slope towards the Parramatta River with local slopes towards creeks and bays. To the south, the surface slopes towards the Cooks River. Ground surface elevations within the project boundary range from sea level (along the shore of the Parramatta River and where the project crosses drains at George Street in North Strathfield and Croydon Road in Croydon) to about 29 metres Australian Height Datum (AHD) near Concord Road. The maximum depth in the Parramatta River adjacent to the project boundary is around 20 metres.

The start of the mainline tunnels east of Homebush Bay Drive is located at an elevation of about 10 metres AHD, the Concord Road interchange is at about 14 metres AHD, and the Wattle Street and Parramatta Road interchanges are at about five to 20 metres AHD.

Geology

The 1:100 000 Sydney Basin geology map (NSW Department of Mineral Resources 1983) indicates the surface geology in the vicinity of the project footprint primarily consists of Triassic Ashfield Shale deposits. These comprise shallow marine sediments characterised by black to dark grey shale and laminite, and some sandstone beds. The maximum thickness of Ashfield Shale above the mainline tunnels is around 36 metres near the Concord Road interchange, thinning out to less than 20 metres over much of the eastern two kilometres (east of Dawson Street at Croydon).

The Mittagong Formation is considered a transitional phase between the Hawkesbury Sandstone and the Ashfield Shale and generally has thicknesses of five to 10 metres beneath the project corridor. In terms of engineering properties, it is grouped with the Hawkesbury Sandstone (Pells 2004), but has hydraulic properties similar to the overlying Ashfield Shale (Tametta and Hewitt 2004).

The Triassic Hawkesbury Sandstone deposits underlie the Mittagong Formation and outcrop to the north-east of the project corridor, where the Parramatta River has incised through the overlying Ashfield Shale and Mittagong Formation deposits. The Hawkesbury Sandstone thickness in the general region of the project is at least 180 metres. The unit comprises massive and interbedded/crossbedded quartzose sandstone with a variable clay matrix. The interbedded laminite, shale and quartz to lithic sandstones of the Newport Formation provide an effectively impermeable basement to the Hawkesbury Sandstone aquifer.

Quaternary alluvium, comprising silty to peaty quartz sand, silt and clay, overlies these older deposits along the Parramatta River and where some of the larger creeks (such as Iron Cove Creek) drain in to the river and estuary. In some areas they form relatively deep (in the order of 20 metres) palaeochannel fill deposits. Fill material, consisting of dredged estuarine sand and mud, demolition rubble, industrial and household waste, overlies the alluvium in some areas (such as at Powells Creek and near Cintra Park).

Basic igneous intrusions occur throughout the Sydney Basin, commonly in the form of basaltic dykes less than one metre thick and basaltic volcanic breccias in diatremes in the order of 200 to 500 metres across, up to larger dolerite bodies more than one kilometre wide. Recent geotechnical investigations for the project have identified the following dykes along the corridor:

- A dolerite dyke in the Mittagong Formation and Hawkesbury Sandstone, intersected approximately 80 metres west of Concord Road at North Strathfield
- An unknown number of basaltic or dolerite dykes intersecting the alignment at Broughton Street at Burwood
- A dolerite dyke in the Mittagong Formation and Hawkesbury Sandstone, intersected at the east end of Concord Oval.

Recent geotechnical investigations have also identified actual and potential faulting at a number of locations along the project corridor.

Regional geology is shown in **Figure 18.1**. A detailed geological long section, showing subsurface and geological structures in relation to the vertical alignment of the tunnel, is provided in **Figure 5.10** to **Figure 5.13** in **Chapter 5** (Project description).

Soils

As described in **Chapter 15** (Soil and water quality), three soil landscapes (Birrong, Blacktown and Disturbed) are encountered in the vicinity of the project footprint. The predominant soil type in the Parramatta River catchment is the Blacktown landscape.

18.2.2 Groundwater levels and movement

The principal geological layers within which aquifers occur in the region are: alluvial aquifers, fill aquifers, shale aquifers (associated with the Ashfield Shale) and sandstone aquifers (associated with the Hawkesbury Sandstone). These are summarised below.

Alluvium and fill

Shallow and sometimes perched groundwater is located within fill material, residual fill and alluvium in low-lying areas. The alluvium and fill materials form discontinuous, local groundwater flow systems. Interconnection with the deeper sandstone aquifer is generally low, due to the intervening Ashfield Shale and clayey residual soils. However, the perched aquifers may be connected to the Hawkesbury Sandstone where the shales and clayey residual soils are absent, potentially adjacent to the Parramatta River and near Dobroyd Canal (Iron Cove Creek). No instances of sandy alluvium or soil directly overlying sandstone were observed in drillholes completed as part of site investigations.

The unconsolidated shale-derived materials have thicknesses of between zero and about six metres along the corridor. The thickest zones are between Underwood Road and Ismay Avenue at Homebush, in elevated areas near Scott Street at Croydon, and in areas flanking alluvium at Dobroyd Canal (Iron Cove Creek). Over the majority of the corridor the residual shale soils have thicknesses of less than about four metres.

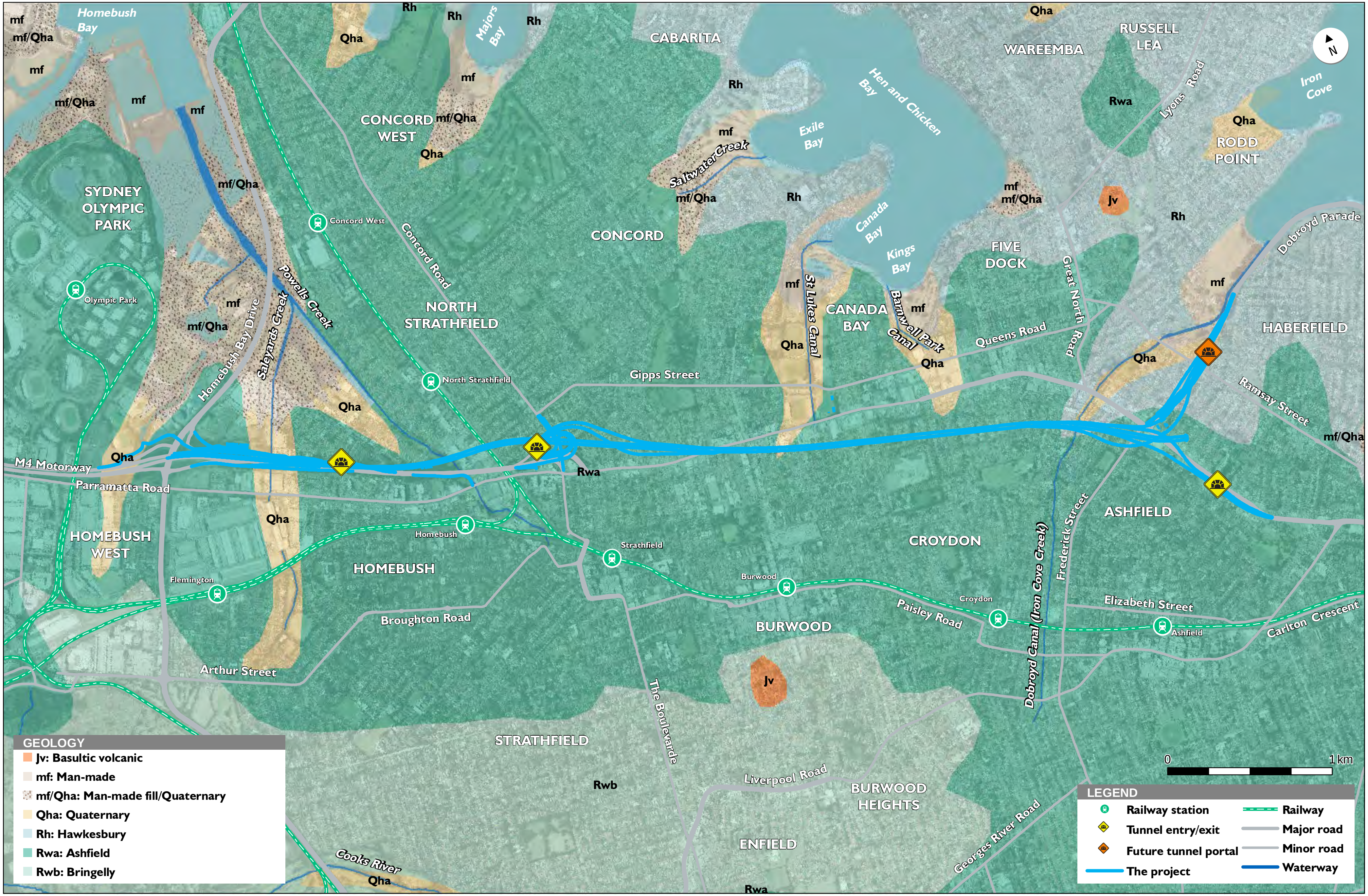

Figure 18.1 Regional geological context

Groundwater levels in the alluvium are likely to be controlled by nearby surface water levels and local recharge and discharge zones, with shallow groundwater flowing primarily towards the adjacent streams, and deeper flows along the axis of the alluvial valley fill. Deeper palaeochannels extending southwards from Homebush Bay, Hen and Chicken Bay and Iron Cove may represent significant zones of high permeability, with relatively high interconnection with surface water bodies.

The June 2015 groundwater monitoring included monitoring of groundwater elevations at nine wells within alluvium. Groundwater elevations ranged between 0.55 metres and 5.03 metres below the top of the monitoring well casing. Average groundwater elevations were about 2.5 metres below top of casing.

Apart from widespread filling used to reclaim shallow areas, localised areas of fill are likely under various buildings within the study area. East of Powells Creek fill deposits are about five metres thick, but these gradually thin as the corridor extends east toward Main North Rail Line and Queen Street at North Strathfield. Near Concord Oval, fill thickness is about three metres, while elsewhere along the corridor, fill deposits are generally absent or less than two metres thick. Extensive fill deposits that may have discontinuous groundwater systems are separated from the Hawkesbury Sandstone by low permeability residual soils and Ashfield Shale.

Localised perched aquifers are likely in most fill areas overlying the poorly drained Blacktown soils; this is discussed in **Chapter 15** (Soils and water quality). Where the fill overlies the Hawkesbury Sandstone and associated soils, fill is more likely to be readily drained, making perched aquifers less likely except in areas of highly permeable fill and high recharge. These systems would mainly be present near Powells Creek and Concord Oval, where more extensive zones of fill are present. Groundwater levels and flow would tend to be controlled by local discharge/drainage zones and are likely to respond rapidly to short-term rainfall events.

Groundwater elevations in the fill material are not currently being monitored. Groundwater was not encountered during drilling of the contamination assessment bores along the alignment. . As such, the depths to groundwater in the fill are currently unknown; however it is expected that groundwater elevations in thick fill would be similar to the depths observed for other unconsolidated materials and elevations in the coastal areas would be close to sea level.

Hydraulic conductivity is expected to be highly variable, ranging from low in clayey material and increasing in sandy material. Higher hydraulic conductivity is possible in poorly controlled rubble fill.

Ashfield Shale

The Ashfield Shale is a low permeability material which generally acts as a barrier, forming an impervious confining bed to the Hawkesbury Sandstone aquifer. The shale acts as a fractured rock aquifer, with hydrogeological characteristics varying with the degree of weathering and jointing.

West of Burwood Road at Burwood, the Ashfield Shale is between 15 and 33 metres thick. East of Burwood Road, shales are between five to 15 metres thick and are absent further to the east of Croydon Road at Croydon.

Localised perched aquifers are present in areas of the Ashfield Shale where jointing and bedding plane parting is well developed, but not filled with clayey weathering products. As with most fractured rock aquifers, groundwater levels are expected to reflect local topography, due to higher recharge in elevated areas with thinner soils, and the decreasing permeability with depth constraining drainage as water levels recede.

The June 2015 groundwater monitoring event included monitoring of groundwater elevations at 13 wells within Ashfield Shale. Groundwater elevations ranged between 2.2 metres and 7.37 metres below top of casing. Average groundwater elevations were about 2.5 metres below top of casing.

Groundwater monitoring data shows an overall random variability in hydraulic conductivity within Ashfield Shale. No specific areas of high or low hydraulic conductivity within the shale could be distinguished from the data.

Hawkesbury Sandstone

The Hawkesbury Sandstone is a regionally significant aquifer with relatively high yields of good quality water in many areas, although no bores tapping the aquifer were identified within the project boundary. This may be a function of the good availability of alternative water supplies; it may also be a product of the lack of local recharge and the area's proximity to saline coastal waters, which create the potential for more saline groundwater. Hawkesbury Sandstone underlies the Ashfield Shale and the Mittagong Formation, and is up to 290 metres thick beneath the project footprint.

Groundwater in the Hawkesbury Sandstone flows between grains in the rock (intergranular) and through features such as fractures, joints and bedding planes.

At a regional level, the general flow is from the west to east. Locally, however, flow would be controlled by discharge, generally northward to where the Parramatta River and Sydney Harbour intersect the sandstone, and southward towards the Cooks River and Georges River. Given the presence of Ashfield Shale over much of the study area, local recharge is expected to be minimal and water levels would be subject to long-term changes in regional recharge rather than short-term rainfall events. The exceptions are likely to be in sandstone outcrop areas to the north, and in areas subject to tidal influence in the sandstone adjacent to waterways.

The June 2015 groundwater monitoring included monitoring of groundwater elevations at four wells within Hawkesbury Sandstone. Groundwater elevations ranged between 2.28 metres and 5.47 metres below top of casing. Average groundwater elevations were about 3.8 metres below top of casing.

Previous investigations for tunnel projects in Hawkesbury Sandstone in the Sydney basin showed a distinct relationship between hydraulic conductivity and depth of aquifer. The data shows a weak correlation of decreasing hydraulic conductivity with depth. The highest hydraulic conductivity values were recorded at a relatively shallow 15 to 20 metres; however, this result was in low lying areas leading to Iron Cove, indicating it may be within a zone of more jointed − and therefore more easily erodible − sandstone.

Igneous intrusions

Dykes are known to be areas of higher permeability than the surrounding sediments and are associated with higher inflows in tunnel excavations in the Hawkesbury Sandstone (Lees, Edwards and Grant 2005). It is likely that permeability and hence inflows in the vicinity of dykes (as described in **section 18.2.1**) would be higher than in the surrounding geology (Mittagong Formation and Hawkesbury Sandstone).

18.2.3 Groundwater quality

Salinity

Salinity measured in the June 2015 groundwater monitoring ranged between an electrical conductivity (EC) of 760 microSiemens per centimetre (estimated total dissolved solids (TDS) of 490 milligrams per litre) and 20,000 microSiemens per centimetre (TDS of 12,000 milligrams per litre). The salinity characteristics for different aquifer systems intersected across the site are summarised below:

- Salinity in shallow groundwater in unconsolidated sediments ranges between 990 microSiemens per centimetre (780 milligrams per litre total dissolved solids (TDS)) and 3,300 microSiemens per centimetre (2,300 milligrams per litre TDS). These concentrations would be on the margin of suitability for potable uses, but have potential to be used for stock purposes
- Ashfield Shale has relatively saline groundwater, which ranges between 1,600 microSiemens per centimetre EC (1,000 milligrams per litre TDS) and 20,000 microSiemens per centimetre EC (12,000 milligrams per litre TDS). These concentrations are likely to have marginal beneficial use for potential potable or stock purposes
- Groundwater salinity levels in Hawkesbury Sandstone range between 760 microSiemens per centimetre EC (490 milligrams per litre TDS) and 1,700 microSiemens per centimetre EC (1,100 milligrams per litre TDS). These concentrations are generally suitable for potable use.

Organic constituents

The November 2014 groundwater sampling assessed the presence of organic compounds in groundwater. Overall there were low levels of organic compounds identified with minor detectable concentrations of total recoverable hydrocarbons (TRH) present in three wells. One of these wells also reported several anomalies of contaminants of potential concern above detection.

Major ions

Concentrations of sulfate in groundwater were consistently above human health criteria for drinking water in monitoring data. The values were all below the recommended recreational water criteria. The data suggests that while groundwater is not suitable for drinking, discharge to surface water would not represent a risk to human health.

Nutrients

Based on the latest groundwater monitoring event, ammonia is present at concentrations that exceed the adopted marine and freshwater criteria at a number of locations. This suggests that ammonia concentrations may require treatment before discharge to surface water. However, these exceedances occur intermittently along the project footprint, and the overall concentrations in seepage water are expected to be acceptable.

Data suggests that nitrate and phosphorus concentrations in groundwater and surface water are similar. However, ammonium concentrations in groundwater may convert to nitrate when exposed to air, and seepage water may therefore require treatment for nitrate before discharge to surface water.

pH

The pH values from monitoring data generally range between 4.3 and 7.6 with the majority being equal to or below 6.5.

Metals

Data from the latest groundwater monitoring indicates that background concentrations of cadmium, chromium, copper, manganese, nickel and zinc are present in groundwater above the adopted fresh water quality criteria. Nickel and zinc concentrations are consistently above the fresh water criteria. Total iron and beryllium concentrations are also above the adopted low reliability criteria for fresh water.

Data also indicates that background concentrations of cadmium, chromium, cobalt, copper, mercury, nickel, vanadium and zinc are present in groundwater at concentrations in excess of the adopted marine water quality criteria. Cobalt, nickel and zinc concentrations consistently exceed the marine water criteria.

Surface water concentrations of copper and zinc are present above the adopted marine and freshwater criteria at most sites, suggesting that background concentrations are naturally above criteria (refer **section 15.2.4**, **Chapter 15** (Soil and water quality)). These concentrations were generally in a similar range to those present in groundwater although there are isolated occurrences of higher concentrations in groundwater. Concentrations of other metals were below criteria and below concentrations observed in the groundwater, particularly for cadmium, chromium and nickel. Overall this suggests that metals in groundwater seepage would require treatment before discharge to surface water (refer to **section 18.4.8**).

Concentrations of manganese and nickel in groundwater were above the human health criteria for drinking water; however, no concentrations of metals were above the recommended recreational water criteria. This suggests that metals concentrations in groundwater seepage discharge to surface water are unlikely to represent a human health risk.

Ferrous iron concentrations ranged from below 10 milligrams per litre to 27 milligrams per litre. High concentrations of ferrous iron (above 10 milligrams per litre) indicate the potential for clogging of groundwater drainage and collection systems.

18.2.4 Groundwater dependent ecosystems

Groundwater dependent ecosystems are those that rely on groundwater for their survival and species diversity. These ecosystems are broadly classified as terrestrial vegetation, river base flow, estuarine and near shore marine, aquifer and cave, and wetlands. These ecosystems are dependent on one or more of the characteristics of groundwater, namely flux, level, pressure and quality.

Groundwater dependent ecosystems are most likely to be present in shallow alluvial sediments along major drainage lines, where the water table and associated capillary zone is within the root zone of established vegetation. There may also be localised freshwater aquatic ecosystems in areas fed by groundwater baseflow emanating from the Hawkesbury Sandstone.

There are wetlands present near Homebush Bay; these are the Homebush Bay wetland and Mason Park wetland. The groundwater levels in this area however, are expected to be reliant on the Parramatta River and its associated tidal fluctuations, as such it is not expected that these wetlands are reliant on groundwater, and are not considered to be groundwater dependent surface flows. No other groundwater dependent ecosystems have been identified within the area subject to drawdown from tunnel construction or operation.

18.2.5 Groundwater users

There are 30 registered groundwater bores within five kilometres of the proposed tunnel. Five bores are within about four kilometres of the project corridor (GW024096, GW102402, GW105215, GW109699 and GW110899), as shown in **Figure 18.2**, all of which are licensed for domestic use. No usage data for the bores are available and there are no water quality data for the bores.

18.3 Assessment of construction impacts

18.3.1 Groundwater inflow rates and recharge

Short-term groundwater inflow into the tunnel structures during construction would depend on the rate of tunnel progress, tunnel construction methods and the presence of localised zones with potential for high, short-term inflows. As none of the approach structures or main tunnels cut through areas of alluvium, there is no potential for the tunnel to block or otherwise interfere with significant shallow groundwater systems.

In order to assess the changes in water levels and flow over time, a transient groundwater model was developed. Tunnel construction was split into quarterly intervals based on the indicative construction program outlined in **Table 6.2** in **Chapter 6** (Construction work). The transient model was used to gain an understanding of the likely initial inflows relative to long-term or near steady-state conditions.

Figure 18.3 shows transient tunnel inflow during construction. The staggered results in the graph are due to the quarterly input of data into the model which increases as additional sections of the tunnel are completed, followed by a slow decrease upon completion of the tunnel works and final waterproofing. Tunnel inflows during construction are expected to reach a maximum rate of about 1.6 megalitres per day, or 584 megalitres per year. The capacity of the groundwater source is currently 43,323 megalitres per year. This inflow volume is therefore unlikely to result in exceedance of the sustainable potential for the aquifer systems.

Groundwater drawdown resulting from construction of the tunnels would be a long-term change and is therefore discussed in **section 18.4.1**.

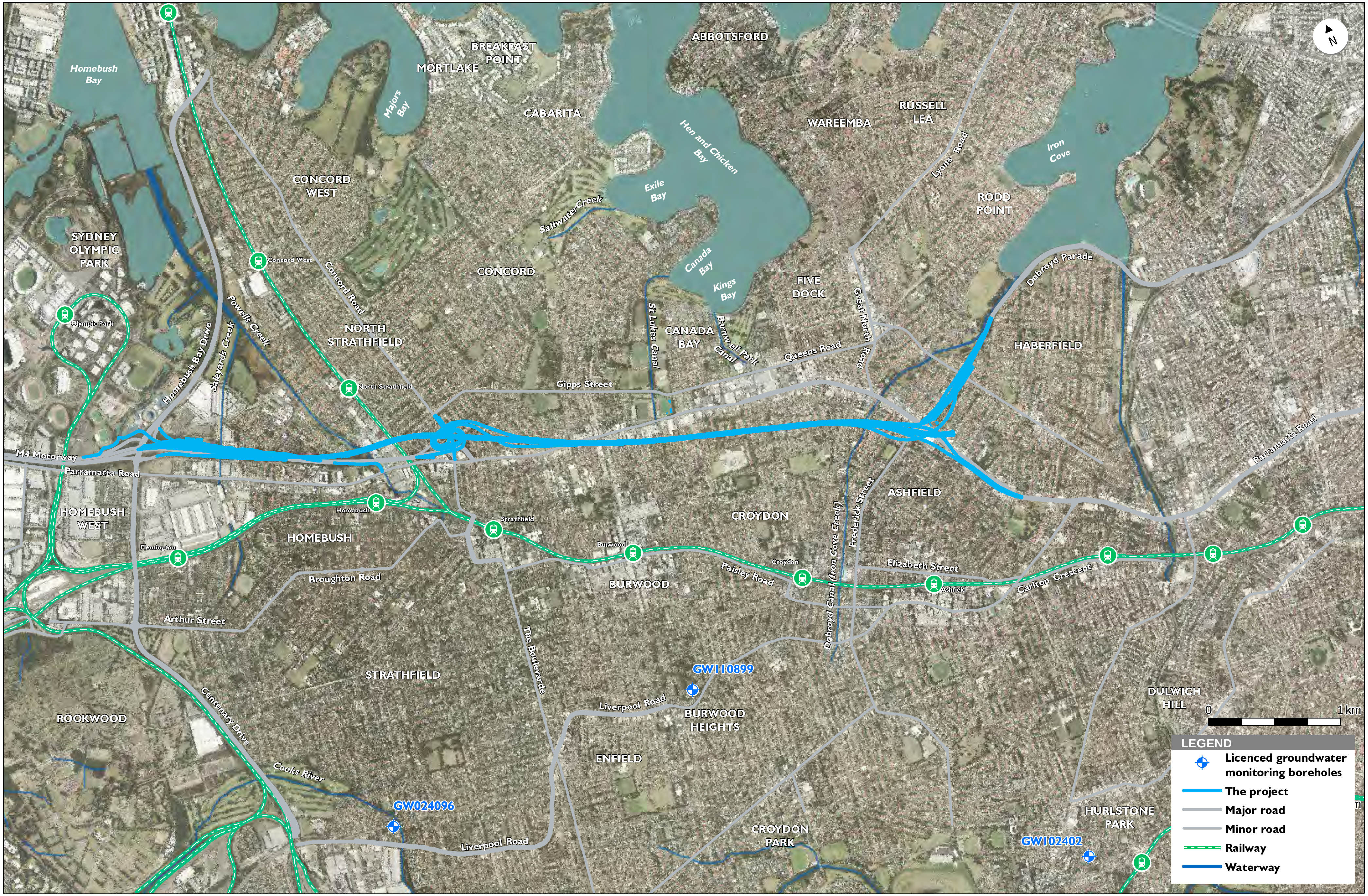

Figure 18.2 Existing groundwater bores surrounding the project

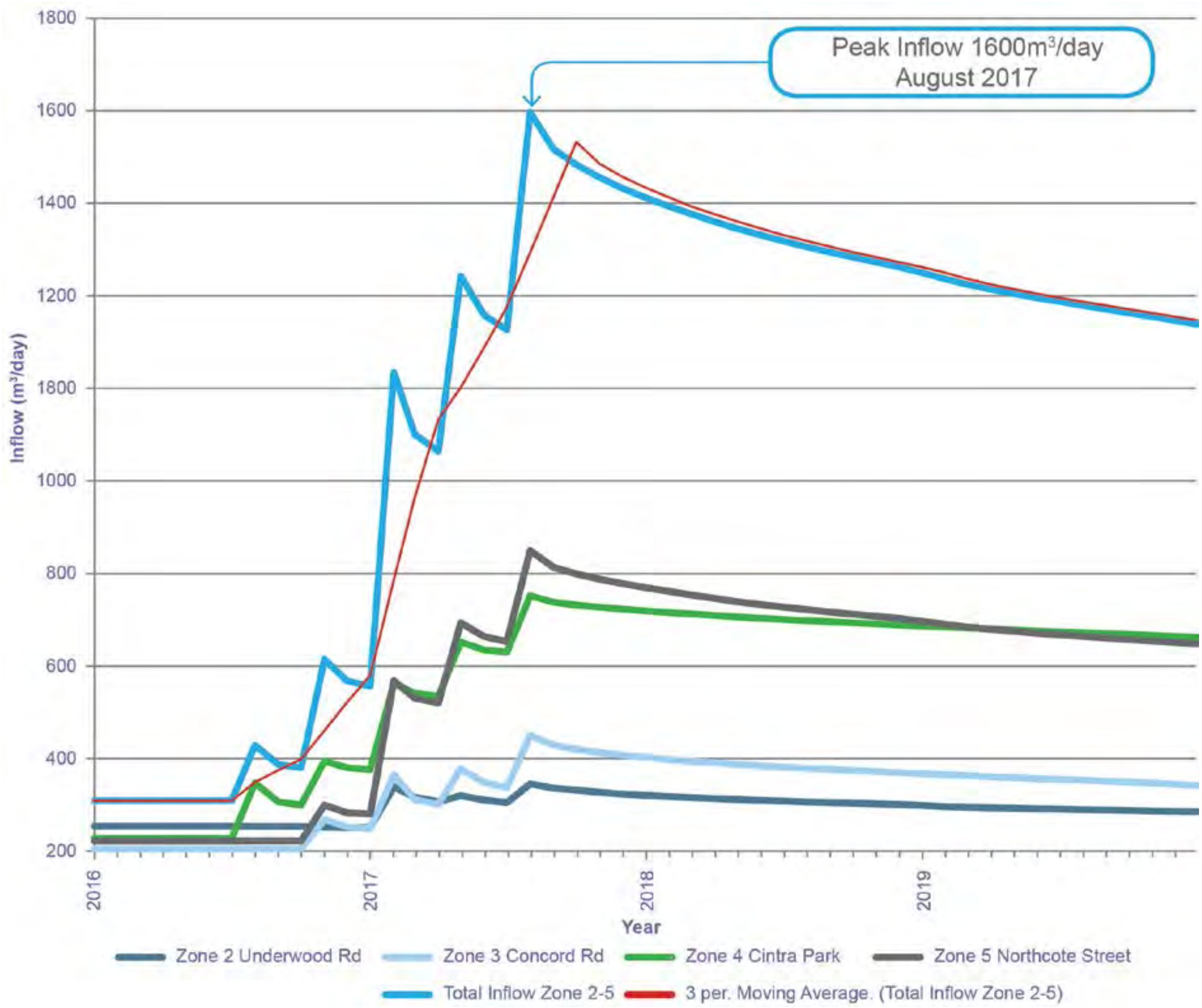

Figure 18.3 Transient tunnel inflow during construction (cubic metres per day)

For this assessment it is assumed that all production bores are screened within the most impacted layers of the Hawkesbury Sandstone. Based on this assumption, the rate of drawdown in the two closest bores (GW110899 and GW024096), is shown in **Figure 18.4**. The 50-year drawdowns in GW110899 and GW024096 are less than two metres and consequently water levels would remain well above sea level.

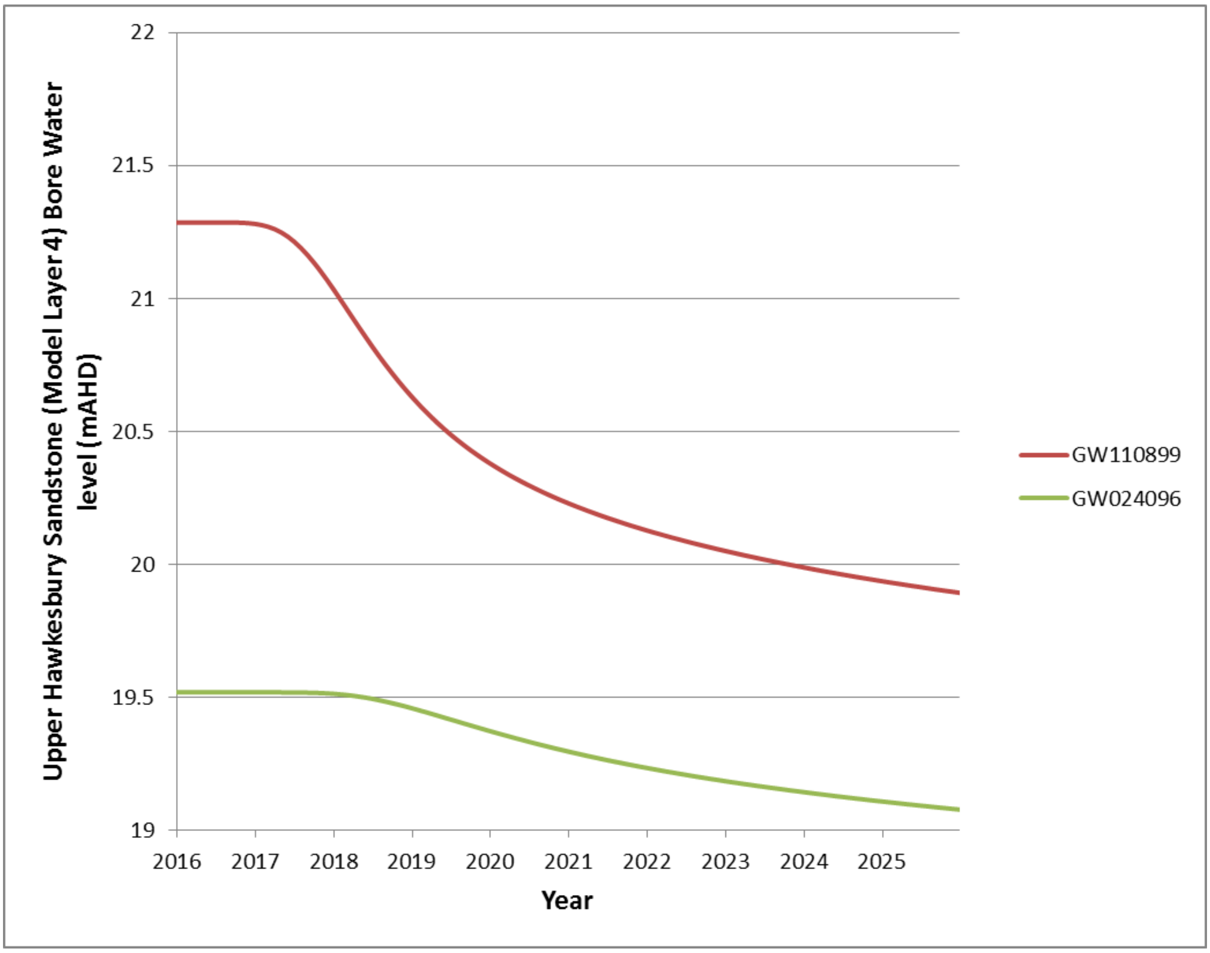

Figure 18.4 Predicted water levels in impacted bores during construction (metres AHD)

High rainfall events that coincide with the presence of open cut-and-cover areas or open dive structures may cause temporary flooding of the works and lead to a short period of localised increase in recharge to the aquifer system. In such instances, the impacts would be considered minor, localised and of short duration.

18.3.2 Impact on groundwater quality and contamination

Based on the local groundwater chemistry and experience in other tunnels in the Hawkesbury Sandstone within the Sydney region, this inflow is likely to contain elevated concentrations of iron and calcium carbonate. It is also likely that ammonia and nitrate concentrations would be elevated by blasting residues during construction; however, the likely levels and potential impact of these concentrations are expected to be negligible. Saline inflow would not be expected to develop during the construction phase.

The potential for spills and leaks, which are further discussed in **Chapter 15** (Soils and water quality), may increase the potential for chemical constituents to be present in groundwater seepage. Mitigation and management practices adopted during construction would reduce this risk to low.

Groundwater encountered during construction would be collected and treated before discharge. This is discussed further in **section 18.5.1** and in **Chapter 6** (Construction).

18.3.3 Ground movement

Ground movement may occur as a result of:

- Tunnel induced movement caused by the relief of stress from tunnelling through intact rock
- Settlement induced from groundwater drawdown.

The risk to individual structures would be dependent on the geotechnical conditions, the depth of the tunnel, the number of storeys of the building, and the position, condition, and masonry of the structure itself.

Table 18.3 outlines the typical impacts of ground movement based on maximum building settlement, based on Burland et al. (1977), Boscardin and Cording (1989) and Rankin (1988).

Table 18.3 Typical impacts of ground movement

Maximum building settlement	Maximum tensile strain	Maximum ground slope	Degree of impact	Typical impact
Up to 10 millimetres	0.05% to 0.075%	Less than 1:500	Very slight	Fine cracks (0.1 to 1.0 millimetres wide) easily treated during normal redecoration. Perhaps isolated slight fracture in building. Cracks in exterior visible on close inspection.
10 to 50 millimetres	0.075% to 0.015%	1: 500 to 1:200	Slight	Cracks (1 to 5 millimetres wide) easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible; some repainting may be required for weather-tightness. Doors and windows may stick slightly.
50 to 75 millimetres	0.15% to 0.3%	1:200 to 1:50	Moderate	Cracks (5 to 15 millimetres wide, or a number of cracks greater than 3 millimetres wide) may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Brick pointing and possible replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather-tightness often impaired.

Preliminary ground movement investigations indicate that there may be potential settlement of up to 50 millimetres at the mainline tunnels in the vicinity of Dobroyd Canal (Iron Cove Creek) and the eastern ventilation facility, and the risk category has been assessed as slight to moderate. In the vicinity of the Concord Road interchange cut-and-cover tunnel structure, there may be potential settlement of up to 25 millimetres, and the risk category has been assessed as slight. Elsewhere, the risk category has been assessed as negligible to very slight.

This indicates that ground movement is generally likely to result in cosmetic damage only. For the majority of properties, the anticipated impacts are negligible, typically resulting in hairline cracking only. For a limited number of properties, ground movement may result in cracking of up to 15 millimetres. **Table 18.4** lists the potential impact on existing buildings resulting from settlement due to tunnel construction.

Table 18.4 Assessed impact on existing building structures

Location	Building type	Degree of impact	Number buildings potentially impacted
Between Powells Creek and George Street	Type 3	Slight	2
Between Concord Road and Concord Lane	Type 1	Slight	1
Near intersection of Coles Street and Ada Street	Type 1	Slight	2
Near intersection of Broughton Street and Parramatta Road	Type 1	Slight	5
	Type 2	Slight	3
		Very slight	2
	Type 3	Slight	3
Between Croydon Road and Earle Avenue	Type 1	Very slight	5
		Slight	49
	Type 2	Very slight	1
		Slight	9
	Type 3	Very slight	1
		Slight	7
Near intersection of Frederick Street and Parramatta Road	Type 3	Slight	1
Near intersection of Bland Street and Parramatta Road	Type 3	Very slight	1
	Type 1	Slight	3
Total			**95**

Note: Type 1 – single storey masonry building
Type 2 – two storey masonry building
Type 3 – masonry building greater than three storeys

These results are preliminary and do not take into account the specifics of individual buildings or heritage buildings. Further assessments would be undertaken during detailed design to determine the level of potential impact on structures and to identify feasible and reasonable mitigation and management measures required to minimise potential ground movement impacts.

18.4 Assessment of operational impacts

18.4.1 Groundwater drawdown

A steady-state groundwater model was run in order to assess the long-term drawdown of groundwater. This model was calibrated against only steady-state water level data from the monitoring bores intersecting sandstone.

The model was three-dimensional and assessed the impacts on the following broad geological layers:

- Layer 1 – Surface soil, weathered zone and Quaternary alluvium
- Layer 2 – Ashfield Shale
- Layer 3 – Mittagong Formation
- Layers 4 to 6 – Hawkesbury Sandstone.

The long-term predicted tunnel inflow was 1,277 cubic metres per day. Predicted groundwater drawdown for the impacted area is shown in **Figure 18.5** to **Figure 18.7**. These figures show the modelled level that groundwater would lower in metres (drawdown) from the existing levels, decreasing incrementally out from the location of the project. The three figures show the expected drawdown in different geological layers.

Figure 18.5 Predicted groundwater drawdown in layer 1 alluvium (metres)