Chapter 14

Groundwater and ground movement

14 Groundwater and ground movement

This chapter provides an assessment of the potential impact of the proposal on groundwater and ground movement and identifies mitigation measures to address these impacts. This chapter draws on information in Technical Paper 7 (Hydrogeology).

14.1 Overview

There are no registered groundwater users or groundwater dependent ecosystems located within the area of potential drawdown impacts for the proposal. As a result, there would be no impact to groundwater users, beneficial use or groundwater dependent ecosystems as a result of this proposal.

Interactions between surface water and groundwater due to tunnelling activities are not expected due to the depth of tunnels.

Groundwater levels would experience limited changes as the proposed tunnels, cross passages and underground station structures would be tanked to prevent the inflow of groundwater, typically using concrete lining and waterproofing membranes. This would limit the potential for groundwater inflows to enter underground station structures and therefore minimise groundwater drawdown.

The groundwater flow regime in the vicinity of each of the construction sites are expected to change due to mined excavations at both Pyrmont Station and Hunter Street Station (Sydney CBD) construction sites.

At most sites, there would potentially be very little change from pervious to impervious surfaces and therefore potential impacts to groundwater recharge would be low.

Groundwater drawdown may occur during construction at locations with temporarily untanked excavations, such as the caverns, stations and shafts associated with the proposal. These excavations would result in groundwater ingress and lowering groundwater levels in nearby soils and bedrock. Groundwater level disruptions would be temporary, and groundwater levels would return to normal following the end of construction work. Drawdown of the water table as a result of tunnel excavation is considered to be negligible.

There is some potential for groundwater both within and adjacent to the Pyrmont Station and Hunter Street Station (Sydney CBD) construction sites to be impacted by hydrocarbons and volatile organic compounds. The proposed use of The Bays tunnel launch and support site to launch and support tunnel boring machines is not anticipated to further impact groundwater quality.

A small number of existing buildings, infrastructure and utilities have been assessed to be in ground movement risk categories slight or above. Risk category of slight indicates possible superficial damage which is unlikely to have structural significance. For assets where a risk category of slight or above has been assessed, further assessments at later design stages would be undertaken. These include detailed assessment using more sophisticated methods of calculating ground movement, building strains, investigating the existing structural condition of the asset and the consideration of soil-structure interaction effects. Based on such detailed assessment, it may be required to develop mitigation measures to address potential impacts supported by detailed instrumentation and monitoring.

14.2 Legislative and policy context

The Secretary's Environmental Assessment Requirements relating to groundwater and ground movement, and where these requirements are addressed in this Environmental Impact Statement, are outlined in Appendix A.

The relevant legislation, policies and assessment guidelines considered in the preparation of the groundwater and ground movement assessment include:

- *Environment Protection and Biodiversity Conservation Act 1999*
- *Water Management Act 2000*
- *Water Act 1912*
- *Protection of the Environment Operations Act 1997*
- Water Management Regulation 2018

- *National Water Quality Management Strategy* (Australian Government, 2018)
- *Guidelines for Groundwater Quality Protection in Australia* (Australian Government, 2013)
- *Australian Groundwater Modelling Guidelines* (Australian Government, 2012)
- *NSW Aquifer Interference Policy* (Office of Water, 2012)
- *NSW Groundwater Dependent Ecosystem Policy* (Department of Land and Water Conservation, 2002)
- Relevant Water Sharing Plans
- Relevant NSW Water Quality Objectives.

Further information regarding legislative and policy context is presented in Chapter 2 of Technical Paper 7 (Hydrogeology).

14.3 Assessment methodology

14.3.1 Groundwater

The assessment approach of potential groundwater-related impacts includes:

- Desktop assessment to characterise the existing environment including:
  - Climate
  - Topography and geology
  - Groundwater occurrence, quality and use
  - Existing groundwater users
  - Groundwater dependent ecosystems
- Review of other relevant groundwater assessments, including:
  - *Sydney Metro West Environmental Impact Statement – Westmead to The Bays and Sydney CBD* (Sydney Metro, 2020a)
  - *West Connex M4-M5 Link, Groundwater Modelling Report* (AECOM, 2017)
- Site investigations, including the installation of the following groundwater monitoring infrastructure at the time of investigation:
  - 14 groundwater wells relevant to this proposal
  - Two single vibrating-wire piezometers relevant to this proposal
- Development of a conceptual hydrogeological model to assess potential changes
- Prediction of the potential groundwater impacts, using the conceptual model, including:
  - Inflows to excavations and shafts
  - Associated groundwater level drawdown
  - Changes to flow directions
  - Impacts to beneficial use (groundwater dependent ecosystems and registered bores)
- Assessment of the potential groundwater-related impacts listed above based on the modelling results, to satisfy the minimal impact considerations of the Aquifer Interference Policy, and address groundwater related issues
- Recommendations for monitoring and management of identified impacts and risks, including management and mitigation measures as appropriate.

The methodology is further described in Chapter 3 of Technical Paper 7 (Hydrogeology).

The *Sydney Metro West Environmental Impact Statement – Westmead to The Bays and Sydney CBD* (Sydney Metro, 2020a) assessed the impacts of The Bays Station construction site to:

- Carry out the excavation of The Bays Station
- Launch and support two tunnel boring machines for the drive west to the Sydney Olympic Park metro station construction site.

The Bays Station construction site is being established under the Sydney Metro West Concept and Stage 1 planning approval. The Bays tunnel launch and support site would be located within a part of The Bays Station construction site. As such, only the impacts of the proposed use of The Bays tunnel launch and support site are assessed in this Environmental Impact Statement.

Conceptual hydrogeological model

A conceptual hydrogeological model of the existing environment has been developed for the proposal. A conceptual hydrogeological model is a mostly qualitative description of the groundwater system, including groundwater levels, quality, inputs/outputs and a description of geology and its properties. It allows the effect of newly introduced changes to the hydrogeological system to be understood and assessed, such as the proposed construction activities. It also allows consideration of whether more detailed numerical modelling is necessary.

The conceptual hydrogeological model for the proposal incorporates the groundwater and geology elements described in Section 4.11 of Technical Paper 7 (Hydrogeology).

14.3.2 Ground movement

A two-step approach was implemented to investigate the anticipated ground movement and associated potential impact on existing buildings, infrastructure and utilities:

- Step 1 – Ground movement assessment
  - Identification of the ground movement zone of influence as triggered by construction
  - Classification of all existing buildings and infrastructure within that zone
- Step 2 – Identification and risk assessment (impact assessment)
  - Risk assessment of the structures within the zone of influence against acceptance criteria
  - Determine potentially impacted buildings, infrastructure and utilities which will require further detailed assessment during detailed construction planning.

During future stages of detailed design and detailed construction planning, further assessment would be undertaken including:

- Planning for impact minimisation and protection where necessary, by the development of solutions to minimise the impact of construction by consulting with the relevant owners/stakeholders of assets to obtain further information on the properties and refinement of the assessment of the performance of critical buildings, infrastructure or utilities
- Consideration of potential protective works for the buildings and review of the structural arrangements to support the construction works. This would include further detailed assessment of some listed heritage buildings or highly sensitive structures
- Developing an instrumentation and monitoring plan capable of monitoring the actual changes of the ground surface, and of existing buildings, infrastructure and utilities to confirm the movements experienced as a result of construction activities.

14.4 Avoidance and minimisation of impacts

The design development of the proposal has included a focus on avoiding or minimising potential groundwater impacts and ground movement. This has included:

- Designing Pyrmont Station and Hunter Street Station (Sydney CBD) caverns to prevent the inflow of groundwater, typically using concrete lining and waterproofing membranes (referred to as 'tanked') to avoid ongoing groundwater inflow
- Tanking of tunnels to avoid ongoing groundwater inflow.

14.5 Existing environment

14.5.1 Geological context

Topography

The proposal would include three main construction sites within relative proximity of various bays of inner Sydney Harbour. The elevation at The Bays tunnel launch and support site, is primarily at sea level. Elevation ranges from eight to 15 metres Australian Height Datum (AHD) at the Pyrmont Station construction sites and 22 metres AHD at the Hunter Street Station (Sydney CBD) construction sites.

Geology

The Sydney 1:100000 geological map (Herbert, 1983) shows that most of the tunnel alignment is underlain by Hawkesbury Sandstone bedrock. Surface soils comprising of existing fill and residual materials can also be expected to be found on top of the sandstone bedrock with variable thicknesses. Existing fill material of notable thickness can be found at The Bays tunnel launch and support site.

Deep alluvial and marine soil deposits are encountered on the western side of The Bays tunnel launch and support site, within Sydney Harbour.

The regional geological formations are shown in Figure 14-1 and a geological long-section is provided in Technical Paper 7 (Hydrogeology).

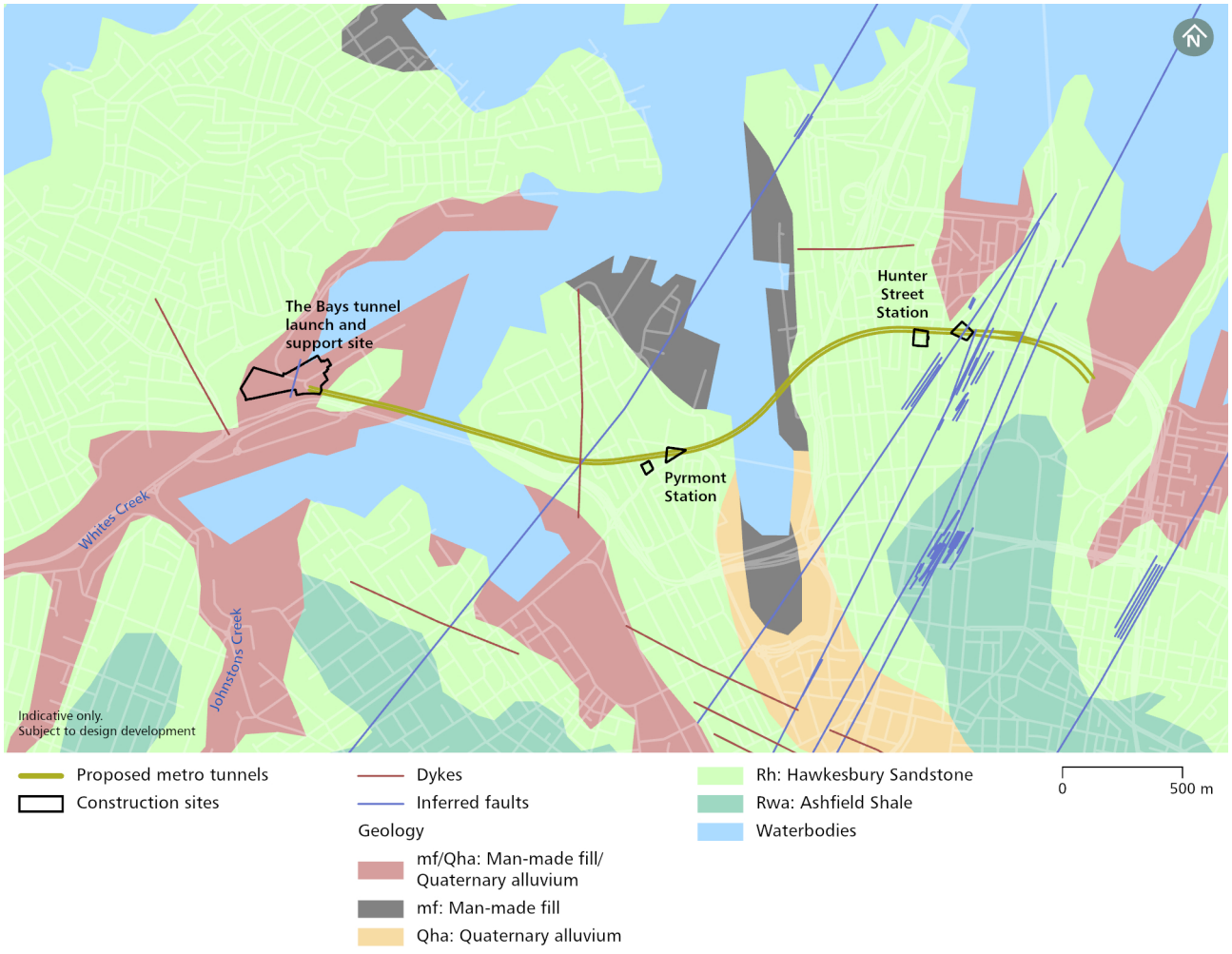

Figure 14-1 Geology of the proposal

Geological structure features

Structural features near the proposal include:

- The Great Sydney Dyke, an igneous intrusion comprising typically dolerite material with varying weathering and strength properties, which may be encountered at the eastern end of The Bays tunnel launch and support site
- Possible fault zones and a dyke may be encountered about 150 metres to the west of the Pyrmont Station western construction site, however, there is limited geotechnical information along the tunnel alignment in this area
- Several fault zones have been inferred and identified within the Sydney CBD, at the Hunter Street Station (Sydney CBD) construction sites and along the turnback tunnels to the east of these sites.

14.5.2 Groundwater

Aquifers

Aquifers are permeable rocks or soil that transmit groundwater and are related to the geological units. Aquifers near the proposal include porous and fractured rock aquifers. Porous aquifers in alluvial soils are continuous (unconfined) over an area. Porous aquifers in residual soils are often ephemeral, localised and discontinuous. They are reflective of water moving down the soil profile and building up on the underlying bedrock.

Fractured rock aquifers occur where groundwater is transmitted through fractures or joints and bedding planes, such as in the shales and Hawkesbury Sandstone.

Groundwater levels

Existing groundwater depth is higher in elevated areas and becomes shallowest adjacent to creeks and bays and generally follows the topography. Table 14-1 shows the approximate typical depth to groundwater near the construction sites.

Table 14-1 Approximate groundwater levels near construction sites

Construction site	Typical depth to groundwater in the vicinity of the construction site (metres below ground level)
The Bays tunnel launch and support site	4.5
Pyrmont Station construction sites	17.4
Hunter Street Station (Sydney CBD) construction sites	12.0 – 20.5

Surface water and groundwater interactions

Interactions between surface water and groundwater in the vicinity of the proposal are expected to be negligible or minimal due to:

- The proposal area is highly urbanised with predominantly impervious surfaces across the catchments, which reduces possible surface water infiltration into soils and underlying groundwater
- A lack of surface watercourses near the proposal construction sites. Surface watercourses are generally located south of the proposal, outside the area of potential groundwater drawdown impact
- Watercourses in the vicinity are generally lined (they have a concrete base and sides) and therefore are assumed to have negligible or limited interaction with groundwater
- The dominant groundwater discharge mechanism is to Sydney Harbour.

Table 14-2 and Figure 14-2 identifies the receiving waterbodies near the proposal construction sites.

Table 14-2 Waterbodies near the proposal construction sites

Construction site(s)	Receiving waterbody	Approximate distance from construction site (metres)
The Bays tunnel launch and support site	White Bay	0
Pyrmont Station western construction site	Blackwattle Bay	390
	Cockle Bay	350
	Pyrmont Bay	325
Pyrmont Station eastern construction site	Blackwattle Bay	490
	Cockle Bay	225
	Pyrmont Bay	240
Hunter Street Station (Sydney CBD) western construction site	Sydney Cove	540
Hunter Street Station (Sydney CBD) eastern construction site	Sydney Cove	475

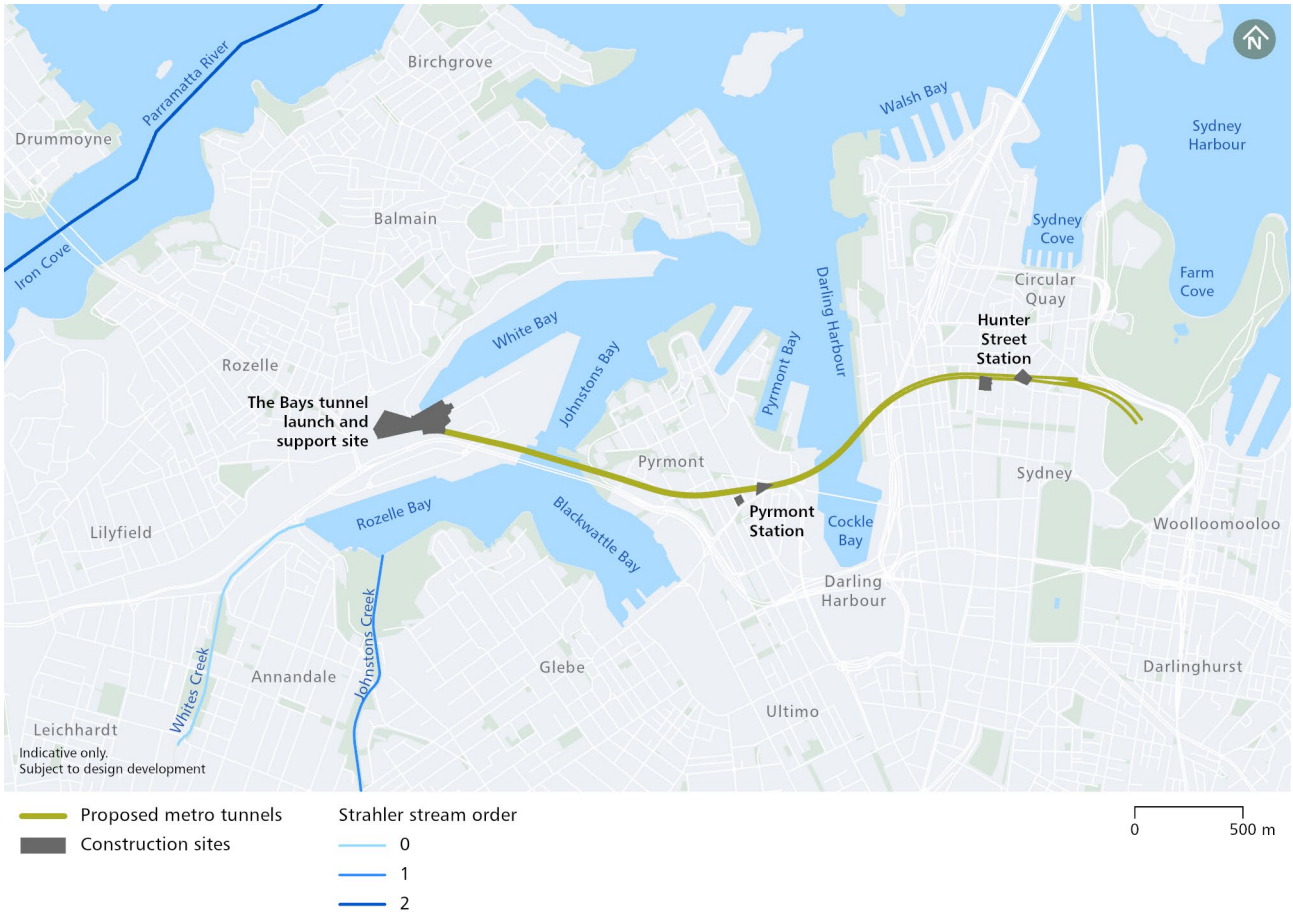

Figure 14-2 Receiving waterbodies and waterways for the proposal

Groundwater quality

Groundwater quality is influenced by the underlying geological units. The quality of groundwater within the Hawkesbury Sandstone regionally is typically of low to moderate salinity, pH values being neutral to slightly acidic ranging between 4.5 and 8. Human activities may also have influenced groundwater quality and groundwater contamination from current or historical land uses in some areas along the alignment.

Existing monitoring data (Golder-Douglas, 2021 and 2021a) for The Bays shows that groundwater currently exceed the ANZECC/ARMCANZ (2000) and ANZG (2018) trigger levels for 95 per cent species protection level (or 99 per cent species protection for toxicants that bioaccumulate) at a number of groundwater wells. Ammonia and heavy metal parameters exceeded this protection level at 20 per cent of the samples tested. Concentrations exceeded the trigger levels for cobalt, manganese and zinc at the majority of the monitoring well locations.

Concentrations in the vicinity of the Pyrmont Station construction sites currently exceed the ANZECC/ ARMCANZ (2000) and ANZG (2018) trigger levels for 95 per cent species protection level (or 99 per cent species protection for toxicants that bioaccumulate) for cobalt, iron and manganese. No current groundwater monitoring information is available in the vicinity of the Hunter Street Station (Sydney CBD) construction sites.

Further information regarding groundwater contamination is provided in Chapter 16 (Contamination) and Technical Paper 8 (Contamination).

Groundwater users and extraction

Groundwater boreholes are shown in Figure 14-3. There are no registered users within the area of potential drawdown impacts.

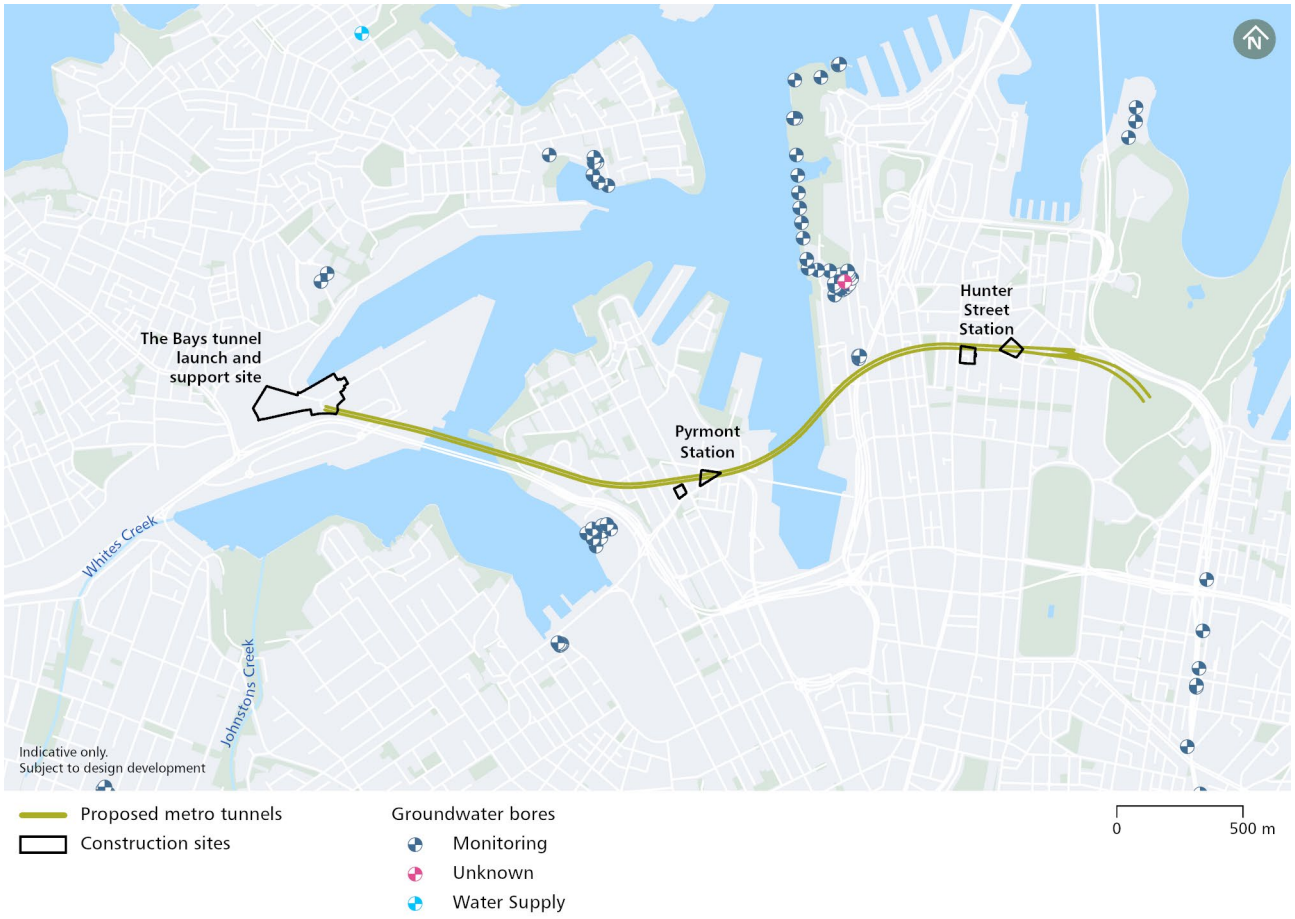

Figure 14-3 Groundwater boreholes in the vicinity of the proposal

Groundwater dependent ecosystems

There are no mapped aquatic groundwater dependent ecosystems within 500 metres of the tunnel alignment, and none in the area of potential groundwater drawdown associated with Pyrmont Station and Hunter Street Station (Sydney CBD) construction sites.

Groundwater inflow in existing infrastructure

Groundwater inflows are usually more prominent for existing structures like tunnels, and primarily designed to be free draining, under the restriction of a maximum inflow rate of one litre per second per kilometre of tunnel. Tunnels in the vicinity of the proposal have been recorded as having water inflow ranging between 0.6 to three litres per second per kilometre of tunnel. Further detail about groundwater inflow in existing structures is provided in Section 4.10 of Technical Paper 7 (Hydrogeology).

14.6 Potential impacts

14.6.1 Ground movement

Ground movement may result from construction activities such as underground tunnelling and from major excavations including deep excavations for station access shafts. Ground movement may occur due to the redistribution of stresses within the ground upon excavation shortly after excavation. Potential impacts on existing buildings, infrastructure and utilities arising from construction and the corresponding ground movement are required to be investigated and assessed.

Ground movement may also result from groundwater drawdown caused by the ground water drainage during the construction activities. In unconsolidated soft soils, the increase in effective stress of the soil caused by this drawdown of the groundwater, can lead to consolidation of the soils over time, resulting in additional ground movement. However, in rock formations ground water drawdown is less likely to result in significant additional movement and the resulting impact on structures above ground can therefore be considered negligible. As most excavations associated with the proposal would be within rock, it is anticipated that any potential ground movement associated with groundwater drawdown would be negligible.

Unconsolidated, soft soils are expected to be locally found only within existing water bodies and away from existing buildings, infrastructure and utilities. As a result, the impact of any potential ground movement from these soils as a result of the proposal is considered negligible.

Preliminary settlement contours were developed for the proposal to identify the expected zone of influence and magnitude of induced settlement from construction. Ground surface settlement contour intervals at five millimetres were developed to estimate the range of ground movement. The one millimetre settlement contour was also included to indicate the likely extent of ground movement. For the purposes of undertaking preliminary impact assessments, the 5mm ground surface vertical settlement contour has been defined as the zone of influence. Any existing buildings, infrastructure and utilities located within the zone of influence have been identified and considered for preliminary impact assessment.

Table 14-3 provides the risk-based criteria outlined by the Construction Industry Research and Information Association (1996) and used to assist with preliminary ground movement risk levels. The criteria in the table specify the maximum settlement of the building and the maximum slope of the ground below building foundations for each risk level.

Table 14-3 Ground movement risk levels

Risk	Description	Maximum slope of building	Maximum settlement of building (millimetres)
1	Negligible: Superficial damage unlikely	<1:500	<10
2	Slight: Possible superficial damage which is unlikely to have structural significance	1:500 to 1:200	10 to 50
3	Moderate: Expected superficial damage and possible structural damage to buildings, possible damage to relatively rigid pipelines	1:200 to 1:50	50 to 75
4	High: Expected structural damage to buildings. Expected damage to rigid pipelines, possible damage to other pipelines	>1:50	>75

Based on a preliminary assessment using a conservative approach, the identified existing buildings, infrastructure and utilities currently fall within risk category 1 or 2 where the damage is negligible or slight. Further assessments at later design stages and during detailed construction planning would be carried out to check the preliminary findings and are likely to include more sophisticated methods of assessing ground movement, investigating the existing structural condition of the asset, calculating building and infrastructure strain, undertaking structural assessments, and developing mitigation measures to address potential impacts supported by detailed instrumentation and monitoring.

14.6.2 Groundwater levels

During tunnel construction, tunnel boring machines would place a pre-cast segmental tunnel lining as tunnelling progresses. Groundwater level drawdown due to the tunnels is not likely to be significant as the tunnels would be tanked almost immediately following tunnelling and given the relatively low hydraulic conductivity and storativity (i.e. a measure of the capacity of the aquifer to release groundwater) of the rock and the short timeframe over which an unlined excavation would be open in the tunnels.

The tunnel cross passages would have a relatively small footprint and may be open for a short period of time prior to being waterproofed. As such, the impacts of cross passage construction on groundwater are not likely to be significant.

The estimated groundwater level drawdown resulting from construction at two years post-excavation is shown on Figure 14-4 and Figure 14-5 for the Pyrmont Station and Hunter Street Station (Sydney CBD) construction sites respectively. The proposed use of The Bays tunnel launch and support site to launch and support tunnel boring machines is not anticipated to further impact groundwater levels.

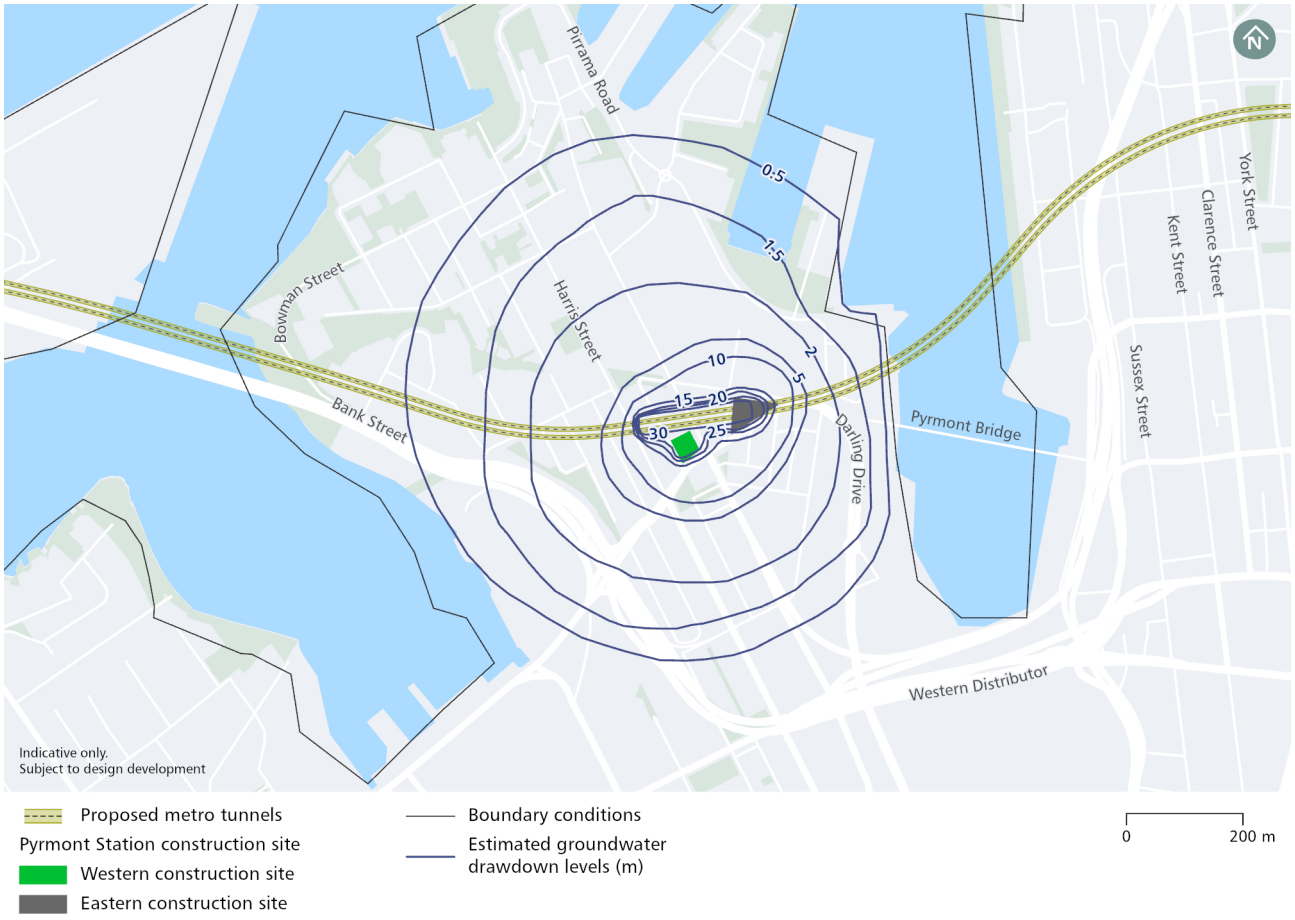

Figure 14-4 Predicted groundwater drawdown levels two years after the start of construction – Pyrmont Station construction sites

Figure 14-5 Estimated groundwater drawdown two years after the start of construction – Hunter Street Station (Sydney CBD) construction sites

14.6.3 Groundwater inflows and local flow regime

Tunnels would be constructed using a tunnel boring machine, predominantly through Hawkesbury Sandstone. Tunnel construction would pass beneath the waterbodies described in Table 14-4.

Table 14-4 Depth of tunnelling and relevant waterbodies

Alignment section	Approximate depth of tunnel (metres)	Waterbodies above tunnel alignment
Between The Bays tunnel launch and support site and Pyrmont Station construction sites	44-52	Johnstons Bay
Between Pyrmont Station construction sites and Hunter Street Station (Sydney CBD) construction sites	27-42	Cockle Bay

The estimated potential inflow ranges from 0.3 cubic metres per day and 40 cubic metres per day. Inflows are highest under The Bays where structures are present and there is a direct hydraulic connection between the harbour, the alluvial sediments, and the sandstone. The tunnel boring machine tunnels would be lined with pre-cast segmental linings as the tunnels progress to limit groundwater inflow.

Most of the groundwater inflow is taken from the rock aquifer in which the station would be located. The potential groundwater take is estimated to be around 2.5 megalitres in the first year increasing to about six megalitres in the second year. Groundwater inflow to The Bays crossover cavern is estimated to be about 16.4 megalitres during construction, although intersection with the Great Sydney Dyke may increase inflow to the cavern. Inflows may also be persistent (not reduce over time) if the dyke is connected to the adjacent alluvium and harbour. Persistent long term inflows associated with a discrete feature may also result in drawdown along the feature.

Table 14-5 provides predicted inflow rates and the indicative maximum inflows at six months, one year and two years after excavation to address the requirements of the NSW Aquifer Interference Policy and the Water Sharing Plan. The proposed use of The Bays tunnel launch and support site to launch and support tunnel boring machines is not anticipated to further impact groundwater inflows and local flow regimes.

Table 14-5 Groundwater inflow to the excavation

Construction sites	Construction design	Predicted inflow rate (litres per second)			Predicted inflows (megalitres)		
		Six months after excavation	One year after excavation	Two years after excavation	Six months after excavation	One year after excavation	Two years after excavation
Pyrmont Station	Tanked	0.70	0.54	0.43	16.2	26	15
Hunter Street Station (Sydney CBD)	Tanked	0.95	0.72	0.6	22.3	35.3	18.2

The groundwater flow regime in the vicinity of each of the construction sites are expected to change due to mined excavations at both Pyrmont Station and Hunter Street Station (Sydney CBD) construction sites. Under existing conditions, groundwater is interpreted to currently flow away from each of the sites towards Sydney Harbour including:

- To the east, north and west from the Pyrmont Station construction sites
- To the north-east, north and north-west from the Hunter Street Station (Sydney CBD) construction sites.

During construction of the proposal, the excavation of Pyrmont Station and Hunter Street Station would act as a groundwater sink, causing groundwater to flow towards the excavation, effectively reversing the flow.

14.6.4 Groundwater recharge

Groundwater recharge is the downward movement of water to the water table (i.e. the saturated part of the geological layer). Soils are recharged by rainfall and localised irrigation, as well as incidental runoff from impervious surfaces. When rock layers are exposed at surface, there can be direct recharge of the rock aquifers, with transmission primarily through rock joints. Recharge to the rock aquifers elsewhere is by downward percolation through soils.

At most sites, there would potentially be very little change from pervious to impervious surfaces and therefore potential impacts to groundwater recharge would be low or negligible.

14.6.5 Groundwater quality

Groundwater inflow would be collected and treated during construction via temporary water treatment plants so that discharged water quality is compliant with the ANZECC/ARMCANZ (2000) and ANZG (2018) guideline values and/or meets the requirements of the relevant environment protection licence for the proposal prior to entering the local stormwater system. Existing contaminated groundwater could be mobilised by groundwater drawdown resulting from proposal construction activities. Potential migration of existing contaminants could impact the beneficial uses of groundwater in nearby areas. This may cause volatile contaminants to come into contact with underground structures, creating a risk of vapour intrusion to underground structures. Both risks could impact groundwater users, the health and safety of construction workers, groundwater disposal options and, potentially other untanked structures in the areas. Potential groundwater contaminants are further described in Chapter 16 (Contamination).

There is potential for groundwater both within and adjacent to the Pyrmont Station and Hunter Street Station (Sydney CBD) construction sites to be impacted by hydrocarbons and volatile organic compounds. There is potential for groundwater impact associated with the ingress of contaminated groundwater into excavations and the management of dewatering during the construction of the station cavern. The proposed use of The Bays tunnel launch and support site to launch and support tunnel boring machines is not anticipated to further impact groundwater quality.

14.6.6 Groundwater users

As described in Section 14.5 there are no registered groundwater users located within the area of potential drawdown impacts for the proposal. As a result, there would be no impact to groundwater users as a result of this proposal.

14.6.7 Groundwater dependent ecosystems

As described in Section 14.5, there are no mapped aquatic groundwater dependent ecosystems within 500 metres of the tunnel alignment. As a result, no impacts to groundwater dependent ecosystems are anticipated as a result of the proposal.

14.6.8 Beneficial use

As described in Section 14.5, there are no registered groundwater bores with a beneficial use within the area of potential groundwater drawdown associated with Pyrmont Station or Hunter Street Station (Sydney CBD) construction sites. As a result, there would be no beneficial use impacts associated with the proposal.

14.6.9 Surface water and groundwater interactions

Interactions between surface water and groundwater due to tunnelling activities are not expected due to the depth of tunnels and absence of natural surface streams. There are no surface freshwater bodies or waterways within the area of potential drawdown associated with Pyrmont Station and Hunter Street Station (Sydney CBD) construction sites. Surface water and groundwater interactions are negligible as summarised in Table 14-6. The proposed use of The Bays tunnel launch and support site to launch and support tunnel boring machines is not anticipated to further impact surface water and groundwater interactions.

Table 14-6 Potential interactions of groundwater with surface water

Construction site	Surface waterbodies and water courses near the construction site	Potential impact
Pyrmont Station	Concrete lined channels located south of the construction site, about 600 metres to 800 metres away at the head of Cockle Bay and Blackwattle Bay	Groundwater is not likely to contribute to these channels as they are concrete-lined channels which serve mainly as stormwater discharge. These channels fall outside the area of predicted drawdown.
Hunter Street Station (Sydney CBD)	There are creeks located south west of the construction site about one kilometre away at the head of Cockle Bay	

14.6.10 Policy compliance

Consistency with minimum harm criteria

The *Water Management Act 2000* includes the concept of ensuring 'no more than minimal harm' for both the granting of water access licences and the granting of approvals. While the proposal does not require a licence or approval under the *Water Management Act 2000*, the minimal harm criteria in the *NSW Aquifer Interference Policy* (NSW Office of Water, 2012) have been used for the purposes of assessment as shown in Table 14-7.

Table 14-7 Minimal impact considerations

Minimal impact consideration	Response
Water table	
1. Less than or equal to ten percent cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 metres from any of the following that are listed in the schedule of the relevant water sharing plan: a. High priority groundwater dependent ecosystem b. High priority culturally significant site. A maximum of a two-metre decline cumulatively at any water supply work.	There are no identified high priority groundwater dependent ecosystems or culturally significant sites within the area of predicted groundwater drawdown. There are no identified water supply works within the area of predicted drawdown.
2. If more than ten percent cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 metres from any of the following that are listed in the schedule of the relevant water sharing plan: a. High priority groundwater dependent ecosystem b. High priority culturally significant site. If appropriate studies demonstrate to the Minister's satisfaction that the variation would not prevent the long term viability of the dependent ecosystem or significant site. If more than a two-metre decline cumulatively at any water supply work, then make good provisions should apply.	
Water Pressure	
1. A cumulative pressure head decline of not more than a two metre decline, at any water supply work.	There are no identified water supply works within the area of predicted drawdown.
2. If the predicted pressure head decline is greater than consideration (1) above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline would not prevent the long term viability of the affected water supply works unless make good provisions apply.	
Water Quality	
Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	Where contaminated groundwater, saline groundwater, or acid sulphate soils are present within the groundwater level drawdown zone of influence, this proposal has the potential to alter the groundwater quality between the excavations and the contaminant/saline water sources. These processes mean that this requirement of the *Aquifer Interference Policy* may not be satisfied. Mitigation measures to address this are presented in Section 14.8.
If consideration (1) is not met then appropriate studies would need to demonstrate to the Minister's satisfaction that the change in groundwater quality would not prevent the long term viability of the dependent ecosystem, significant site or affected water supply works.	There are no identified water supply works within the area of potential groundwater impact.

Minimal impact consideration	Response
Additional Considerations	
Any advice provided to a gateway panel, the Planning and Assessment Commission or the Minister for Planning on a State significant development or State significant infrastructure would also consider the potential for: • Acidity issues to arise, for example exposure of acid sulphate soils • Water logging or water table rise to occur, which could potentially affect land use, groundwater dependent ecosystems and other aquifer interference activities. Specific limits would be determined on a case-by-case basis, depending on the sensitivity of the surrounding land and groundwater dependent ecosystems to waterlogging and other aquifer interference activities to water intrusion.	Where the presence of acid sulfate soils and potential groundwater level drawdown within those soils is confirmed, an acid sulfate soils management plan would be developed for the proposal to reduce the risks associated with oxidation/activation of acid sulfate soils (refer to Chapter 15 (Soils and surface water quality)). Water logging is not predicted as drawdown of the groundwater table will occur.

Consistency with Water Sharing Plan rules

All groundwater and surface water relevant to the proposal is managed through the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. The Water Sharing Plan provides rules to manage and allocate the groundwater resource, including specific rules on taking groundwater near high priority groundwater dependant ecosystems, groundwater dependent culturally significant sites, sensitive environmental areas, and near licenced bores. The groundwater source relevant to this proposal is the Sydney Central Basin Groundwater Source. While the proposal does not require a licence and/or approval under the *Water Management Act 2000*, these rules have been used for the purposes of assessment (refer to Technical Paper 7 (Hydrogeology)).

14.7 Cumulative impacts

Potential cumulative impacts were considered for assessment based on the likely interactions of the proposal with other projects and plans that met the adopted screening criteria. The approach to assessment and the other projects considered are described further in Appendix G (Cumulative impacts assessment methodology).

Potential cumulative groundwater impacts include:

- Overlapping of groundwater drawdown associated with the station and cavern excavation. This could potentially occur in areas where the drawdown extends to the adjacent excavation impact. As the station shafts and station box caverns for Pyrmont Station and Hunter Street Station are likely to be excavated at the same time, construction groundwater modelling shows that there may be a cumulative drawdown impact as a result of simultaneous excavation
- Existing and proposed infrastructure with drained excavations/structures near excavations, including building excavations associated with the Rozelle Interchange (part of the WestConnex M4-M5 Link), the Western Harbour Tunnel project and the Sydney Metro City & Southwest (Chatswood to Sydenham) project.

The groundwater assessment provided in the Environmental Impact Statement for the WestConnex M4-M5 Link project (WestConnex Delivery Authority, 2017), which includes the Rozelle Interchange, does not predict long term (steady state) groundwater level drawdown for the Rozelle Interchange that lies within the predicted zones of groundwater level drawdown for the proposal. Based on this, the Rozelle Interchange is not expected to contribute cumulative impacts to the proposal.

The Environmental Impact Statement for the Western Harbour Tunnel and Warringah Freeway Upgrade (Roads and Maritime Services, 2019) shows that the tunnels associated with this project lie to the west of The Bays Station tunnel launch and support site. Groundwater modelling results reported for this project indicate that it is likely to cause groundwater level drawdown in the vicinity of The Bays tunnel launch and support site. Based on the predicted groundwater level drawdown at the end of tunnel construction for the project, an additional groundwater level drawdown of up to three metres would be expected at The Bays tunnel launch and support site. This drawdown would be additive to the drawdown induced by the proposal. The potential impacts of this cumulative drawdown and their significance are not expected to differ from those predicted for the proposal alone.

The combined or cumulative impacts of groundwater drawdown will vary depending on the timing of the construction stages of each project. If one project is completed and the excavated areas are tanked before the next project starts, then the cumulative drawdown impacts will be less than for a situation where two or more excavations are undertaken simultaneously.

14.8 Mitigation and management measures

The Construction Environmental Management Framework (Appendix C) describes the approach to environmental management, monitoring and reporting during construction. Specifically, it lists the requirements to be addressed by the construction contractor in developing the Construction Environmental Management Plans, sub-plans, and other supporting documentation for each specific environmental aspect. This includes standard mitigation measures, including the preparation of a Groundwater Management Plan.

The environmental management approach for the project is detailed in Chapter 23 (Synthesis of the Environmental Impact Statement). Under these broad frameworks, a series of performance outcomes have been developed to define the minimum environmental standards that would be achieved during construction of the proposal (see Section 14.8.1), and mitigation measures that would be implemented during construction to manage potential identified impacts (see Section 14.8.2).

14.8.1 Performance outcomes

Construction performance outcomes were developed for the proposal as part of the Concept approval. Performance outcomes for the proposal identify measurable, performance-based standards for environmental management. Identified performance outcomes in relation to groundwater and ground movement for construction of the proposal include:

- Groundwater supply for licenced groundwater users is not significantly affected by groundwater drawdown
- The groundwater accessible to groundwater dependent ecosystems is not significantly reduced
- Structural damage to buildings from ground movement associated with excavation, tunnelling or groundwater drawdown is avoided.

Chapter 23 (Synthesis of the Environmental Impact Statement) describes how the proposal addresses this performance outcome. The design development of the proposal has aimed to avoid or minimise potential groundwater impacts and ground movement associated with excavation, tunnelling or groundwater drawdown. There are no groundwater users located within the area of potential drawdown impacts for the proposal or groundwater dependent ecosystems within 500 metres of the tunnel alignment.

14.8.2 Mitigation measures

The mitigation measures that would be implemented to address potential groundwater and ground movement impacts are listed in Table 14-8.

Table 14-8 Mitigation measures – Groundwater and ground movement

Reference	Impact/issue	Mitigation measure	Applicable location(s)
GW1	Ground movement and settlement	A detailed geotechnical model for the proposal would be developed and progressively updated during design and construction. The detailed geotechnical model would include: • Assessment of the potential for damage to structures, services, basements and other subsurface elements through settlement or strain • Predicted changes to groundwater levels, including at nearby water supply works. Where building damage risk is rated as moderate or higher, a structural assessment of the affected buildings/structures would be carried out and specific measures implemented to address the risk of damage. Where a significant exceedance of target changes to groundwater levels are predicted at surrounding land uses and nearby water supply works, an appropriate groundwater monitoring program would be developed and implemented. The program would aim to confirm no adverse impacts on groundwater levels or to appropriately manage any impacts. Monitoring at any specific location would be subject to the status of the water supply work and agreement with the landowner.	Where required
GW2	Ground movement and settlement	Condition surveys of buildings and structures in the vicinity of the tunnel and excavations would be carried out prior to the commencement of excavation at each site.	Where required

14.8.3 Interaction with other mitigation measures

Interactions between mitigation measures in other technical papers and chapters that are relevant to the management of potential groundwater and ground movement impacts include:

- Chapter 15 (Soils and surface water quality) – Specifically measures relevant to the management of potential water quality
- Chapter 16 (Contamination) – Specifically measures relevant to management of potential contamination.

Together, these measures would minimise the potential groundwater and ground movement impacts of this proposal. A full list of mitigation measures is presented in Chapter 23 (Synthesis of the Environmental Impact Statement).