Transport Asset Standards Authority

T HR CI 12051 ST

**Standard**

# Development Near Rail Tunnels

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## Standard governance

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## Document history

| Version | Summary of changes |
|---|---|
| 1.0 | First issue 14 November 2016. |
| 2.0 | Second issue – this issue incorporates feed-back from the industry received after the first issue, technical note TN 026:2017, expanded text at several sections for further clarity and the ECRL corridor has been removed from this standard. |

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# Preface

The Asset Standards Authority (ASA) is a key strategic branch of Transport for NSW (TfNSW). As the network design and standards authority for NSW Transport Assets, as specified in the *ASA Charter*, the ASA identifies, selects, develops, publishes, maintains and controls a suite of requirements documents on behalf of TfNSW, the asset owner.

The ASA deploys TfNSW requirements for asset and safety assurance by creating and managing TfNSW's governance models, documents and processes. To achieve this, the ASA focuses on four primary tasks:

- publishing and managing TfNSW's process and requirements documents including TfNSW plans, standards, manuals and guides
- deploying TfNSW's Authorised Engineering Organisation (AEO) framework
- continuously improving TfNSW's Asset Management Framework
- collaborating with the Transport cluster and industry through open engagement

The AEO framework authorises engineering organisations to supply and provide asset related products and services to TfNSW. It works to assure the safety, quality and fitness for purpose of those products and services over the asset's whole-of-life. AEOs are expected to demonstrate how they have applied the requirements of ASA documents, including TfNSW plans, standards and guides, when delivering assets and related services for TfNSW.

Compliance with ASA requirements by itself is not sufficient to ensure satisfactory outcomes for NSW Transport Assets. The ASA expects that professional judgement be used by competent personnel when using ASA requirements to produce those outcomes.

## About this document

This standard sets out the requirements to assess the impacts on existing rail tunnels and underground infrastructure during developments near such tunnels and infrastructure in the metropolitan rail area.

This standard supersedes all previous guidelines used for development approvals near existing rail tunnels. In case of any conflicts, legislation related to developments near rail tunnels takes precedence.

This standard is a second issue. This update incorporates the feed-back received from the industry after the first issue, technical note TN 026:2017 and expanded text at several sections for further clarity. The ECRL corridor has been removed from this standard since this section of the tunnel has become part of the Sydney Metro network. Refer to Sydney Metro Underground Corridor Protection Technical Guidelines for developments near the ECRL corridor.

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# 1. Introduction

Developments near existing rail tunnels have the potential to affect the tunnel infrastructure. Development related loads and ground displacements can cause deformation of existing tunnels and other associated structures and, in extreme situations, can cause structural failure and collapse.

Transport for NSW (TfNSW) reviews the development applications of projects near rail tunnels on a case by case basis to ensure that the existing rail tunnels are not adversely affected by the proposed development and the rail operations are not affected during and after the proposed construction.

This standard is developed to provide the requirements and technical guidance to developers to assess the development-induced effects and associated risks.

# 2. Purpose

This standard provides the technical requirements to assess and manage the risk associated with developments near existing rail tunnels.

The purpose of this standard is to assist external developers in the planning, design and construction near rail tunnels and associated rail infrastructure. This standard supports the key objective of the *State Environmental Planning Policy* (Infrastructure) 2007, commonly known as SEPP 2007, to protect the safety and integrity of key transport infrastructure from adjacent developments.

## 2.1. Scope

This standard covers the specific requirements and provides guidelines to be followed for developments near existing rail tunnels in the metropolitan rail area during the planning, design, construction and operation stages.

This standard does not provide the process involved in lodging the development applications and obtaining approvals.

The information and guidelines for the application lodgement and approval process for developments near existing rail tunnels can be obtained from the TfNSW (building near the railway) website.

This standard primarily covers the developments near the following tunnels:

- City Circle Line (CCL) tunnels
- Eastern Suburb Rail (ESR) tunnels
- Airport Line (APL) tunnel

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## 2.2. Application

This standard applies to developments near existing rail tunnels and rail infrastructure such as station caverns, cut and cover boxes, cross passages, refuges, adits, egress passages, underground electrical and mechanical substations, dive and portal structures, and underground walkways.

This standard applies to the planning, designing, constructing and operating stages of development.

The principles of this standard and guidelines can be applied to other existing rail tunnels within the Sydney metropolitan rail area on a case by case basis.

This standard is intended to be used by qualified personnel engaged in the provision of services relating to interaction of developments with the existing rail infrastructure.

Compliance with the requirements in this standard will not, by itself, be sufficient to ensure that satisfactory outcomes will be produced. Personnel providing services based on the standard need to bring appropriate expertise to the matters under consideration.

If the proposed development affects both TfNSW rail tunnel infrastructure and Roads and Maritime Services (RMS) road infrastructure, then the RMS standards take precedence for assessing the effects on RMS assets.

If, when using the standard, it is considered that the intent of stated requirements is not clear, a clarification should be sought from the Asset Standards Authority (ASA).

This standard is not applicable for developments near protected future rail tunnel corridors.

This standard does not provide specific requirements for developments that require encroaching into the first protection reserve (zone immediately around the tunnel); for example, physical connections into existing rail tunnel infrastructure. In these situations, an interface agreement is required between TfNSW and the developer to manage the risk associated with developments within the first protection reserve.

# 3. Reference documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

**Australian standards**

AS 5100 Bridge design (suite)

**Transport for NSW standards**

SPC 207 Track Monitoring Requirements for Undertrack Excavation

T MU MD 20001 ST System Safety Standard for New or Altered Assets

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T MU MD 20002 ST Risk Criteria for Use by Organisations Providing Engineering Services

T HR CI 12070 ST Miscellaneous Structures

T HR CI 12075 ST Airspace Developments

T HR CI 12080 ST External Developments

T HR EL 12002 GU Electrolysis from Stray DC Current

**Legislation**

State Environmental Planning Policy (Infrastructure) 2007 (SEPP 2007) under the Environmental Planning and Assessment Act 1979

Environmental Planning and Assessment Act 1979

Heritage Act 1977

**Other reference documents**

Rail Access Corporation, 2000, Airport Line Tunnel Protection Guidelines - Guidelines for Development within the Vicinity of the Airport Line - Part A: Planning and Design Matters - Part B: Technical Matters

CIRIA 2003, C580 Embedded retaining walls: guidance for economic design

Department of Planning, NSW Government 2008, Development Near Rail Corridors and Busy Roads – Interim Guideline

Transport Infrastructure Development Corporation 2008, ECRL Underground Infrastructure Protection Guidelines, Report No. 20007300 / PO-4532, Rev 3

SMEC, October 1976, ESR Sydney, City tunnels, Stations at Town Hall and Martin Place and appurtenant works (OM OC to IM 57C)

# 4. Terms and definitions

The following terms and definitions apply in this document:

**APL** Airport Line

**ASA** Asset Standards Authority

**CCL** City Circle Line

**developer** the person or organisation responsible for the new construction or alteration works, or both

**development** new construction or alteration works or both that could affect existing rail tunnel and associated infrastructure. These works can include demolitions, alterations of existing structures, basements, foundations, anchors, temporary and permanent groundwater drawdown, pipe jacking, site investigations, tunnel and retaining wall constructions.

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**easement** a right to use for a specific purpose land owned by others. The easement can be limited in either height or depth or both. This is also referred as easement land.

**ECRL** Epping to Chatswood Rail Link

**ESR** Eastern Suburbs Railway

**metropolitan rail area** the rail freight network and the rail passenger network within the metropolitan rail area bounded by Newcastle (in the north), Richmond (in the northwest), Bowenfels (in the west), Macarthur (in the southwest) and Bomaderry (in the south), and all connection lines and sidings within these areas, but excluding private sidings

**PPV** peak particle velocity

**qualified person** a person who is registered as a professional engineer under any law relating to the registration of engineers and who under law is allowed to practice or carry on the business of a professional engineer

**railway infrastructure** facilities other than rolling stock necessary for a railway to operate safely including railway track, associated track structures, over-track or under-track structures, supports (including supports for railway equipment or items associated with the use of a railway), tunnels, bridges, stations, platforms, train control systems, signalling systems, communication systems, electric traction infrastructure, buildings, workshops and associated equipment.

**RPZ** railway protection zone; the railway safety zone which is measured 25 m away from the easement or stratum boundary, both horizontally and vertically (SEPP 2007)

**rail tunnel** an underground space through which one or more railway tracks are continuously enclosed above, below and on both sides

**RMS** Roads and Maritime Services

**SEPP** State Environmental Planning Policy

**SFAIRP** so far as is reasonably practicable

**stratum** land owned for a rail tunnel is limited in either height or depth or both. This is also referred as stratum land

**support zone** a zone where tunnel supports are located. Tunnel support comprises rock bolts and anchors, ground improvement measures such as grouted zones, rock pillar stich bolts, steel sets, lattice girders, brick lining, cast-in-situ lining, shotcrete lining and waterproof membranes

**TBM** tunnel boring machine

**TfNSW** Transport for NSW

**WHS** workplace health and safety

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# 5. Rail protection reserves

Rail protection reserves, also known as protection reserve zones, are defined for the protection of existing rail tunnels. For the purpose of assessing the effects of adjacent developments, the rail tunnels include the main tunnel and the associated structures such as station caverns, cross passages, egress passages, refuges, adits, cut and cover tunnels, short and long underpasses and walkways, dive and portal structures, and underground electrical substations.

The APL tunnel had documented guidelines for adjacent developments that define different protection reserves and easements surrounding the tunnel and station caverns.

The CCL tunnels and ESR tunnels did not have clearly defined protection reserves. Tunnel easement details for CCL tunnels and ESR tunnels are registered on land titles for individual lots located near rail tunnels.

To unify all existing guidelines, new protection reserves are defined for rail tunnels in this standard. The developers shall establish the protection reserve zones based on the requirements provided in Section 5.1 to Section 5.4 and shall ensure that the design and construction meets the requirements given in this document.

Appendix A provides a brief description of the metropolitan area rail tunnels, primarily discussed in this standard.

## 5.1. Protection reserves

The rail protection reserves are categorised as 'first reserve' and 'second reserve'. These reserves are defined to ensure the protection of tunnel and rail infrastructure during construction and operation of adjacent developments.

Figure 1 represents the area that forms the first reserve and the second reserve around a rail tunnel.

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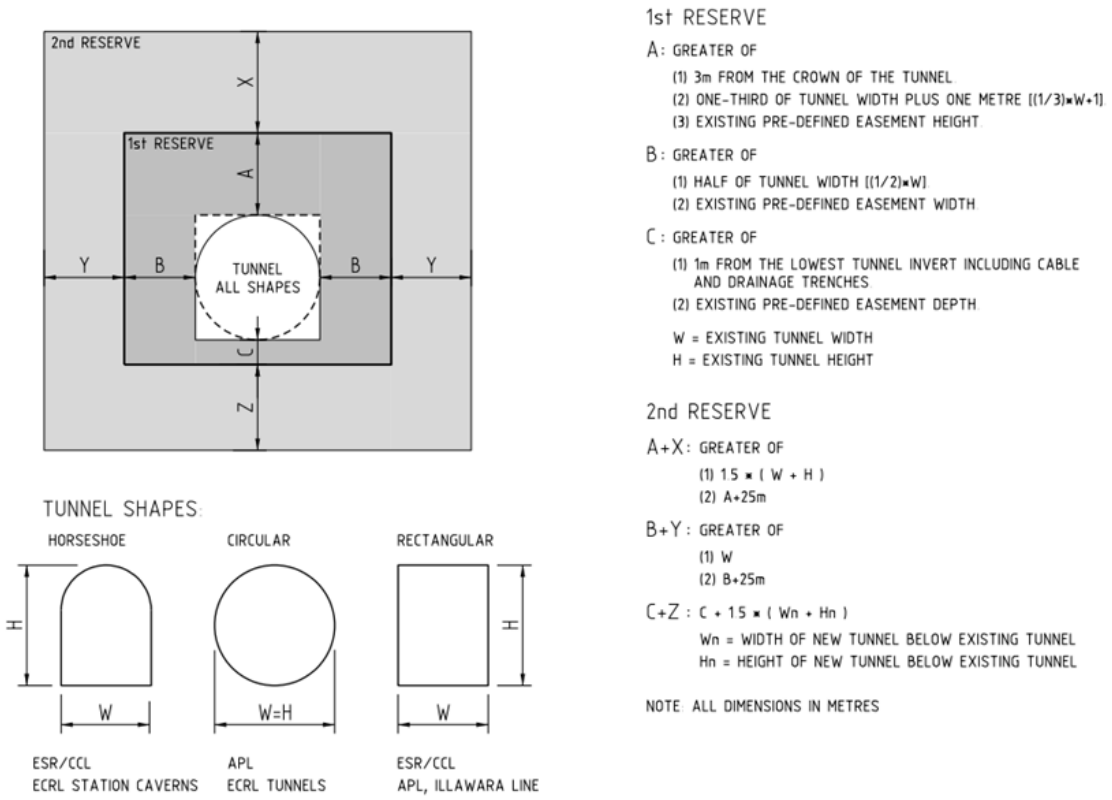


**Figure 1 - Rail protection reserves**

For open cut dive structures, shafts and station boxes,

A+X = 0

1st RESERVE

B: Greater of:

(1) 3 m, if the excavation is supported from inside (passive support)

(2) Wall support zone (anchors and soil nails) + 0.5 m. If the temporary support elements during construction is still attached to the structure, the support zone should consider temporary support zone also.

(3) Existing pre-defined easement width

C: Greater of:

(1) 1 m from the lowest excavation face including cable and drainage trenches

(2) Existing pre-defined easement depth

2nd RESERVE

B+Y: Greater of:

(1) Width of the shaft or excavation

(2) B + 25 m

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C+Z: Greater of:

(1) C+25 m

The extent of rail protection reserves can vary depending on the type of tunnel construction, support elements and surrounding ground.

Figure 2 shows the definition for measuring tunnel width for different tunnel configurations to establish the extent of protection reserves.

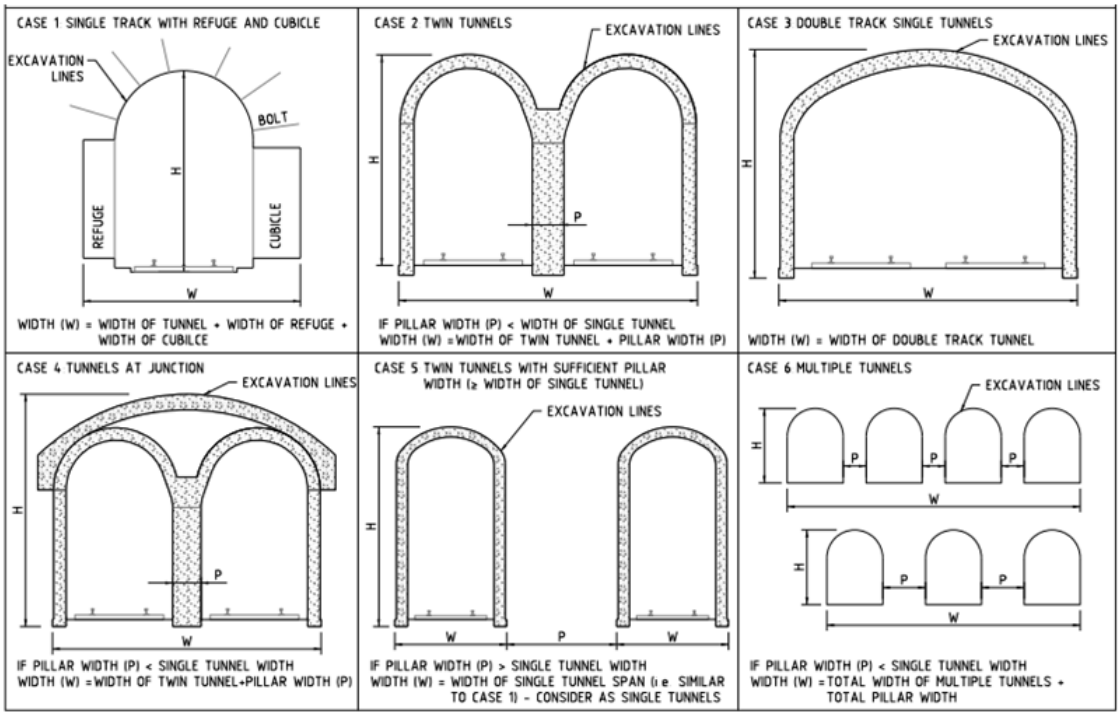


**Figure 2 - Definition for tunnel width (W)**

The width (W) of the tunnel or cluster of tunnels is determined based on the width of the ground load arching induced by the tunnel excavation. If the separation of two tunnels, that is, the pillar width (P) exceeds the width of the larger tunnel, then these two tunnels shall be assessed separately for adjacent development impacts. For case 2 to case 6 shown in Figure 2, the width (W) is measured from the outer edge of the tunnel support wall and shall include the outermost wall at refuges and cubicles as shown in case 1.

The definition of equivalent tunnel width shown in case 6 is for identical tunnels in terms of support system and the tunnel crown is at same level where the load distribution between tunnels is similar. If the group of tunnels have mixed support system and located at various levels, the equivalent tunnel width needs to be estimated case by case considering the following guidelines:

- Ground load attracted by 'passively' supported tunnels (thick tunnel lining) will be higher compared to 'actively' supported tunnels (rock bolts). Passively supported tunnels can be considered as a single group of tunnels.

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- Tunnels located in higher elevations attract more loads and act as a group. Tunnels in higher elevation can be considered as a single group.

If the tunnel wall is constructed monolithically incorporating thicker wall to support building loads (as at some locations in the ESR), the thicker combined wall should be considered as tunnel lining. Reserve distances shall be measured from outside of the combined wall.

## 5.2. First reserve

The first reserve zone comprises the immediate surrounds of the tunnel. This zone represents the area that shall not be encroached upon by any future construction or development.

The limits of this zone are indicated as 'A' (above the crown), 'B' (sides of tunnel wall) and 'C' (below the invert) as shown in Figure 1. These limits are determined based on the following:

- appreciation of general tunnel design methods and supports provided in rail tunnels
- tunnel support system which comprise support elements such as rock bolts, ground anchors, spot bolting at side walls and forward crown reinforcements
- over break during construction and void backfill zones behind the cast-in-situ or sprayed shotcrete lining
- required zone for future rock reinforcement to stabilise potential tunnel lining instability caused by weathering or creep of rock wedges, or both
- rock pillar width that enhances the stability of cluster or group of tunnels
- tunnel drainage system, foundations for internal structures and any invert rock reinforcement

The following factors have also been considered in determining the first reserve in this standard:

- existing protection reserve 1 for APL tunnel and existing easements for CCL tunnels and ESR tunnels
- load arching height above tunnel which diverts development induced loads around the existing tunnel without affecting the tunnel lining
- disturbed zone during the construction of the existing tunnel such as extent of rock bedding movements and stress changes around the tunnel
- drainage pits and potential over break and backfill at the invert
- spot bolts on the sidewalls to stabilise rock wedges

The limits for the first reserve of the rail tunnels within the Sydney metropolitan rail area shall be derived as shown in Table 1.

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**Table 1 - Definition of first reserve**

| Boundary (distance in 'm' shown in Figure 1) | Reserve dimensions (m) |
|---|---|
| Top (A) | For tunnels, the greater of the following:<br>• 3 m from the crown of the highest tunnel<br>• ⅓ x tunnel width plus 1 m (1/3 x W+1)<br>• existing pre-defined easement height<br>For open cut, shafts and station boxes,<br>A = 0 |
| Side (B) | For tunnels, the greater of the following:<br>• ½ x tunnel width (1/2 x W)<br>• existing pre-defined easement width<br>For open cut, shafts and station boxes, the greater of the following:<br>• 3 m, if the excavation is supported from inside (passive support).<br>• Wall support zone (anchors and soil nails) + 0.5 m. If the temporary support elements during construction are still attached to the structure, the support zone should consider temporary support zone also.<br>• Existing pre-defined easement width. |
| Bottom (C) | The greater of the following:<br>• 1 m from the lowest tunnel invert including cable and drainage trenches<br>• existing pre-defined easement depth |

## 5.3. Second reserve

The second reserve zone is determined around the first reserve zone and comprises the area of stress changes and rock joint and bedding displacements that have occurred during the construction of the existing tunnel.

The second reserve zone covers the areas where development works have the potential to impact the performance of the tunnel support elements and the operation of the tunnel.

Any development within the railway protection zone (RPZ) requires detailed impact assessment in accordance with SEPP 2007. The second reserve limits determined in this standard accommodate the currently defined RPZ.

Any development that takes place within the second reserve shall require an engineering assessment of the works to determine their effects on the underground rail infrastructure.

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The following factors have been considered in determining the second reserve in this standard:

- zone of negligible ground stress changes due to the construction of the existing tunnel
- extent of shear displacement of horizontal rock defect or bedding and joints during construction both laterally and vertically above the tunnel
- drainage and cable pits at the invert
- potential stress and displacement influence zones associated with external developments based on case histories
- potential groundwater drawdown influence zone
- vibration influence zone

The limits for the second reserve of the rail tunnels within the metropolitan rail area shall be derived as shown in Table 2.

**Table 2 - Definition of second reserve**

| **Boundary (distance in 'm' shown in Figure 1)** | **Reserve dimensions (m)** |
|---|---|
| Top (A+X) | For tunnels, the greater of the following:<br>• 1.5 x (W+H)<br>• A+25<br>Where 'W' and 'H' are width and height of the existing rail tunnel<br>For open cut, shafts and station boxes,<br>A+X = 0 |
| Side (B+Y) | For tunnels, the greater of the following:<br>• W<br>• B+25<br>For open cut, shafts and station boxes, the greater of the following:<br>• Width of the shaft or excavation<br>• B + 25 m |
| Bottom (C+Z) | For tunnels,<br>C + 1.5 x (Wn+Hn)<br>where, 'Wn' and 'Hn' are width and height of new tunnel under the existing tunnel or cavern<br>For open cut, shafts and station boxes,<br>C+25 m |

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## 5.4. Construction restrictions on protection reserves

The purpose of defining the protection reserves is to protect the existing rail tunnels and associated infrastructure from future adjacent development activities.

Table 3 provides the construction restrictions that are applied to each protection reserve as shown in Table 1.

**Table 3 - Construction restrictions**

| Types of construction | First reserve | Second reserve |
|---|---|---|
| Excavations for basements, footings | Not allowed | • Excavations less than 2.0 m depth from surface level, assessment not required.<br>• Excavations greater than 2.0 m depth, assessment required. |
| Shallow footings or pile foundations | Not allowed | Allowed, subject to load restrictions. Assessment required. |
| Tunnels and underground excavations | Not allowed | Allowed, subject to assessment. |
| Ground anchors | Not allowed | Allowed, subject to assessment. |
| Demolition of existing subsurface structures | Not allowed | Allowed, subject to assessment. |
| Penetrative subsurface investigations | Allowed away from support zone. Assessment required. | Allowed, subject to assessment. |

Future developments such as the metro rail, egress passages, utility tunnels, and ventilation and access shafts can require construction through first reserve for connections with existing rail tunnels. Such activities are not covered in this standard and require agreement of specific interface requirements between TfNSW and the future developer.

# 6. Load limits

Previous development guidelines and design reports for CCL tunnels, ESR tunnels, and APL tunnel specify load limits that can be imposed by the future developments without causing adverse effects on the tunnel support system and operation.

These load limits were derived at that time of construction of these tunnels based on a set of assumptions on tunnel lining conditions, engineering standards requirements and inferred geotechnical conditions during the design and construction of the rail tunnel lining. These assumptions are subject to change with time due to change in design standards and codes, geotechnical conditions, condition of linings and other structural elements and adjacent constructions. Application of these load limits provided in earlier guidelines can lead to adverse effects on tunnel lining and structures.

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This standard specifies guideline load limits for assessing the effects of developments. These load limits are derived based on the protection reserves and the specific geotechnical conditions.

The developer is responsible for proving to the satisfaction of TfNSW that the tunnel lining and structures will have no adverse effect due to loads applied by the development.

The existing condition of the tunnel lining and support structure shall be taken in to account for the assessment.

If the guideline limits for loading on the tunnel reserve boundaries are proposed to be exceeded, then an independent verification of the engineering analysis and impact assessment is required. Refer to Section 8.4 for information on independent verification.

The guidelines for imposed load limits for different tunnels are provided in Section 6.1 to Section 6.3.

## 6.1. City Circle Line tunnels

Table 4 shows the guidelines for imposed load limits for CCL tunnels.

**Table 4 - Load limits on CCL tunnels**

| Tunnel type | Description | Load limits |
|---|---|---|
| Arch tunnels | Arch tunnels in good rock (class I/II sandstone) | 500 kPa above the top of second reserve |
| Flat top tunnels | Shallow tunnels in poor rock, cut and cover tunnel | 150 kPa above the top of second reserve |

Ground anchors within the 2$^{nd}$ reserve shall be assessed for their effects on the underground infrastructure including the effects of construction method.

## 6.2. Eastern Suburbs Railway tunnels

Table 5 and Table 6 show the guidelines for imposed load limits on ESR-Erskineville to Bondi Junction tunnels.

**Table 5 - Load limits on ESR - Redfern to Bondi Junction**

| Feature | Sound rock cover (m)- class i/ii sandstone | Uniform loading (kPa), raft footing or close footing (note 1) | Concentrated loading (kPa), column or isolated footings of lift core (note 2) |
|---|---|---|---|
| Typical tunnel section | Rock cover thickness 'A'- top of first reserve | 100 | 50 |
| Typical tunnel section | Rock cover thickness 'A+X'- top of second reserve | 500 | 200 |

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| Feature | Sound rock cover (m)- class i/ii sandstone | Uniform loading (kPa), raft footing or close footing (note 1) | Concentrated loading (kPa), column or isolated footings of lift core (note 2) |
|---|---|---|---|
| Tunnel section with a cubicle and refuge | Rock cover thickness 'A'- top of first reserve | 100 | 10 |
| Tunnel section with a cubicle and refuge | Rock cover thickness 'A+X'- top of second reserve | 200 | 50 |

*Note 1: Close footings are those in which stress zones of adjacent footings on a 1:2 distribution through rock intersects above the first reserve.*

*Note 2: Concentrated loadings are those in which the stress zones of adjacent footings do not intersect at or above the first reserve on a 1:2 distribution through rock.*

**Table 6 - Load limits on ESR box tunnels - Redfern to Erskineville**

| Feature | Uniform loading (kPa) |
|---|---|
| Easement rights and load restriction for ESR double box tunnels | 150 kPa above the top of second reserve. Any footing loads within second reserve are subject to assessment. |

Ground anchors within the second protection reserve shall be assessed for their effects on the underground infrastructure including the effects of construction method.

## 6.3. Airport Line tunnels

Table 7 shows the allowable imposed load limits on APL tunnels derived from the *Airport Line Tunnel protection Guidelines, Part B (Technical Matters)*, Rail Access Corporation 2000.

**Table 7- Load limits on APL tunnels**

| Element | Description |
|---|---|
| Station structures including diaphragm walls and other retaining structures | Future buildings adjacent to the stations are allowed to impose an additional lateral pressure on the station walls equivalent to a lateral pressure due to a uniform surface loading of 10 kPa. If the lateral pressure from the proposed future building foundations exceeds 10 kPa, then the building foundations shall be designed to transfer the building loads past the base of the station wall. |
| Loading limit - good rock (Class I/II) tunnel | 150 kPa maximum imposed load above the top of second reserve. 500 kPa maximum footing load above the top of second reserve, if the second reserve zone is within good rock (class I/II). Engineering assessment is required for other rock classes. |

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| Element | Description |
|---|---|
| Loading limit - soft ground tunnel | If the applied pressure on the tunnel lining from foundation loads exceeds 10 kPa, but less than 30 kPa, then an independent verification of the engineering analysis and impact assessment is required. When the applied pressure on the tunnel lining exceeds 30 kPa, then the foundation loads shall be transferred past the tunnel.<br>10 m minimum cover over tunnel to retain stability of the segmental concrete lining and to counter buoyancy effects.<br>Load limits and associated ground movements shall not compromise the function of the waterproof gasket of the segmental lining. Gasket decompression assessment shall be performed based on the as built details obtained from TfNSW. |
| Ground anchors | Ground anchors within the second reserve zones shall be assessed for their effects on the underground infrastructure including the effects of construction method. |
| Track alignment | Any excavation adjacent to the APL tunnel shall not adversely impact the track alignment and the rail operation. |

# 7. General requirements for adjacent developments

Any developments above, below or alongside the existing rail tunnel within the protection reserves are known as adjacent developments.

Any developments outside protection reserves, where construction-induced groundwater drawdown and vibration can affect the existing rail tunnel are also considered as adjacent developments.

Developments near rail tunnels shall be planned, designed, constructed and maintained to ensure the protection of existing tunnels and the rail infrastructure. These developments shall not affect the rail operations including the operational capacity or the efficiency of the rail network during any stage of the life cycle of that development including plan, acquire, maintain and dispose.

## 7.1. Types of developments

The following is a list of possible types of developments near rail tunnels, that is, above, alongside or below:

- excavations for basements, shafts
- shallow footing or pile foundation
- tunnels and underground excavations
- ground anchors
- demolitions of existing structure – above or alongside
- geotechnical investigations / instrumentation

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The load, displacements and stress changes that occur due to the construction of adjacent developments can affect the existing rail tunnels. The induced changes in load and displacements depend on the types of developments. Section 7.1.1 to Section 7.1.6 describes the commonly encountered activities impacting adjacent tunnels.

Refer to Section 5 and Section 6 for limits and restrictions of protection reserves.

## 7.1.1. Open excavation

Open excavations can be above the tunnel, on the side or below the existing tunnel as shown in Figure 3. Such excavations can alter the in situ stress regime in the ground that directly affects the tunnel lining, support elements and other sensitive infrastructure. The excavations can additionally reduce the structural support provided by the surrounding rock where the rock provides active support. Stress relief effects have had significant effects on the rail tunnels in the past. An engineering assessment shall be carried out where such excavations encroach on the protection reserves.

The assessment shall include all applicable extreme load combinations that can affect the underground rail infrastructure. For segmentally lined tunnels, the effect on the waterproof gasket due to induced lining movement shall be included in the impact assessment. In addition, effects on rail tunnels due to vibration induced by excavation activities shall be assessed.

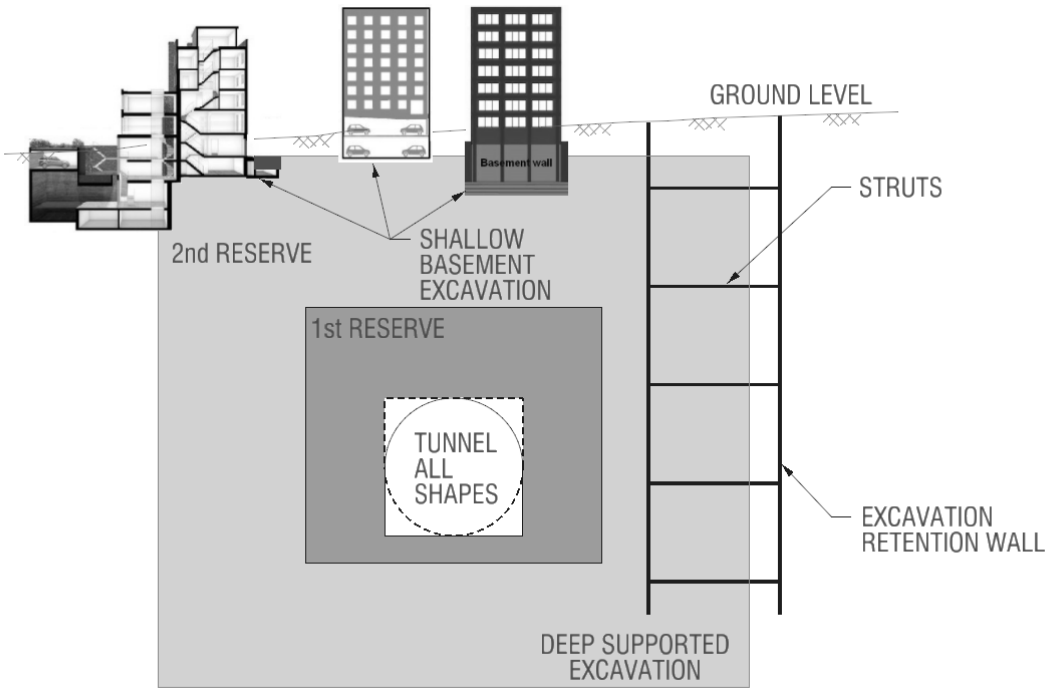


**Figure 3 - Deep open excavation**

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## 7.1.2. Foundations

Additional pressures from shallow spread footings and piled foundations can increase stresses in the tunnel linings and surrounding rock as shown in Figure 4. The effects of the footing loads, including any uplift forces at the invert of the tunnel shall be assessed. Redistribution of footing loads away from protection reserves is required to minimise the effects on the rail tunnels. The effects of vibration from activities such as pile driving or bored pile installation and sheet pile installation shall be assessed.

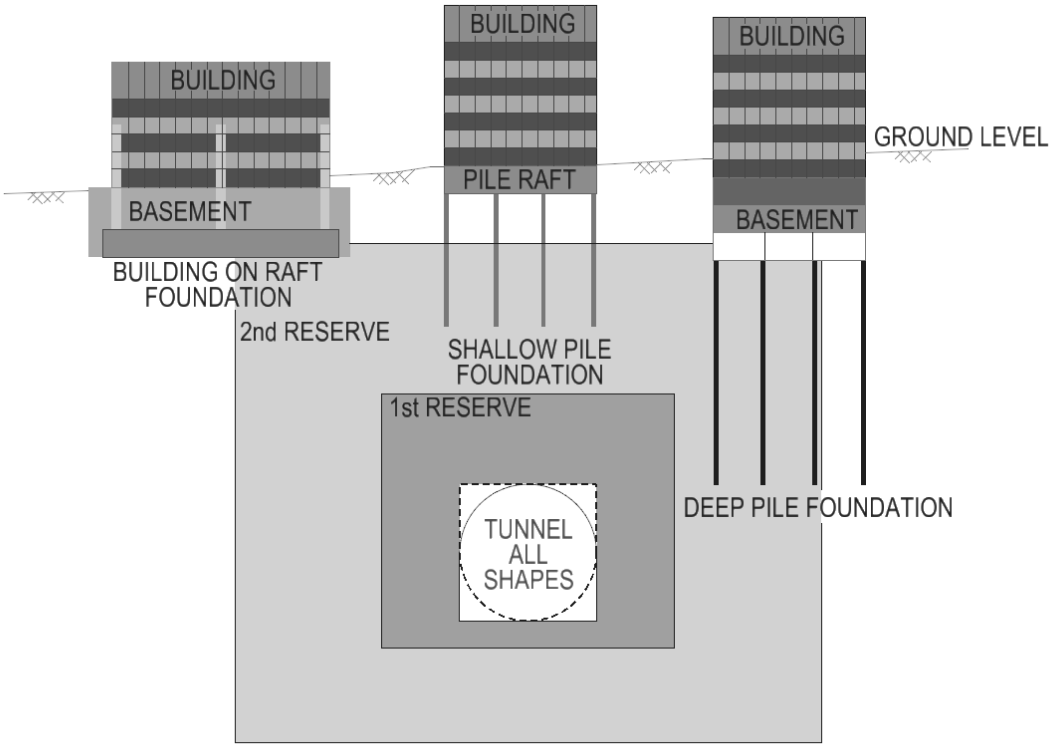


**Figure 4 - Deep and shallow foundations**

## 7.1.3. Underground excavations

Underground excavations include adjacent rail and road tunnels (above, at sides and below), utility tunnels, cable conduits, drainage pipes, and pedestrian walkways and underpasses as shown in Figure 5. Such underground excavations significantly alter the in situ stress field in the surrounding ground resulting in stress concentrations, stress relief and displacements. These changes can significantly affect the existing tunnel lining and support elements of other rail infrastructure.

A detailed impact assessment shall be carried out if underground excavation activities encroach into the second reserve zone. If the proposed adjacent development comprises drained tunnels, that is, the tunnel lining is built to support the ground but allows the groundwater inflow into the tunnel then the developer shall perform a groundwater drawdown induced impact assessment even if the tunnel is located outside the second reserve zone. If the drawdown influence zone is

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located outside the second reserve, then no further impact assessment is required. Assessment of excavation induced vibration shall be carried out.

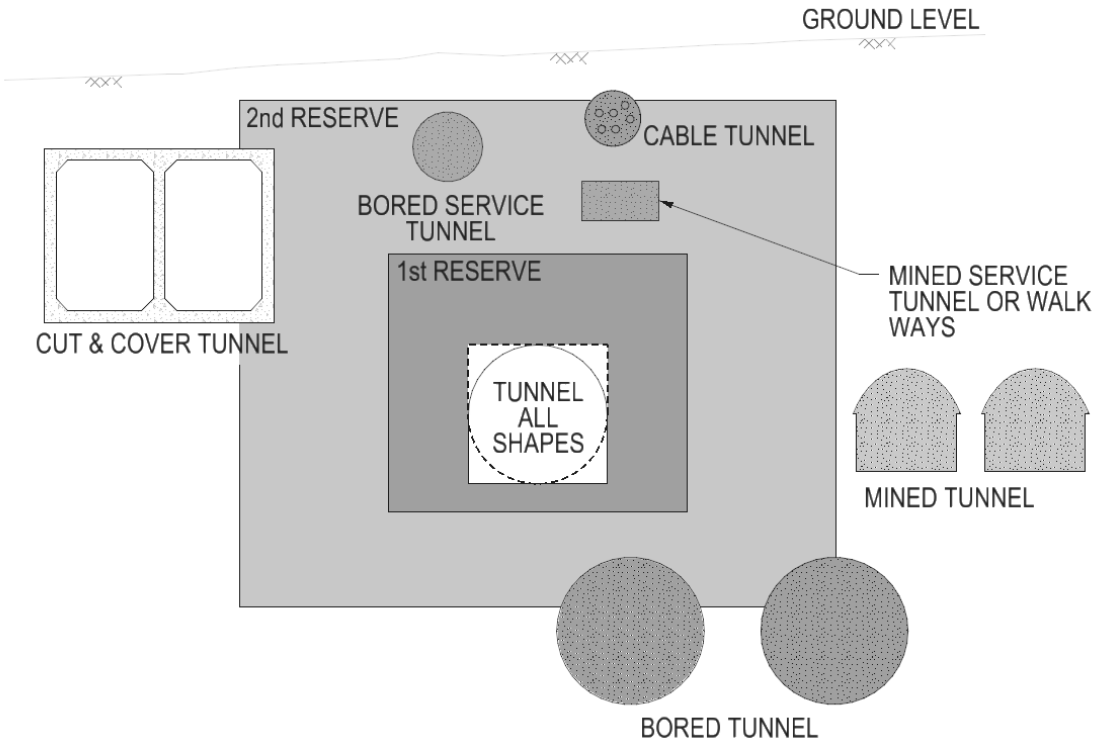


**Figure 5 - Underground excavations**

## 7.1.4. Ground anchors

Temporary and permanent anchors can be part of the development to support open excavations, underground excavations and uplift resistance for construction cranes and basements as shown in Figure 6. High stress concentrations at the anchors can affect the surrounding ground locally with potential effects on the stability of the rock and existing tunnel structure.

Anchors shall not be subject to testing which can result in collapse or failure, or both, in the soil or rock structure surrounding it. For temporary anchors, an assessment shall be carried out if the anchors encroach into the second reserve zone.

Ground anchors shall not be allowed within the first reserve zone.

Any ground anchors within the second reserve shall be assessed for their effect on the underground infrastructure, including the effect of their construction method.

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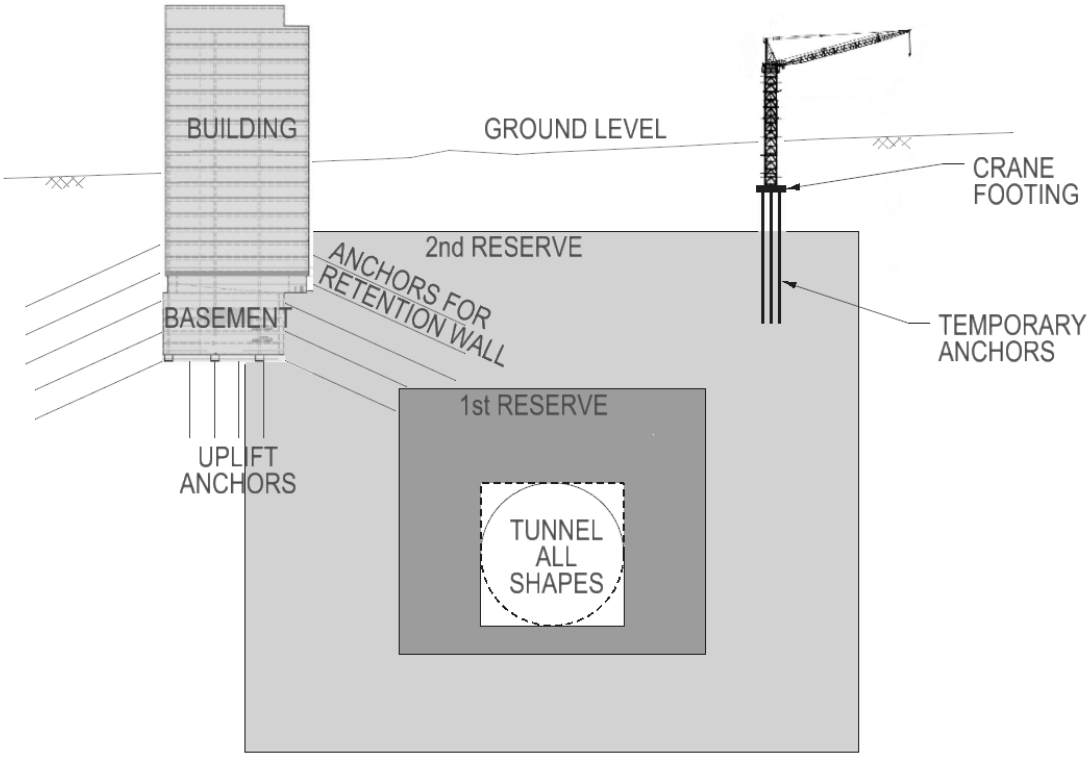


**Figure 6 - Ground anchors**

## 7.1.5. Construction method

The existing tunnels can be impacted by temporary loads such as crane loads and temporary support systems, excessive noise and vibration from rock breaking, pile driving and rock drilling works as shown in Figure 7. Ground improvement works such as grouting and ground freezing works can also affect existing rail tunnel structures. Grouting can block water drainage paths and impose excessive hydrostatic load on tunnel lining. Ground freezing causes volume increase and can impose loads on tunnel lining. Excessive vibration can dislodge rock wedges on existing rail tunnels and impose additional non-uniform loads on tunnel lining.

The vibration and ground improvement induced impacts shall be investigated and assessed in detail.

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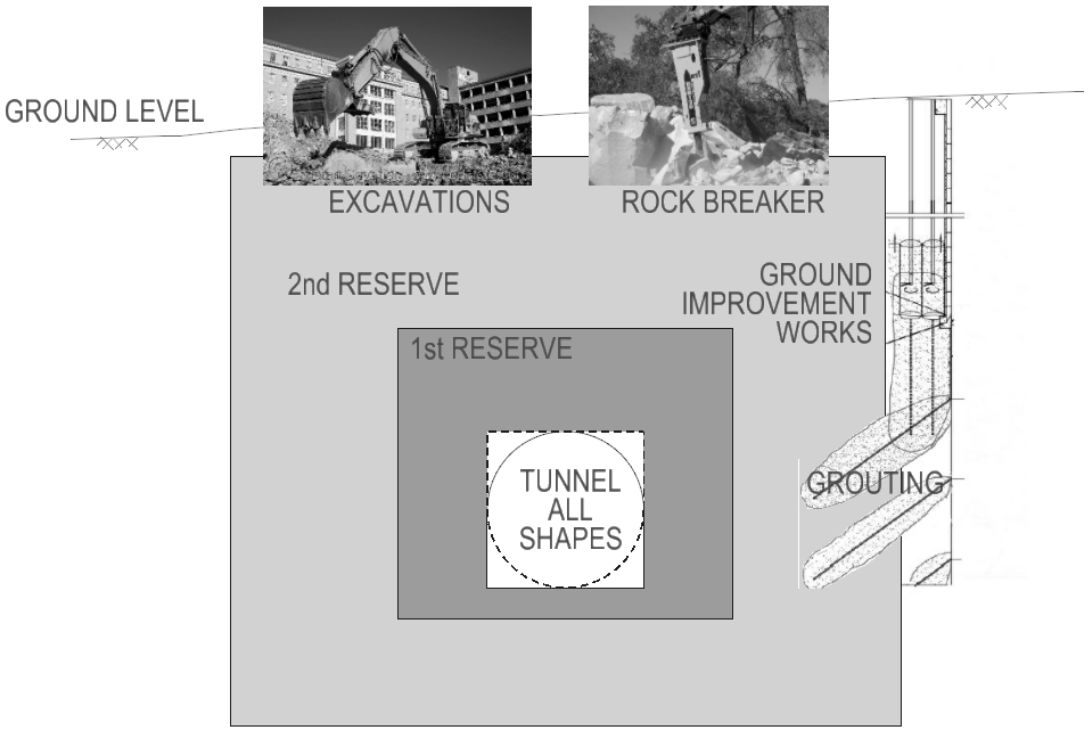


**Figure 7 - Construction methods**

## 7.1.6. Site investigation and instrumentation holes

Development activity requires geotechnical and subsurface investigations that can include drill holes, geophysical exploration, in situ tests and permeability tests. During construction, instrumentation holes such as inclinometers, piezometers and extensometers can be drilled to measure the ground reaction and the impacts as shown in Figure 8. Installation of instrumentation and investigation holes is permissible within first reserve; however it shall be away from the support zones.

Bore hole coordinates shall be verified against the as-built location of the existing tunnel to minimise the risk of damage. Bore holes shall be carefully grouted to their full depth with bentonite or cement grout on completion.

Refer to Section 8.1 for details on geotechnical investigations.

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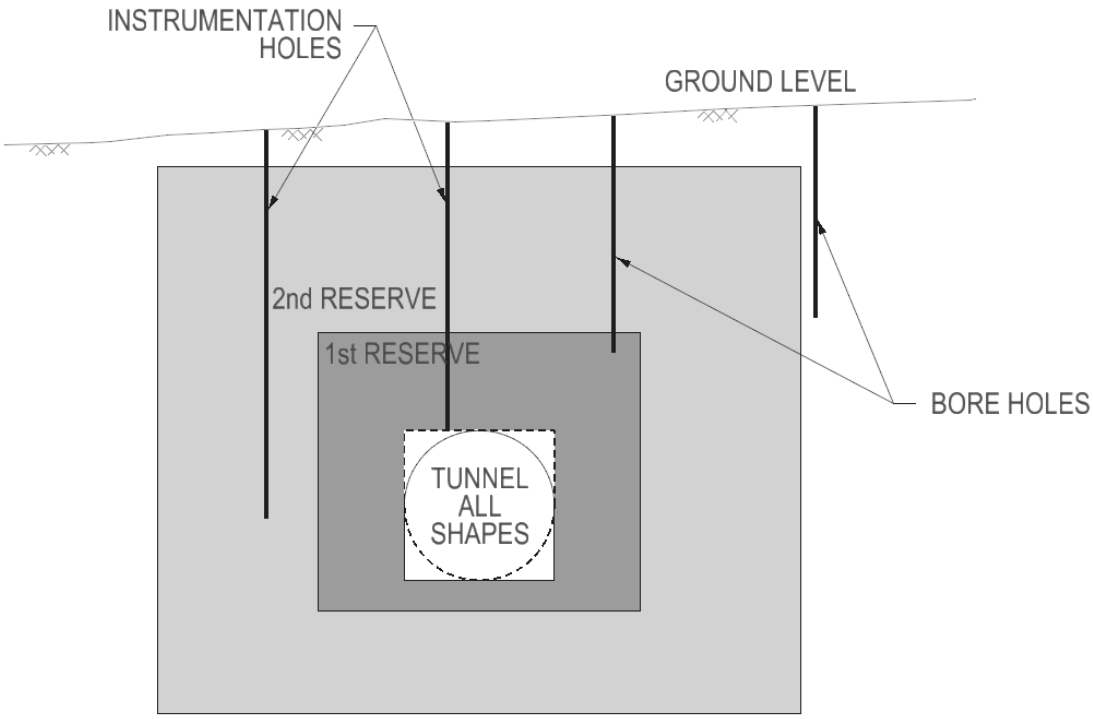


**Figure 8 - Ground penetration holes**

## 7.2. Safety

Developments near tunnels shall meet the following performance requirements of rail tunnels, railway infrastructure and train services at any stage of the life cycle of that development:

- structural safety
- operational safety
- fire safety
- inspection and maintenance
- flood protection

Consideration shall be given to maintenance and the future users of the development.

Refer to Section 9 for performance requirements.

The developer shall satisfy any additional safety requirements imposed by TfNSW. Refer to Section 10.2 for developers' obligation to eliminate risk to safe rail operation so far as is reasonably practicable (SFAIRP).

Developments shall not obstruct emergency access to rail tunnels and any maintenance access.

Approvals from TfNSW are required to enter into the tunnel for dilapidation survey, installation of instruments, monitoring and visual inspections. Persons carrying out these activities shall be

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accompanied by safety personnel from TfNSW or from TfNSW approved organisations when entering the tunnel.

## 7.3. Protection of the environment

The development shall take into account the environmental impacts that can affect the existing rail tunnels and the rail operations with a view to minimising any effects during the whole life cycle of the development.

Typical considerations for developments in the urban environment are as follows:

- stormwater management
- noise and vibration
- air quality, particularly dust
- traffic impacts
- visual impact and amenity
- ability and ease to maintain and 'retro-fit' improvements over time
- disposal and re-use at life cycle end
- ecological impact due to ground water draw-down
- groundwater contamination
- construction materials to be as low toxicity as possible

## 7.4. Heritage

The design, planning and construction of proposed development works, including investigation phase and excavation works shall take into account any heritage issues that are applicable to rail tunnels and associated infrastructure. Heritage issues shall be appropriately addressed wherever new works or modifications are proposed near identified heritage items and where heritage issues arise.

TfNSW is responsible for maintaining and appropriately managing items of heritage significance under its stewardship and control. The significance of heritage items can be historical, aesthetic, scientific, social or spiritual, and is often a combination of a number of these values. Heritage items are also valued for their rarity or as being particularly representative of their type.

Heritage management is governed by legislation in New South Wales. The *Environmental Planning and Assessment Act 1979* (NSW) requires that environmental impacts including impacts on heritage items, resulting from development shall be appropriately assessed.

The *Heritage Act 1977* (NSW) is designed to protect, maintain and manage environmental heritage in NSW, including items of archaeological significance.

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## 7.5. Construction constraints and maintenance

Development shall take into account the construction constraints, particularly live road and rail operating conditions, noise and vibration restrictions and track possession constraints.

Development shall take into account the ability to access components for inspection and maintenance purposes.

# 8. Engineering assessment

The developer should approach TfNSW for information that defines the extent of the existing works when considering a project near underground rail infrastructure.

The engineering assessment shall be carried out to ensure that no adverse effects arise from the proposed development within the protection reserves for the existing rail tunnel and the associated rail infrastructure such as cross passages, egress passages, electrical and mechanical rooms and walkways. The adverse effects can be measured against the code compliance and performance requirements provided in Section 9.

The development shall not affect the stability and integrity of the rail tunnel and associated rail infrastructure, and safe rail operations.

The engineering assessment shall demonstrate that, as a minimum, the following causes that can affect the tunnels do not cause any adverse effect to the rail infrastructure:

- loading or unloading from the development
- ground deformation resulting from excavations and external loading
- induced vibrations during construction and operation
- ground-borne noise impacts
- electrolysis from earth leakage currents, for example, light rail
- discharge of stormwater from development
- changes to groundwater levels affecting design assumptions
- loss of support to any underground rail facility including rock bolts and anchors
- temporary structures
- load from anchors

The engineering assessment shall include geotechnical investigations, detailed engineering analysis and impact assessments, and a summary report to TfNSW as part of the approval package.

Storage of potential contaminants and hazardous materials such as explosives in any of the protection reserves shall be subject to TfNSW approval and may be approved where risk

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assessment demonstrates that the risk to the underground infrastructure is appropriately managed.

A risk assessment and appropriate safety precautions shall be provided for storage of potential contaminants within any of the protection reserves, where there is potential for the contaminants to migrate to or come in contact with the underground infrastructure. This shall include an assessment of the impact on the durability of concrete, grout, resin, steel, waterproofing gaskets and membranes and any other material forming the permanent works of the underground infrastructure.

## 8.1. Geotechnical investigation

The developer shall carry out detailed geotechnical investigations of the soil or rock strata above, alongside and below the rail tunnels, as appropriate, to establish the existing ground conditions within the area affected by the proposed development. The geotechnical investigation shall provide the following:

- accurate geological profile of the sections where the development is proposed and the sections beyond the footprint where the development can potentially impact the tunnels
- existing in situ stress states in soils and rock mass
- critical geological features such as bedding planes, joints, dykes and so on
- rock and soil properties by in situ and laboratory tests
- information on existing ground water regime
- any other man-made features

Geotechnical investigation can comprise the following:

- drilling boreholes
- geophysical exploration
- in situ tests
- geological mapping

Drilling boreholes (for subsurface investigation) within the first reserve shall avoid the tunnel support zone and requires a detailed study of existing arrangements to demonstrate that risk to the underground infrastructure is appropriately managed for approval from TfNSW prior to drilling works.

The project surveyor shall verify the hole coordinates for all locations of proposed bore holes within the rail protection zone. Drilling shall only proceed after obtaining approval from TfNSW.

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## 8.2. Engineering analysis and impact assessment

The developer shall carry out an engineering analysis and impact assessment to demonstrate that the effects of the proposed development on the existing tunnels and underground facilities will not cause any adverse effect.

TfNSW can request the developer to arrange independent verification of the engineering analysis and impact assessment based on the project complexity and potential effect to the tunnel.

The engineering analysis and impact assessment shall take into account other adjacent development activities planned for the future or that are taking place at the time of analysis. This information can be obtained from TfNSW.

Depending on the complexity of the development, a two dimensional or three dimensional numerical modelling (finite element (FE) or finite difference (FD)) shall be carried out to assess the effects on the tunnels and infrastructure elements at different stages of construction and during operation after commissioning. This shall include effects of associated temporary works such as crane and construction material loading.

The numerical modelling shall be based on the realistic geological model derived from the subsurface information gathered through the geotechnical investigation. It shall include critical geological features such as bedding planes, weak layers, joints and other discontinuities.

The numerical modelling shall also account for existing conditions of the tunnel lining including defects such as cracks, drainage conditions and support conditions determined by dilapidation survey and in situ strength tests as appropriate.

The numerical modelling results shall be verified. The predictions can be validated during construction by carefully designed field monitoring instrumentation.

The engineering assessment shall be carried out by suitably qualified persons with experience in tunnel design and analysis.

The engineering assessment report shall be prepared and endorsed by a suitably qualified person and shall be submitted to TfNSW.

## 8.3. Engineering assessment report

The engineering assessment report shall comprise the following:

- geotechnical investigation report
- impact assessment report
- risk assessment report

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### 8.3.1. Geotechnical investigation report

As a minimum the geotechnical investigation report shall include the following:

- borehole location plan, bore logs, test results, geological mapping, photographic documentation and other relevant information used for the analysis
- description of the soil profile of the area
- critical geological features such as bedding planes, joints, dykes and so on
- other relevant data from geotechnical investigation
- rock and soil properties, laboratory and in situ test results
- existing in situ stress states in soils and rocks
- ground water levels and condition
- detailed geotechnical model for the analysis including geotechnical design parameters
- recommended footing design, methods of shoring and excavation
- copy of all plans, geotechnical data, operations and maintenance records with any qualifications and limitations provided by TfNSW to the developer

### 8.3.2. Impact assessment report

As a minimum the impact assessment report shall include the following:

- Detailed scope of the development.
- Verified survey plans by NSW registered surveyor showing the location of the proposed development in relation to the easements, rail protection reserves, track centre lines, tunnel walls, tunnel refuges and associated rail infrastructure.

  Multiple tunnels at different elevations shall be indicated in plans and in cross sections. Rail protection reserves shall be derived as defined in this standard.
- Zone of influence due to proposed development relative to rail corridor boundary.
- Detailed drawings depicting structural layout, foundation layout, foundation loads, drainage plans, temporary works such as dewatering, shoring and anchoring and permanent works of the proposed development.
- Structural drawings with designs for shoring plan and detail as recommended by the geotechnical consultant.
- Predicted displacements of existing tunnel lining and infrastructure elements due to proposed development at various stages such as pre-construction including demolition, during excavation, during construction and post-construction.

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- Predicted stresses on tunnel lining and infrastructure elements at various stages of construction such as pre-construction including demolition, during excavation, during construction and post-construction.
- Structural assessment of likely effects of displacements and stresses on existing tunnel and associated infrastructure. This shall include structural integrity of tunnel lining, track beds, existing drainage structures, water proofing and structural clearances.
- Appropriate sensitivity analysis to ensure that the predictions are not adversely affected by reasonable variations in input parameters and different conditions that can occur during all stages of construction works.
- Assessment of the effects of the construction method on the tunnel and associated rail infrastructure.
- Discussion on any design assumptions, qualifications or limitations that are not adequately considered as part of the sensitivity analysis that shall then be integrated as risks in the risk assessment.
- Recommendations of preventive and remedial action for any effects on rail tunnel as a consequence of the proposed development.
- Drainage impact assessment (refer to Section 9.2.2)
- Vibration assessment report (refer to Section 9.4).
- Stray dc current signature report including risk assessment (refer to Section 9.2.1).
- Certification that the proposed development will produce no adverse effects on the tunnel and associated rail infrastructure.

### 8.3.3. Risk assessment report

Risk assessment report shall be prepared in accordance with Section 10.2. The risk assessment report shall cover the following:

- safety in design
- all stages of construction
- whole of asset life cycle

## 8.4. Independent verification

Independent verification of the engineering analysis and impact assessment shall be carried out if the guideline load limits on tunnel reserve boundaries in Section 6 are proposed to be exceeded or if required by TfNSW.

The independent verification shall be arranged by the developer.

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The independent verification shall be carried out by an organisation that is independent of the organisation that prepared the engineering analysis.

The independent verification organisation shall be subject to the approval of TfNSW.

Independent verification shall include a detailed engineering proof check of all aspects of the engineering analysis and impact assessment including any proposed temporary works.

The independent verification organisation shall prepare a report that describes its verification activities and includes certification that the proposed development will produce no adverse effects on the tunnel and associated rail infrastructure.

The independent assessment report shall be submitted to TfNSW with the engineering assessment report.

# 9. Design and performance requirements

The developer shall ensure that the construction activities do not have any adverse effects on the performance of rail tunnel and infrastructure, including any impact on the following:

- amenity
- aesthetics
- structural integrity
- durability
- function
- user benefits
- safety during construction and operation
- environmental performance

Throughout the developer's activities, the developer shall monitor the actual effects of the construction activities in accordance with the project-specific construction phase monitoring requirements.

## 9.1. Structural stability and integrity

Development induced loads and displacements shall not have any adverse effects on the tunnel structure in short and long term conditions. The requirements described in Section 9.1 shall be satisfied.

Structures that are proposed to be constructed over the tunnels or adjacent to tunnels or both shall be suitably designed to take into account the existing tunnel infrastructure. Construction work methods shall be developed as part of the design process.

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The effects on the tunnel lining or any of the structural elements and rail infrastructure at any stage of the whole life cycle of the development shall be assessed to ensure that the works remain structurally code compliant. The structural elements include rock pillar supports, load bearing columns, walls and roof beams, slabs, rock anchors or bolts, track slabs, drainage structures, tunnels refuges, ventilation shafts and underground stations.

Refer to Section 8 for details on engineering assessment and reports.

### 9.1.1. Design loads

Any temporary or permanent works adjacent to the rail boundary can be subjected to the influence of train loading and shall be assessed in accordance with AS 5100 *Bridge design* for live load surcharge. Parts of the structure so affected shall be designed in accordance with T HR CI 12070 ST *Miscellaneous Structures*, T HR CI 12075 ST *Airspace Developments* and T HR CI 12080 ST *External Developments*.

Permanent works adjacent to the rail boundary shall take into account the design actions resulting from any proposed future construction within the rail corridor or easement. This advice shall be obtained from TfNSW.

Load limits criteria provided in Section 6 shall be satisfied.

### 9.1.2. Crack criteria

The following criteria shall be met for the cracking of tunnel lining and support structures as a result of the development. The extent of cracking and crack criteria shall be confirmed for all stages of the development by engineering analysis and impact assessment:

- The calculated maximum crack width shall be less than or equal to 0.3 mm. Cracks with lengths exceeding 300 mm and width exceeding 0.2 mm shall be repaired by the developer.
- Configuration of cracks shall not result in concrete spalling or affect the safe operation of the rail system.
- Any unfavourable crack patterns that affect the current structural stability and integrity observed during dilapidation survey shall be repaired before commencing development.
- New water seepage observed through the cracks during construction shall be sealed by grouting by developer.

Monitoring of the existing cracks and critical structural elements during construction shall be part of overall monitoring plan.

Dilapidation survey of the rail tunnels and associated infrastructure shall be carried out by qualified personnel and a report shall be submitted to TfNSW together with the engineering assessment report. Refer to Section 10.1 for dilapidation survey details. The extent of the

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dilapidation survey shall be determined based on the predicted deformation and load influence zone imposed by the proposed development. This survey shall establish the extent of any existing cracks in the tunnel linings, have them suitably marked and identified to enable any deterioration in the lining during and after the construction to be monitored.

The engineering analysis and assessment shall take into account the existing cracks in the lining and supports.

### 9.1.3. Displacements

The development induced tunnel displacements shall not affect the operational functionality and the durability of the existing rail tunnel and associated infrastructure.

The following displacement limits apply:

- Shear movement across rock bedding as induced by the development activities shall not exceed 10 mm where permanent rock bolts, installed as part of the rail tunnel and associated infrastructure support system, intersect these bedding planes.
- For tunnels that are supported by a precast concrete segmental lining, the allowable total movement in any direction is 10 mm and differential movement in any plane is 10 mm or 1:2000 whichever is less. The main purpose of these limits is to ensure that the watertightness of the lining through joints is not compromised as consequence of gasket decompression and/or damage.
- For cast in situ cavern, station and tunnel concrete linings, the allowable total movement in any direction is 10 mm and differential movement in any plane is 10 mm or 1:2000 whichever is less.
- For cut and cover tunnels and stations, the allowable total movement in any direction is 15 mm and differential movement in any plane is 15 mm or 1:1000 whichever is less.

Any development activity, whether beneath or adjacent to the track, that has the potential to cause track displacement shall comply with the requirements of SPC 207 *Track Monitoring Requirements for Undertrack Excavation*. The track shall be monitored and managed in accordance with the requirements stated in SPC 207 for monitoring, notification and intervention levels and emergency procedure.

## 9.2. Design requirements

Any temporary or permanent works adjacent to the rail boundary may be subjected to the influence of train loading and shall be assessed in accordance with the requirements in Section 9.1.1.

Allowance should be provided for minimum unplanned excavation in accordance with CIRIA C580 *Embedded Retaining Walls, Guidance for Design*, 2003.

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Any temporary components of shoring systems that are located such that their stability has the potential to affect the railway tunnel shall have a minimum service life of 10 years.

Shoring systems shall be designed by an approved design organisation and verified by an independent qualified person. A design report with independent verification certification shall be provided to TfNSW.

Engineering assessment shall be carried out for any temporary dewatering (at any stage of the development) to demonstrate that effects on rail tunnels are insignificant. No dewatering shall be commenced without the prior approval from TfNSW.

Appropriate crane loadings and crane foundation anchor loadings shall be taken into account in the assessment.

### 9.2.1. Stray current and electrolysis from rail operations

The potential effects of stray electrical currents and electrolysis in the electrified area of the rail network shall be considered in the design of the development in accordance with T HR CI 12080 ST and T HR EL 12002 GU. For further information on stray currents and electrolysis, refer to the ASA website.

TfNSW does not accept liability for the generation of dc stray currents and associated loss from an operating electrified railway.

When designing developments above or adjacent to rail tunnels consideration, including detailed risk assessment, shall be given to operational stray dc currents that will be present. A suitable test program shall be established early in the design phase to quantify a dc stray current signature for the development site before enabling works. Suitable dc current mitigation strategies shall be integrated into the design of the development. Following construction, dc stray current testing shall be carried out to verify that electrolysis mitigation strategies are proven to be effective including comparison to the pre development stray current signature. This information shall also be used to establish maintenance baselines for the life of the development.

### 9.2.2. Drainage

The developer shall carry out an engineering assessment of the impact of any changes to ground water regime, dewatering works, or installation of barriers to ground water flow that can dam ground water above the underground rail infrastructure. Detailed drainage plans and an impact assessment shall be submitted to TfNSW for review and approval.

During construction near rail tunnels, water collection on or adjacent to the tunnels that can affect the tunnel lining design assumptions shall be prevented. The developer shall ensure that any water proofing of the tunnels is not damaged.

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## 9.3. Excavation requirements

The excavation, retaining works and other ground disturbance works associated with the proposed development shall not affect the safety and operational integrity of the railway or cause the destabilisation of railway infrastructure.

Risks associated with excavations include slippage, slumping, creation of fissures or cracks, rock or earth falls, exacerbated ground movement, water inflows, cracking the lining and structural elements, and in extreme cases structural failure can occur.

Explosives shall not be used for the splitting and removal of rock or excavation.

### 9.3.1. Requirements before excavation begins

The developer shall submit the following for TfNSW's approval before any excavation begins:

- an engineering assessment by using numerical modelling that demonstrates that the excavation will not cause any adverse effect on the rail tunnel lining and associated infrastructure
- a detailed work method statement with hold points at various stages of excavation that are subject to review of satisfactory monitoring results
- a detailed monitoring plan for ground deformation, tunnel convergence, stress, crack width monitoring, vibration monitoring and reporting protocol for each party
- risk assessment and contingency plans

### 9.3.2. Requirements during excavation

Depending on the project complexity and potential impact on existing rail tunnel infrastructure, TfNSW can request the developer to engage a geotechnical consultant during the time of excavation process for visual verifications of substrata as perceived during investigation, geological mapping where required and an assessment of monitoring results.

The developer shall submit the monitoring results together with geotechnical consultant's assessments to TfNSW at agreed frequencies and stages of construction. A TfNSW nominated observer may be involved with the monitoring.

### 9.3.3. Requirements after excavation

Monitoring shall be continued until the superstructure is completed. With prior agreement with TfNSW, monitoring frequencies may be reduced when the basement construction is completed. Monitoring shall continue up to an agreed time limit after the completion of the construction activities. As guidance, monitoring can be terminated at a time where no changes occur in three consecutive monitoring cycles. TfNSW shall be informed before termination of the monitoring activities.

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## 9.4. Noise and vibration requirements

The effects of noise and vibration on TfNSW infrastructure and on the development shall be considered in the design and construction of developments near rail tunnels. The noise from construction and rail operation shall be assessed against statutory and project noise vibration limit requirements.

The proposed development is required to minimise the effects of noise and vibration on nearby structures and facilities. An acoustic and vibration assessment report including a vibration monitoring plan shall be prepared by a qualified person and submitted to TfNSW. This assessment shall cover acoustic and vibration levels arising from the proposed development during construction and its operation after completion (including any machinery causing heavy vibration levels), effects on the existing rail tunnels and train operations and vibration monitoring plan.

### 9.4.1. Effects of development on rail tunnels

Any development that occurs within a distance of 25 m horizontally from first reserve shall assess the vibration on the rail tunnels. The assessment criteria shall be a maximum peak particle velocity (PPV) of 15 mm/s at the tunnel lining for brick or mass concrete in good condition or a maximum PPV of 20 mm/s at the tunnel lining for cast iron, steel or concrete segment lining.

### 9.4.2. Construction vibration monitoring

During construction, vibration monitoring of works at the tunnel lining shall be conducted with appropriate trigger levels.

If the vibration levels exceed the tolerable limits, then the developer shall modify the construction methodology in such a way that the vibration limits are satisfied.

### 9.4.3. Impacts of rail tunnels on adjacent developments

TfNSW does not accept liability for the generation of noise and vibration from normal railway operations (including track maintenance), or for its transmission into developments above or adjacent to rail tunnels.

When designing developments above or adjacent to rail tunnels, consideration shall be given to operational vibration and ground or structure-borne noise emissions in accordance with *Developments Near Rail Corridors and Busy Roads - Interim Guideline, Department of Planning, NSW Government 2008*.

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## 9.5. Monitoring plan

A monitoring plan shall be developed and submitted to TfNSW for review and agreement before the construction begins.

For the safety of the tunnels and rail infrastructure, the tunnel and tunnel structure performance shall be monitored during construction and to verify the predicted displacements, stress levels in structural elements and vibration levels. The developer shall implement a comprehensive monitoring system that incorporates early warning criteria developed in agreement with TfNSW. The developer's geotechnical consultant shall assess the monitoring results continually, and submit monitoring assessment reports for TfNSW's review.

The monitoring requirements in this section are equally applicable for developments near or underneath existing dive structures, see Table 8, Table 9 and Figure 9.

**Table 8 - Minimum monitoring requirement for development activities near rail tunnels - In-ground**

| Type of instrument | Deep open excavations | Foundation works – shallow or deep | New underground excavation or new tunnel |
|---|---|---|---|
| Inclinometer | Yes | Yes | Yes |
| Water standpipe | If required by TfNSW | If required by TfNSW | If required by TfNSW |
| Piezometer | Yes | Yes | Yes |
| Extensometer | Yes | If required by TfNSW | Yes |
| Ground settlement markers | Yes | Yes | Yes |
| Building settlement markers | Yes | Yes | Yes |

**Table 9 - Minimum monitoring requirement for development activities near rail tunnels - Within existing rail tunnels**

| Type of instrument | Deep open excavations | Foundation works – shallow or deep | New underground excavation or new tunnel |
|---|---|---|---|
| Tunnel convergence | Yes | Yes | Yes |
| Tiltmeter | Yes | If required by TfNSW | Yes |
| Crack meter | Yes | Yes | Yes |
| Vibration sensor | Yes | Yes | Yes |
| Rail track monitoring (distortion) | Yes | If required by TfNSW | Yes |
| Strain gauges in lining | If required by TfNSW | If required by TfNSW | If required by TfNSW |
| Pressure cells in lining | If required by TfNSW | If required by TfNSW | If required by TfNSW |

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| Type of instrument | Deep open excavations | Foundation works – shallow or deep | New underground excavation or new tunnel |
|---|---|---|---|
| Real time monitoring such as EL beams, optical prism laser scanning | If required by TfNSW | If required by TfNSW | If required by TfNSW |

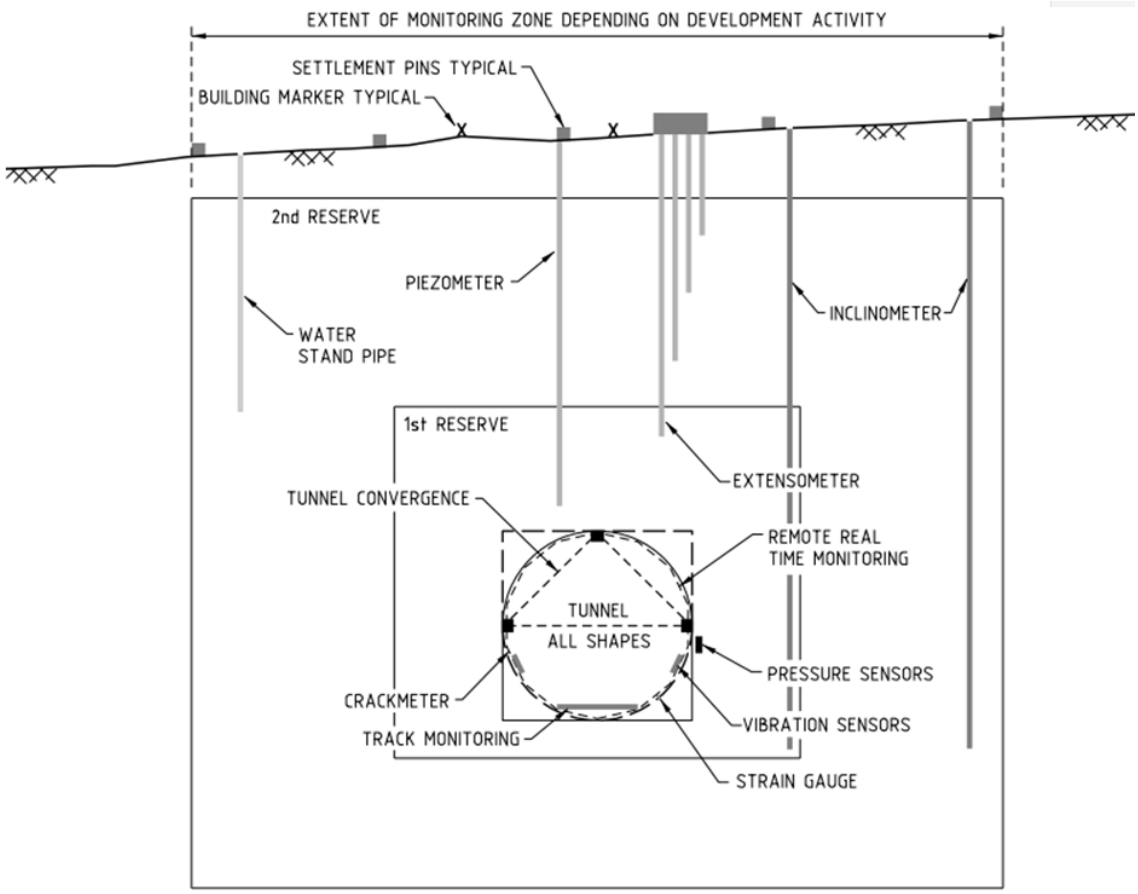


**Figure 9 - Typical instrumentation layout**

The baseline data for each monitoring parameter shall be established before the construction work begins. The developer shall provide as a minimum, three sets of monitoring data as the baseline before excavation.

The equipment that is used for remote monitoring particularly for alarm or warning systems shall have proven reliability in similar applications.

Any alarm or warning system should have a visual and audible alarm system to activate and to stop all works as necessary and notify relevant personnel such as site manager, geotechnical consultant and nominated TfNSW representative.

Depending on the project complexity, physical inspections of the existing tunnel may be required by the developer accompanied by a TfNSW representative on a regular basis during critical stages of construction.

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Depending on the project complexity, TfNSW can request the developer to provide independent verification of the monitoring results.

For monitoring, a response regime and contingency plan shall be agreed between the developer and TfNSW before work begins.

### 9.5.1. Trigger levels

Trigger levels of key monitoring parameters for an alarm or warning system are generally set as follows:

1. based on the impact assessment of the movements, deformations and stresses
2. based on the potential damage to tunnel and associated infrastructure
3. based on project specific requirements
4. based on the operational risk

Trigger levels shall be established by the developer based on these criteria and agreed between the developer and relevant stakeholders including TfNSW prior to commencement of any works.

# 10. Construction requirements

All rail property shall be fully protected during construction and all site work including clearances to tracks and to protection reserves shall comply with this standard and other relevant TfNSW standards pertaining to air space developments, external developments and tunnels, and safe working requirements.

All construction carried out on railway property shall comply with the requirement of the relevant authorities and legislation including workplace health and safety (WHS) requirements and environmental requirements.

## 10.1. Dilapidation survey

Before works begin and the issue of an occupation certificate, joint inspections of the rail tunnel and infrastructure near the proposed development shall be carried out by representatives of the developer and TfNSW. The existing condition of the rail infrastructure shall be agreed and recorded. This inspection shall establish the extent of any existing cracks in the tunnel linings and tunnel floor, have them suitably marked and identified to enable any deterioration in the lining and floor during and after the construction to be monitored.

The length of tunnel and assets to be surveyed shall be determined by TfNSW.

Additional joint inspections may be required during the construction.

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Dilapidation surveys shall be performed during planning stages and submitted as part of the development application. The existing condition of the rail tunnel lining and structures shall be considered in the risk assessment of the tunnel lining and structures.

The dilapidation survey report shall be submitted during the planning stage for tunnels constructed before 30 years from the date of the development application. For tunnels constructed within 30 years, the dilapidation survey report shall be submitted during the design stage.

Detailed dilapidation reports shall be submitted to TfNSW describing conditions before commencement of works and after completion of works.

The dilapidation report shall include the following as a minimum:

- details of defects
- dimensions of cracks
- photos of the defects with labels showing locations
- signs of wetness, staining and seepage on the defects

## 10.2. Risk assessment

A detailed rail related risk assessment report and safe work method statements shall be submitted by the developer to TfNSW as safety assurance evidence prior to commencing any works on site.

The developer has a legal duty to eliminate risks to safe rail operations SFAIRP. As such the developer shall identify all reasonably foreseeable safety risks and hazards to the railway or its operations and eliminate these risks where reasonably practicable and where it does not minimise each risk SFAIRP. The identified risks and their SFAIRP demonstration shall be documented in a manner that can be provided as assurance evidence to TfNSW.
T MU MD 20001 ST *System Safety Standard for New or Altered Assets* describes the assurance for changes impacting rail or transport assets.

The rail related risk assessment report shall be prepared in accordance with the safety management system of TfNSW and shall address the following:

- all risk are managed SFAIRP
- an identification of hazards and risks to the development and rail facilities including tunnels and support elements, and other infrastructure
- the risk identification process shall cover the entire asset life cycle of the rail tunnel
- a risk ranking in accordance with the TfNSW risk criteria. Refer T MU MD 20002 ST *Risk Criteria for Use by Organisations Providing Engineering Services.*

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- controls showing the management of risk to rail infrastructure. This may include early warning criteria for monitoring

The safe work method statements shall detail the following:

- detailed work methods including the incorporation of the controls as stated in the risk assessment plan
- an emergency response plan

## 10.3. Demolition works and construction impacts

The demolition of any existing buildings or basements shall be planned in such a way that there is no risk to rail tunnels and associated structures. The developer shall be required to take every possible action to minimise the risk and is required to meet the costs of any protection of the rail infrastructure and disruption to rail operations.

The impact of any proposed underground demolition work including de-stressing, unloading and resulting ground vibrations shall be assessed to ensure that there are no adverse effects on rail tunnels and associated structures. If large-scale demolition works are involved, then the developer shall be required to install a vibration monitoring system to monitor vibration levels near adjacent rail infrastructure.

Hydraulic rock breakers shall not be used within five metres of any railway tunnel. The developer shall be required to arrange a structural investigation by appropriately qualified person to address the impacts.

Refer to T HR CI 12075 ST for further details.

## 10.4. Piling and excavation works

The following requirements shall be adhered to during piling and excavation work:

- The tunnel position (outer walls) and protection reserves shall be marked clearly on the ground for easy identification.
- All piling contractors shall be made aware of the existing tunnel adjacent to construction site.
- TfNSW shall be informed on the progress of piling and excavation works on a daily basis.
- Field monitoring results during excavation or piling works, assessed by the developer's geotechnical consultant shall be reported to TfNSW at an agreed frequency.

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# 11. Documentation requirements

The development applications (DA) are sent to a consent authority (normally, the council of the local government authority) for review and approvals. The consent authority reviews the DA and sends it to TfNSW if the application falls within the scope of SEPP 2007 criteria. The developer shall submit the minimum required documents to TfNSW during planning, design, construction and operation stages of the development. The list of documents to be submitted by the developer, as a minimum, to TfNSW is provided in Section 11.1 through to Section 11.5.

The requirements stipulated in Section 8 apply to engineering assessment and associated documentation.

TfNSW shall request further information depending on the risk profile of the development.

## 11.1. Planning stage or pre-lodgement stage

The developer shall submit the following documents during the planning stage or pre-lodgement of DA stage for preliminary comment or discussion purposes based on the development concept:

- location of site layout
- existing easements on land and for the rail tunnel
- architectural layout showing general arrangement of development
- plans and drawings of existing rail infrastructure obtained from TfNSW showing rail protection reserve boundaries based on this standard
- section view and plan view of the proposed development and rail protection reserves
- site investigation plans if it involves drilling within rail protection reserves

## 11.2. Development application or concurrence stage

The developer shall submit the following documents to TfNSW during the development application or concurrence stage:

- legal boundary alignment along the length of proposed site identified by a NSW registered surveyor
- drawings showing the development in relation to the rail tunnel and associated rail infrastructure in plan, elevation view and sectional view with dimensions and reduced levels
- easements (including right of ways) or stratums, covenants and caveats identified by a NSW registered surveyor, specifying the purpose of the easement and in favour of whom

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- location of any railway tunnel and its dimensions, relative distances and reduced levels to the proposed excavation face, and levels of foundations
- geotechnical investigation report with details in accordance with Section 8.3.1of this standard
- detailed impact assessment report with details in accordance with Section 8.3.2 of this standard
- detailed risk assessment report in accordance with Section 8.3.3 of this standard
- detailed dilapidation survey report in accordance with Section 10.1 of this standard
- monitoring plan including trigger levels, action plans and remedial measures

## 11.3. Prior to construction

The following documents shall be submitted prior to commencement of construction:

- detailed monitoring plan including trigger levels, action plans and remedial measures, details of the instrumentation and baseline monitoring readings (refer to Section 9.5)
- construction schedule, construction management plan including sequence plan identifying impacts
- construction layout of equipment relative to tunnels
- final detailed work method statement (refer to Section 9.3)
- temporary safety plans and measures
- temporary works plan, temporary access, vehicle, plant and equipment such as crane (including mobile cranes), stockpiling and so on
- noise and vibration studies and control measures
- stray dc current signature report including control measures (refer to Section 9.2.1)
- a rail related risk assessment and management plan
- list of machinery to be used
- groundwater control plans, environmental aspects including contamination
- design loadings and certified drawings for construction related works that affect tunnels
- agreed interface activities plan with TfNSW
- condition and dilapidation survey report of all tunnels and associated infrastructure affected by the development (refer to Section 10.1)

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## 11.4. During construction

The following documentation shall be submitted to TfNSW at agreed intervals by the developer, during the construction phase:

- monitoring report at agreed intervals, which includes monitoring results and assessment by the developer's geotechnical or structural consultant
- notification of work progress at agreed intervals, which is applicable during excavations, foundations and support installations, and superstructure construction up to the ground level
- interim dilapidation survey report as appropriate
- any change to design and construction methods for concurrence by TfNSW
- rock face mapping, inspection and assessment report (refer to Section 9.3.2)

## 11.5. After construction completion and prior to issue of occupation certificate

The following documentation shall be submitted to TfNSW by the developer, after completion of the construction:

- one set of as-built structural and foundation plans signed by qualified person
- one set of as-built drawings for ground anchors and other support details near the tunnels
- monitoring summary report
- copy of the geotechnical mapping report carried out during the excavation for basement
- dilapidation survey report conducted after construction completion (refer to Section 10.1)
- structural safety report
- operational safety report
- dc current mitigation verification report including maintenance base line measurements referenced to measurement locations (refer to Section 9.2.1)

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# Appendix A Sydney rail tunnels

This appendix provides general information on the following rail tunnels that are primarily covered in this standard:

a. City Circle Line (CCL) tunnels

b. Eastern Suburb Rail (ESR) tunnels

c. Airport line tunnel

These tunnels comprise different constructions, shapes, structural concepts and loading actions. The developer can request the location specific tunnel details from TfNSW.

## A.1. City underground rail system

The city underground rail system includes City Circle Line (CCL) tunnels and Eastern Suburb Railway (ESR) tunnels from Erskineville to Bondi junction through Central.

These city tunnels are protected by a registered easement and stratums.

### A.1.1 City Circle Line tunnels

The City Circle Line (CCL) tunnels are the oldest tunnels, completed in 1932 with the opening of the Sydney Harbour Bridge that connected the North Shore with trains terminating at Wynyard. It was not until 1956 that the Circular Quay station was constructed which completed the CCL tunnel system (see Figure 10).

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**Figure 10 - Schematic of City Circle Line (CCL)**

There are four tunnels starting at Goulburn Street that go as far as Wynyard station. They are named as Up Shore, Down Shore, City Inner and City Outer tunnels. An additional two tunnels were constructed at the lower level to service a Western Suburbs Line and are now utilised as part of the ESR system. From Wynyard station, two tunnels continue up to the Western side of the Sydney Harbour Bridge and the outer two tunnels complete the loop back to Goulburn Street through Circular Quay station, St. James station and Museum station.

These tunnels are either flat top or arch shaped tunnels.

The flat top tunnels occur between Goulburn Street and Town Hall Station. There are also short sections of these tunnels to Museum near Goulburn Street portal and North and South of Wynyard station. The typical support detail of such tunnels consists of brick wall, broad flange roof beam with concrete fill. Waterproofing membranes may be present around the tunnel lining.

Tunnel construction details can be obtained from TfNSW.

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## A.1.2 Eastern Suburbs Railway tunnels

The Eastern Suburbs Railway (ESR) tunnels from central Station to Bondi Junction were completed in 1976. It is also known in part as Illawarra Relief (Central to Erskineville) and Southern Suburbs Railway (platforms at Central Station and Redfern Station).

These tunnels are twin horseshoe arch shaped constructed using the drill and blast method or cut and cover method (box tunnel section between Erskineville to Redfern). Figure 11 shows the schematic of the ESR tunnels.

These tunnels are constructed in sandstone rock. The conventional drilling and blasting methods using top and bottom headings were adopted for the section from Central to the Domain portal and Kings Cross. A 179 tonne 'mole' was used to tunnel the section from Edgecliff to Bondi Junction and a roadheader was used to excavate the lower section of the tunnel to form the conventional horseshoe shaped tunnel. The tunnels are completely lined with concrete of 200 mm thick unreinforced to 600 mm thick reinforced for special areas such as portals, crossovers and localised areas of bad rock.

Rock bolting was also carried out in the area where the ground conditions were unstable and the height of easement above the tunnel was in excess of 3 m.

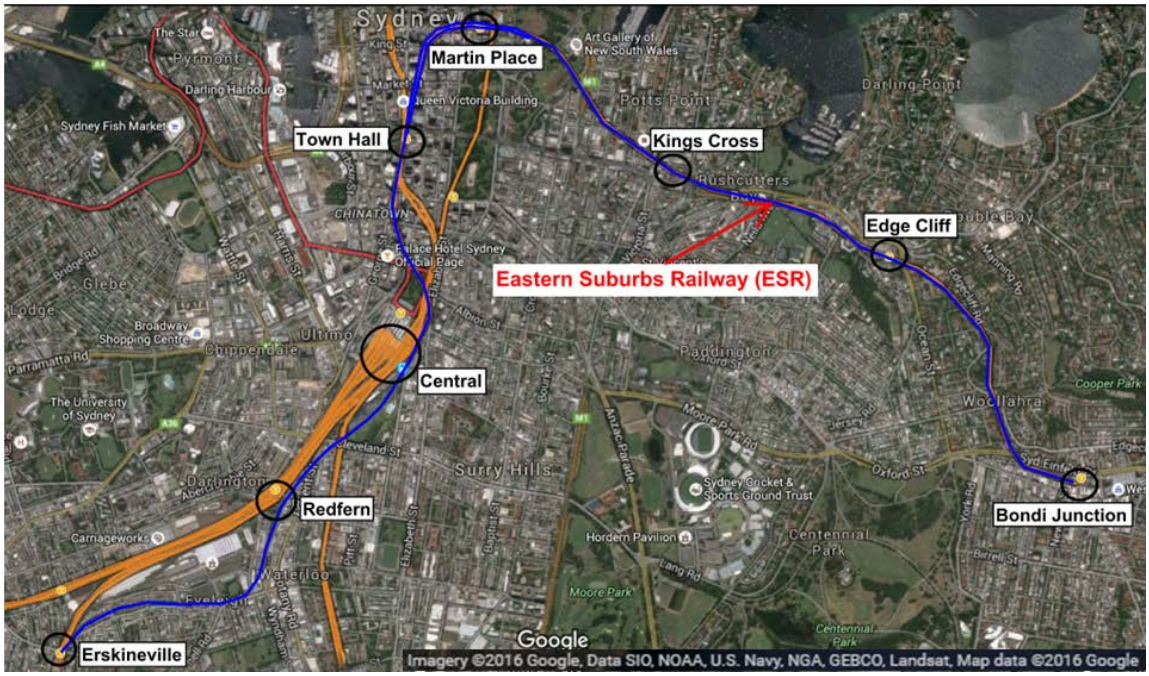


**Figure 11 - Schematic of ESR**

# A.2. Airport Line

The Airport Line (APL) is an underground railway running from Central station to the East Hills rail line near Turrella. This line is approximately 10 km in length and was completed in 2000. The single tube, double track tunnel was constructed through soft ground using tunnel boring machines (TBMs) and through hard rock using roadheaders except for a cut and cover section.

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The cut and cover section at Prince Alfred Park consists of structural slab supported by piles and shotcrete arch between piles that supports either shale or stiff clay. The rock tunnel section was constructed in a variety of ground conditions with varying ground cover. The hard rock tunnel has a permanent concrete arch with shotcrete walls and flexible waterproofing membrane.

The soft ground tunnel is constructed as a circular bored tunnel supported by precast segments. There are eight 450 mm thick segments forming each circular ring.

The APL tunnel is protected by an easement and stratums except for the corridor within Sydney Airport station and at Green Square station.

Refer to the following documents for APL tunnel design and construction details:

- *Airport Line Tunnel Protection Guidelines - Guidelines for Development Within the Vicinity of the Airport Line, Part A: Planning and Design Matters, Part B: Technical Matters*, Rail Access Corporation, Rev A, August 2000
- Nye E. J, 1999, *The Soft Ground Tunnel Under Sydney Airport, Tenth Australasian Tunnelling Conference*, Melbourne - page 75 to page 83

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Figure 12 shows the alignment of APL.

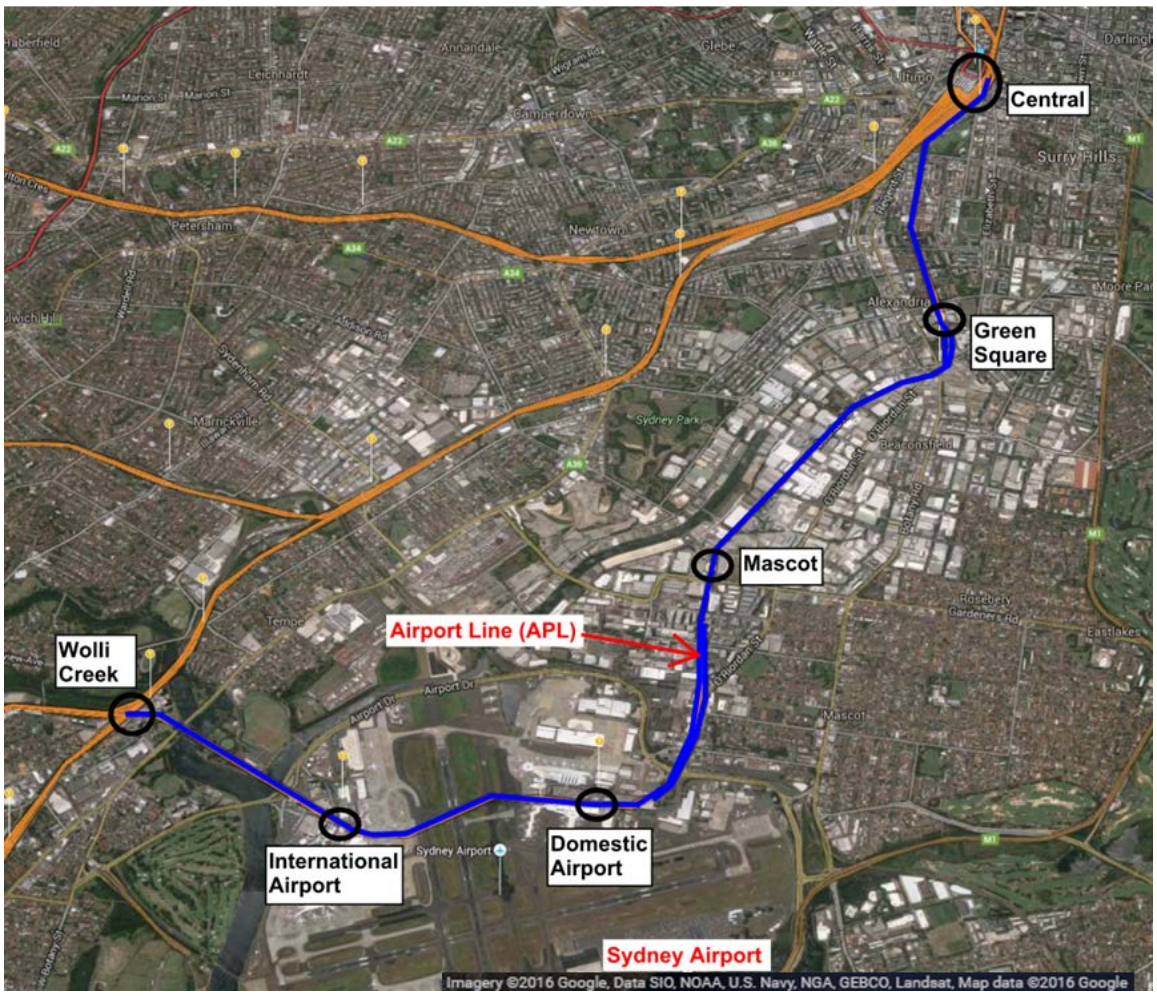


**Figure 12 - Schematic of APL**

# A.3. Rail tunnel details

The Sydney underground rail system tunnels were excavated through hard rock and soft rock, and soft ground, at shallow depths. These tunnels were constructed using mined tunnel techniques, cut and cover method, and bored tunnel method using TBM. Depending on the ground condition, these tunnels were supported using the following support:

- Active support - Active support means the crown of the tunnel opening is supported by the rock above. To provide an intact rock beam above the tunnel opening, the rock beddings and joints are reinforced with permanent rock bolts and shotcrete. A stress arch forms within the rock beam when it deflects.
- Passive support - Passive support means that the ground around the tunnel opening is supported by a thick lining built around the tunnel opening. Passive support can be precast segmental lining, brick arch lining, cast-in situ concrete lining, or a thick shotcrete lining with or without steel sets or lattice girders.

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Figure 13 shows all possible tunnel construction methods and tunnel support systems in varying ground conditions. This chart provides a guideline for tunnel construction details and support systems adopted for Sydney rail tunnels such as CCL, ESR, APL and ECRL.

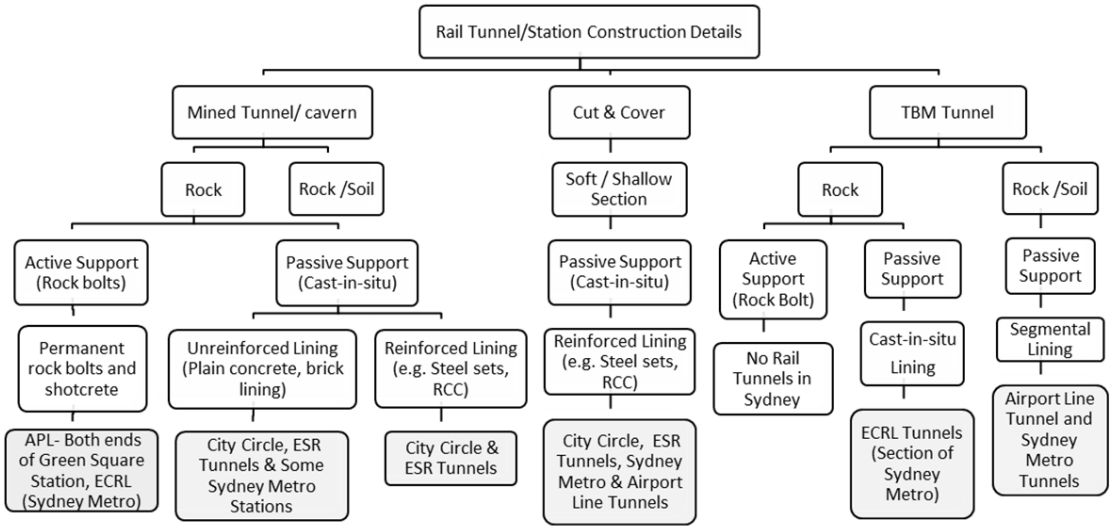


**Figure 13 – Construction details and ground conditions for Sydney tunnels**

These details should be confirmed from project specific construction details at the location of the planned development. Available information such as as-built details of support system and encountered ground conditions can be obtained from TfNSW.

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