Building around existing tunnels

Seminar

Risk Assessment for Development Adjacent to Underground Rail Corridors

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ENGINEERS AUSTRALIA | AUSTRALIAN TUNNELLING SOCIETY 50 years 1972 - 2022 | AUSTRALIAN GEOMECHANICS SOCIETY

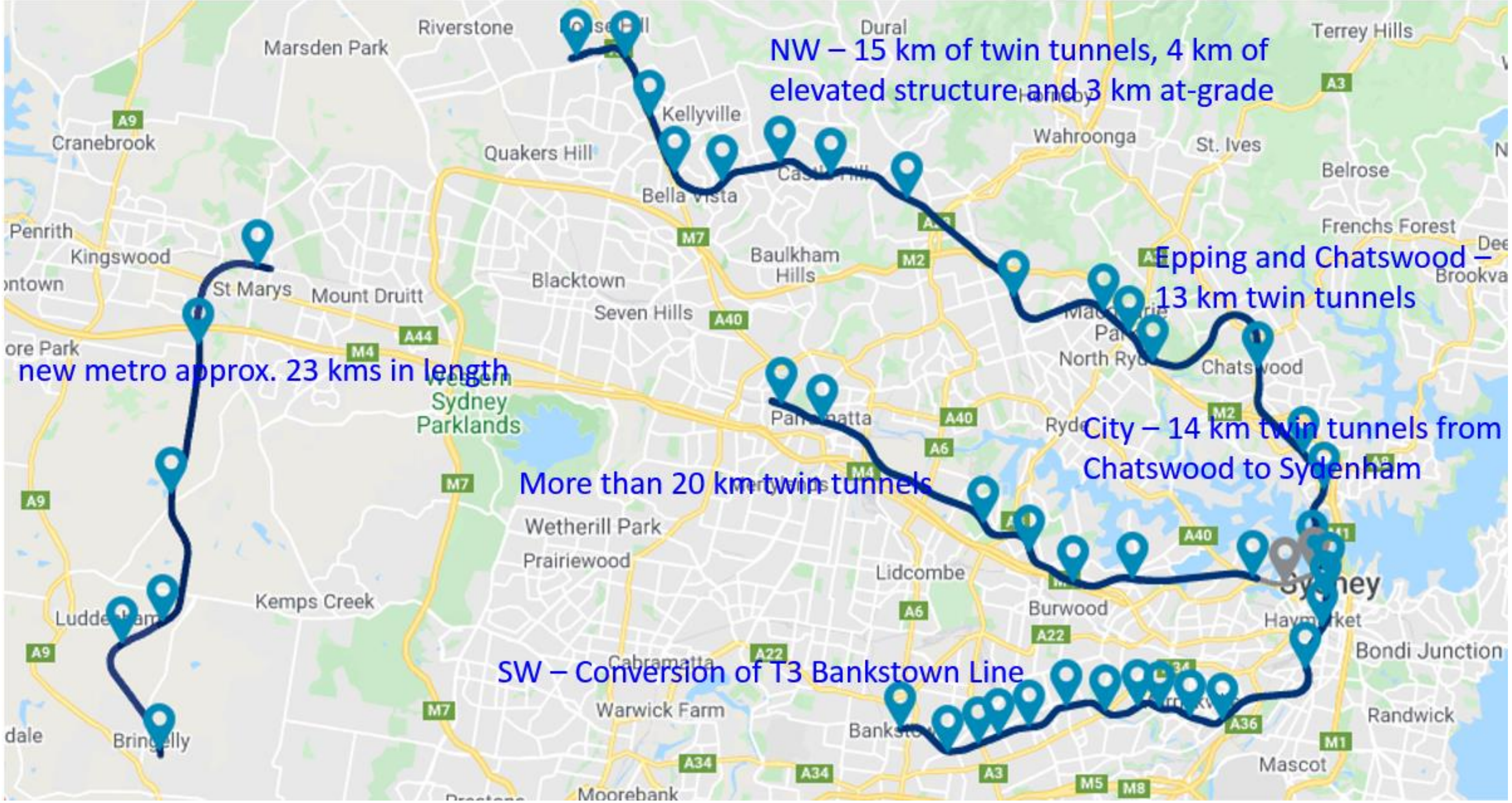
Overview

- Sydney Underground Rail Lines
- Development Site & Rail Corridors
- Engineering Impact Assessment
- Case Studies
  - Adjacent to station shaft & cavern
  - Adjacent to both station cavern and aged running tunnels
- Summary

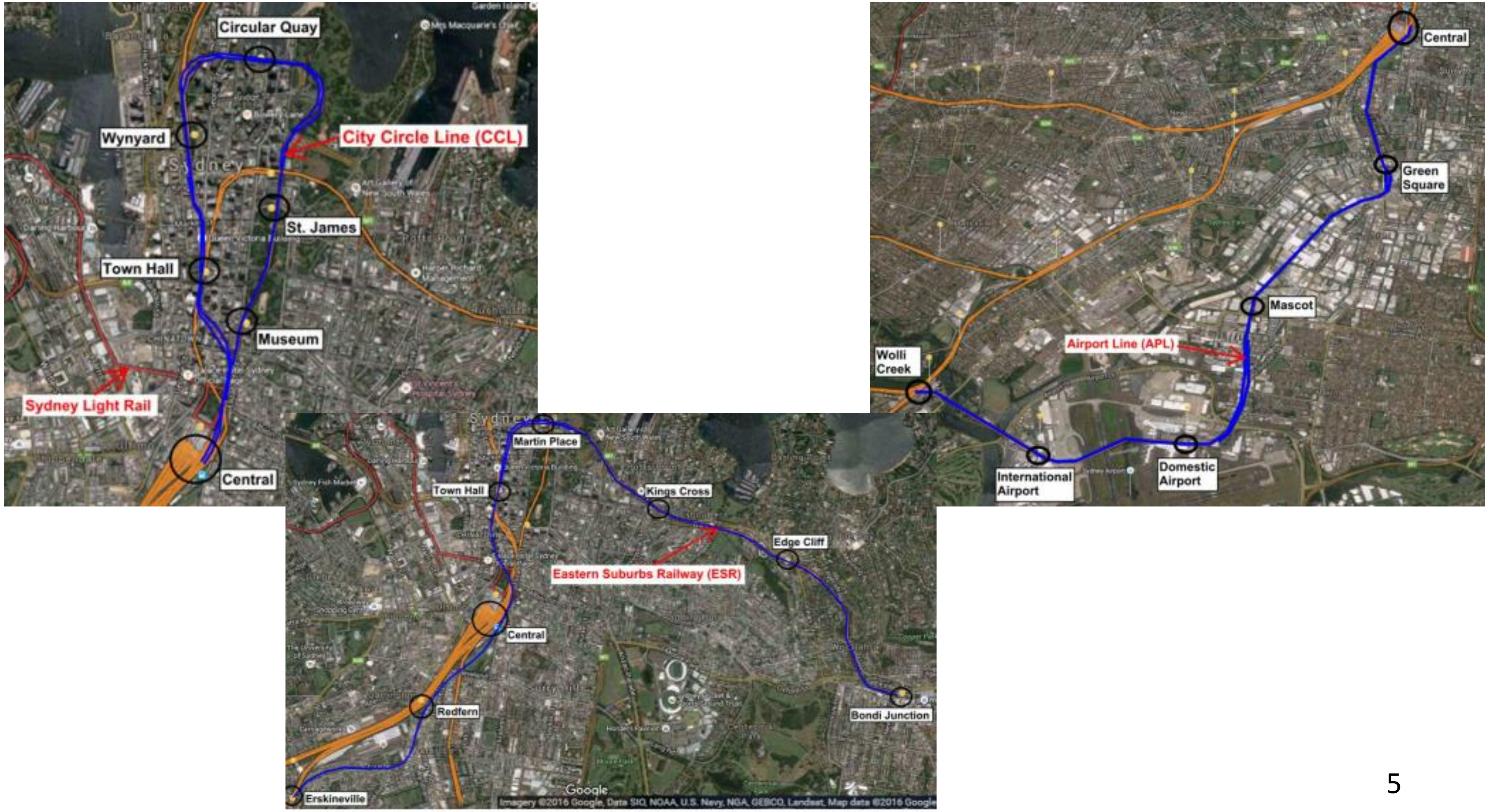
Sydney Underground Rail Lines

- Sydney Metro
- Sydney Trains
- Future Rail Corridors

Sydney Underground Rail Lines – Sydney Metro



Sydney Underground Rail Lines – Sydney Trains



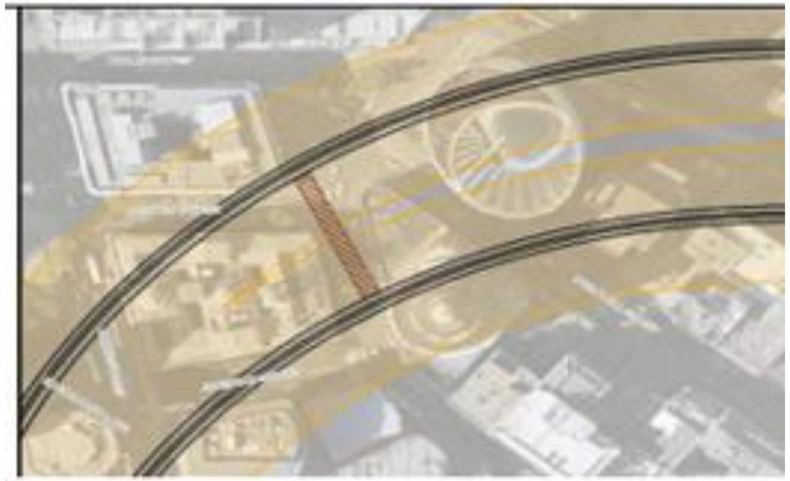
Sydney Planned Rail Lines

Development Site & Rail Corridors

– Identify rail corridor
– Rail authorities & corresponding guidelines
– Protection reserves
– Load limitations

Development Site & Rail Corridors
- Identify rail corridor

- Identify the rail corridor through
  - Dial Before Your Dig service
  - Local knowledge of railway networks
  - Contact rail authorities



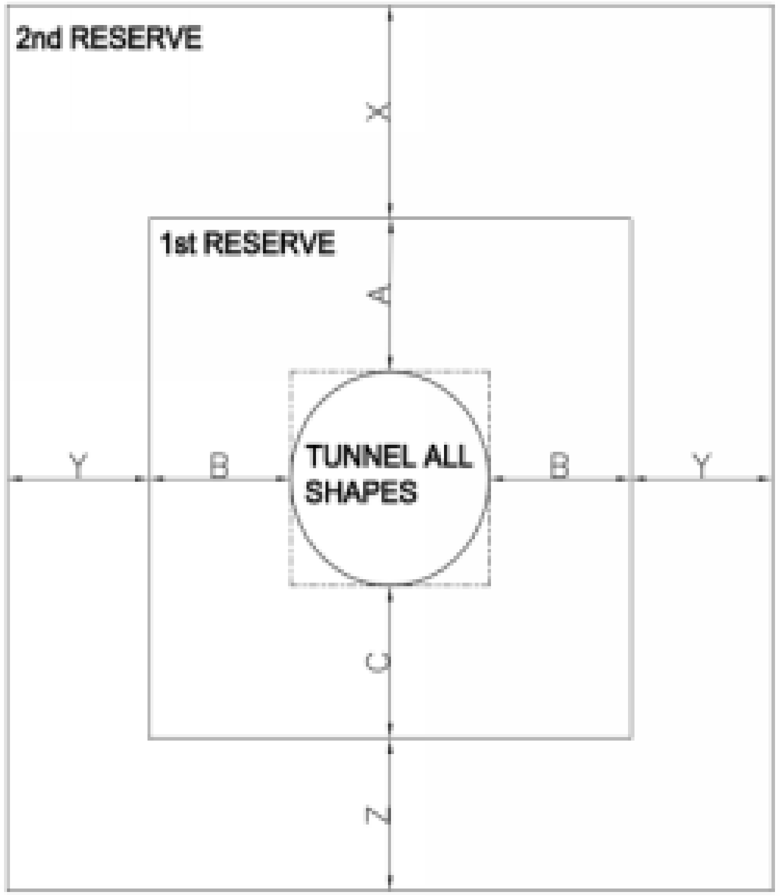
Sydney Metro City & SW

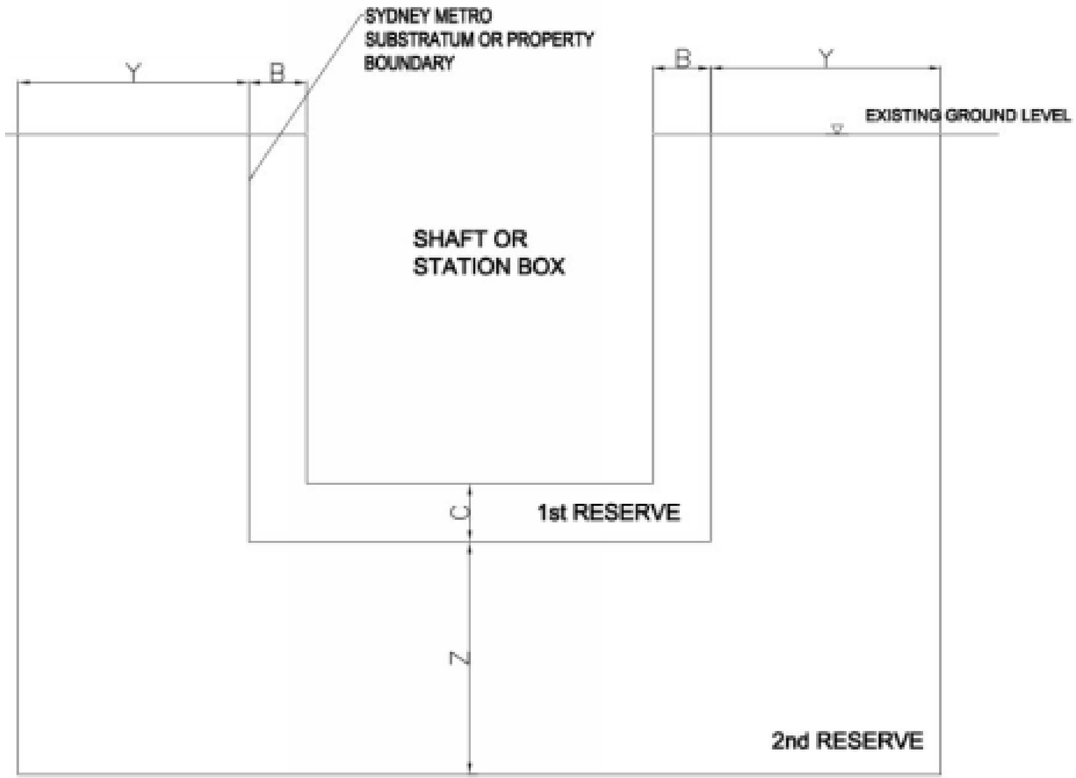
Sydney Trains' City Circle Line

Development Site & Rail Corridors
- rail authorities & corresponding guidelines

- Sydney Trains
  ASA T HR CI 12051 ST "Development Near Rail Tunnels" V2.0 , published in November 2018
- Sydney Metro
  "Sydney Metro Underground Corridor Protection - Technical Guidelines" Rev 2.0, published in April 2021.
- Transport for New South Wales - for future rail corridors
  CBD Metro (2010), CBD Rail Link & Parramatta to Epping Rail Link etc.

Development Site & Rail Corridors
- Protection reserves

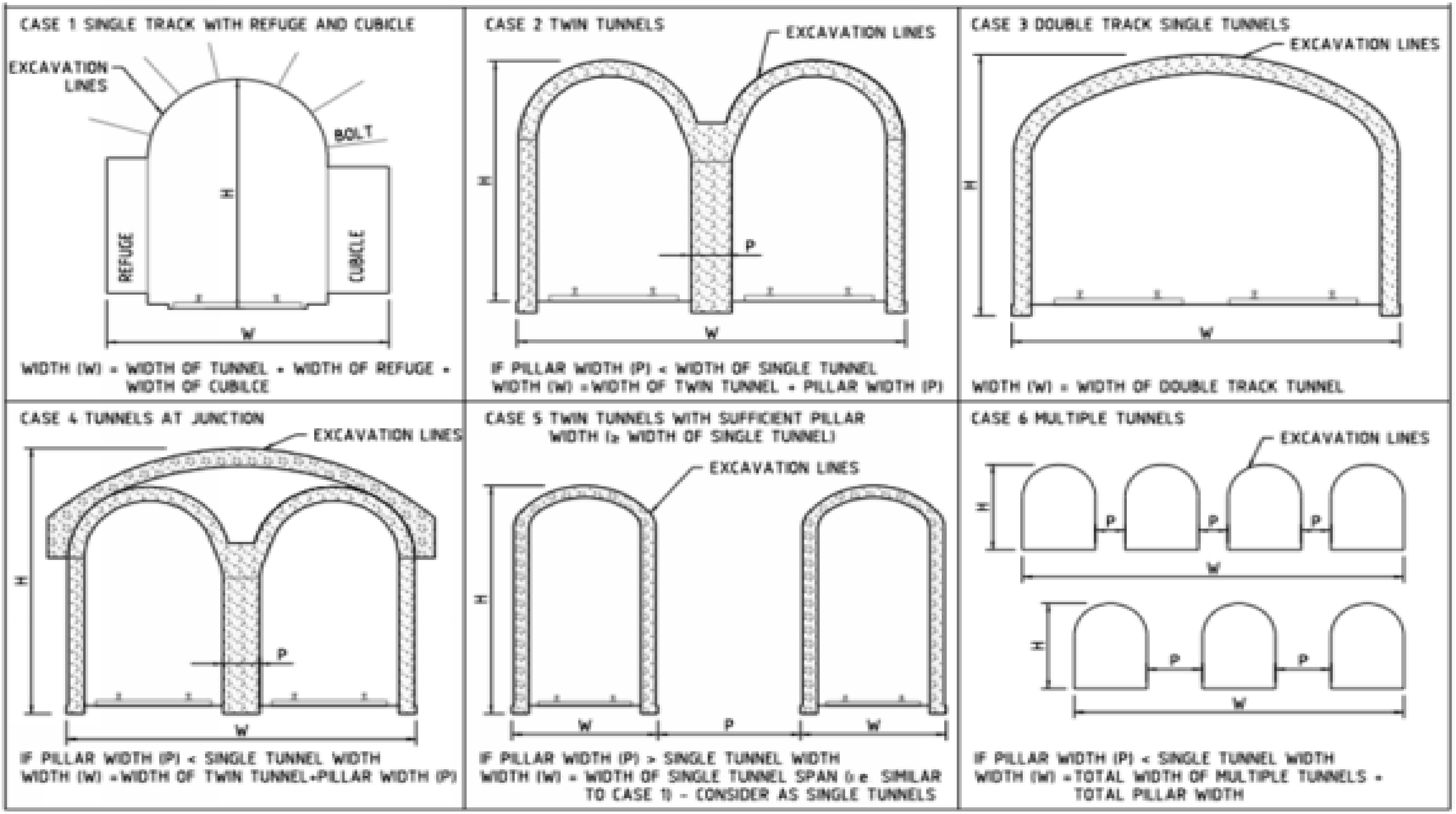




Development Site & Rail Corridors

- Protection reserves

Definition for tunnel width (ASA T HR CI 12051 ST)



Development Site & Rail Corridors - Special load limits

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

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
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

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.

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.
Loading limit - soft ground tunnel	Foundation loads shall be transferred past the tunnel when the applied pressure on the tunnel lining would exceed 10 kPa. 10 m minimum cover over tunnel to retain stability of the segmental concrete lining and to counter buoyancy effects. 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.

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Engineering Impact Assessment

The assessment should ensure the following:

- No adverse impacts arising from the proposed development on existing rail infrastructure
- The development has considered the potential impacts of existing rail lines' operation after completion/operation of the development

Engineering Impact Assessment

The assessment general includes the following:

- Geotechnical Site Investigation
- Geotechnical Assessment – Numerical Modelling

Engineering Impact Assessment
- Key technical documents

- Geotechnical Site Investigation
  - Geological profiles extend below invert level of rail tunnels
  - Geological structures within/adjacent to the site if present
  - Typical geological sections
  - Recommendation of foundation design and methods of shoring and excavation
  - In-situ stresses regime
  - Groundwater
  - Recommended geotechnical parameters
- Geotechnical Assessment/Numerical Modelling
  - Rail structures: tunnel geometry, current conditions (through dilapidation survey), support types etc.
  - Foundations (depths/dimensions) adjacent to rail tunnels and corresponding loads
  - Shoring systems including ground anchors if proposed
  - Construction sequences including unloading and loading

Key technical documents

- Survey – 1st & 2nd reserves
- Structure report/drawings (shoring, foundations)
- Geotechnical investigation report
- Engineering impact assessment
- Risk assessment report
- Acoustic report
- Electrolysis report
- Safe Work Method Statement
- Instrumentation and monitoring plan

Case Studies

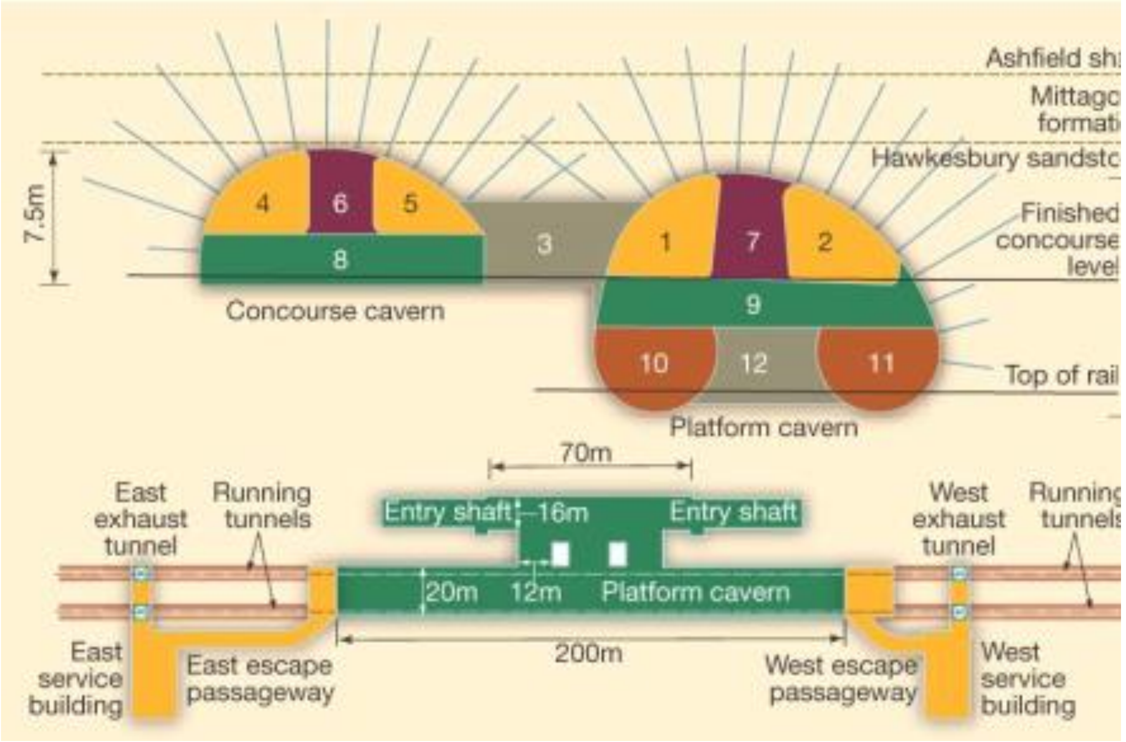
- 396 Lane Cove Road, Macquarie Park: Development adjacent to station entry shaft and station cavern
- Sixty Martin Place, Sydney: Development adjacent to existing station cavern and aged rail tunnels

396 Lane Cove Road, Macquarie Park

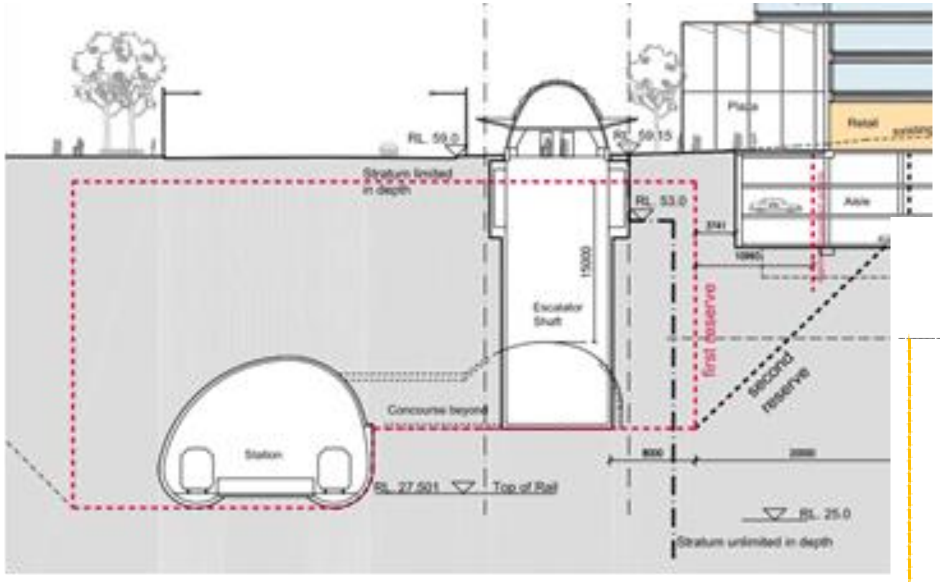
- Four (4) multi storey buildings
- 3 to 4 levels of basement excavation
- The tallest building (Building A)
  - 17 storeys
  - 3 levels of basement
  - adjacent to the Macquarie Park Station

396 Lane Cove Road, Macquarie Park

- 14m high & 20m wide main platform cavern
- approximately 30m deep, 200m long
- 70m long, 16m wide, 7.5m high arched concourse cavern
- escalator shafts at either end of the concourse

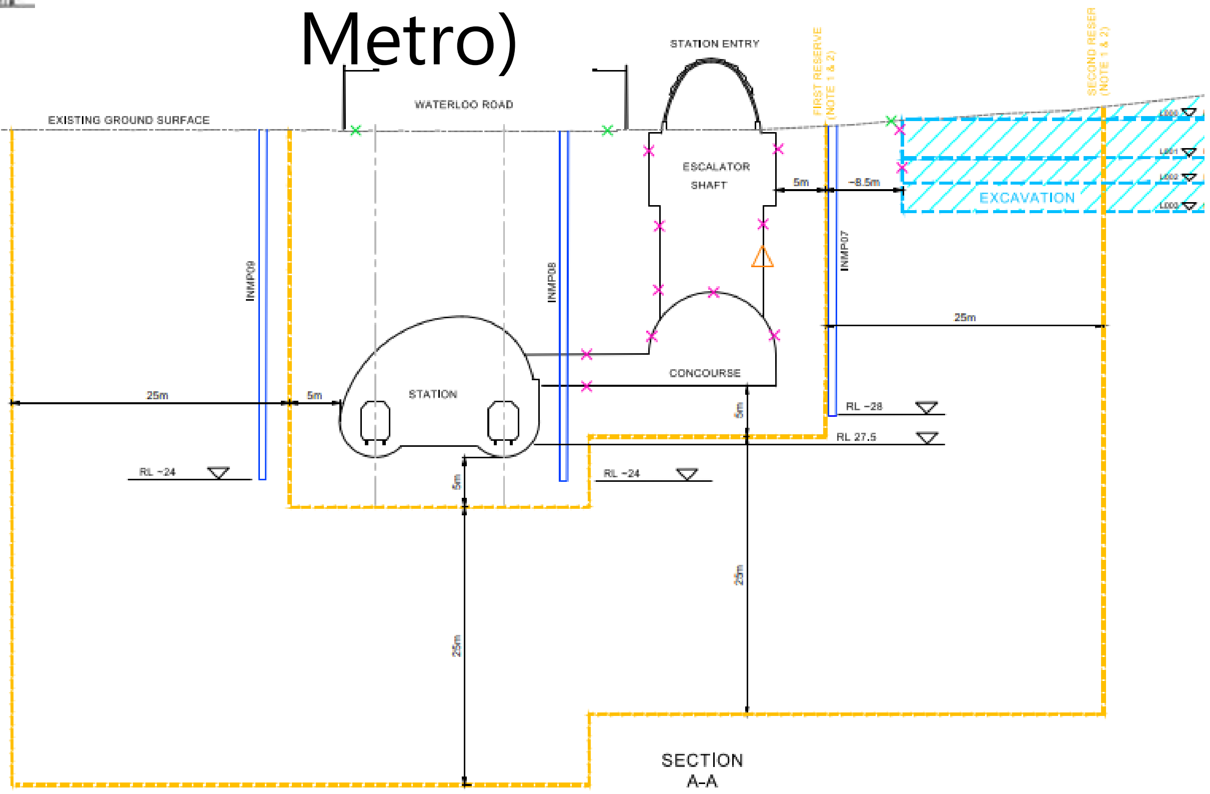


396 Lane Cove Road, Macquarie Park



Protection reserves (TIDC 2008)

Protection reserves (Sydney Metro)



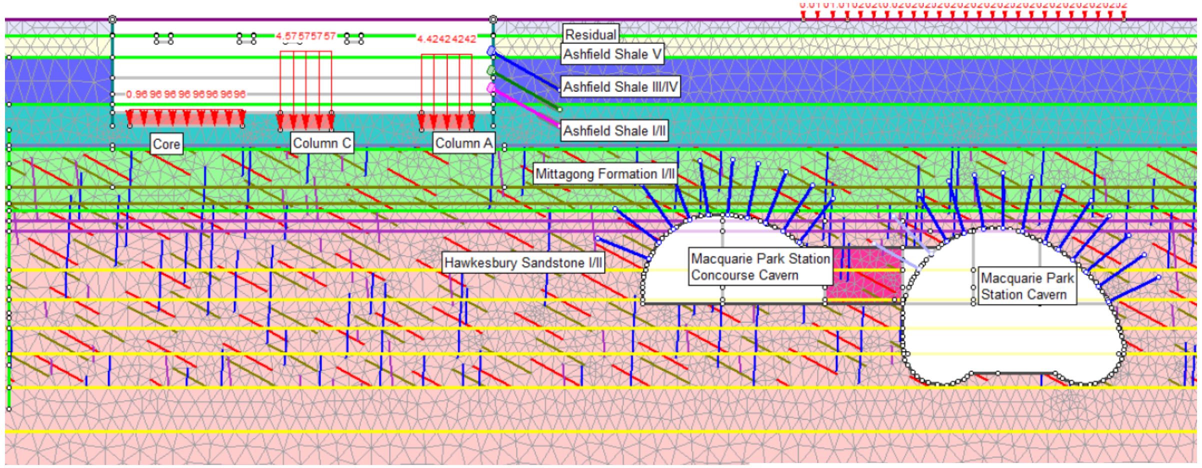
396 Lane Cove Road, Macquarie Park

- Site Geology
  - Fill / Residual (RL 58 m to RL 54 m)
  - Ashfield V, III/IV & I/II (RL 54 m to RL 46 m)
  - Mittagong Formation I/II (RL 46 m to RL 42 m)
  - Hawkesbury Sandstone I/II (below RL 42 m)
- In-situ Stresses
  - Upper bound: $\sigma_{H\,(NS)} = 1.0\text{MPa} + 4.5\,\sigma_v$; $\sigma_H / \sigma_{h(WE)} = 1.5$
  - Lower bound: $\sigma_V = \sigma_H = \sigma_{h(WE)} = 1.0$

396 Lane Cove Road, Macquarie Park

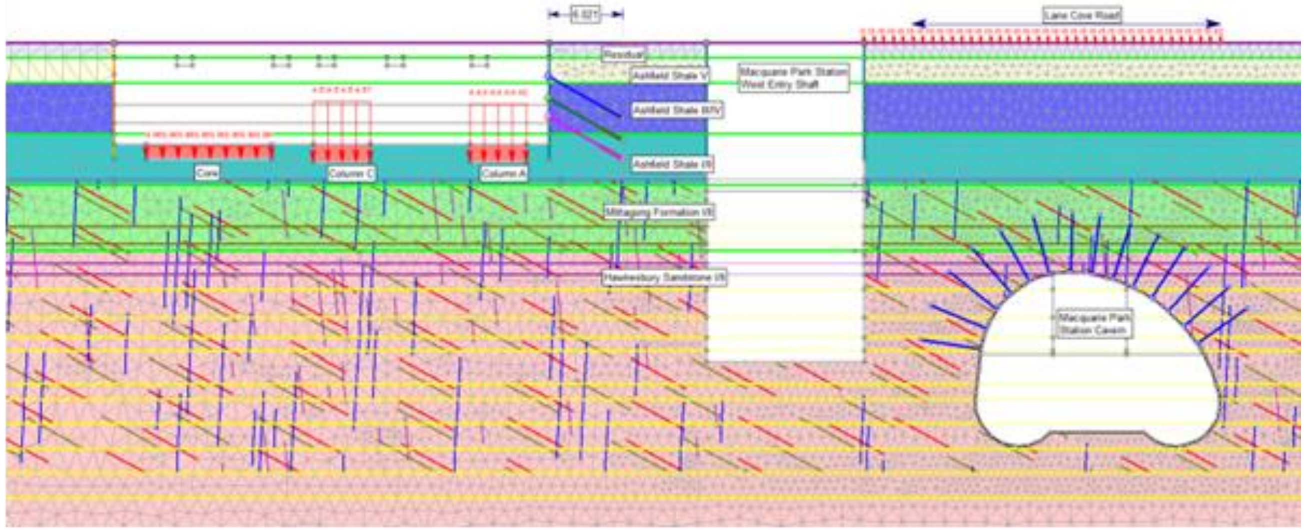
- Key considerations to protect rail assets
  - Minimise changes in integrity of surrounding rocks during basement excavation
  - Temporary ground anchors were not permitted to encroach into protection zone
  - Potential high horizontal displacement along horizontal beddings due to high horizontal in-situ stresses
  - Potential high horizontal movement across discontinuities within the rockmass which could damage the integrity of the permanent rock bolts
  - Building foundation design to ensure the zones of load influence not extend to within the area of the rail infrastructure

396 Lane Cove Road, Macquarie Park



Geotechnical model - section adjacent to station concourse and cavern

Geotechnical model - section adjacent to shaft and cavern



396 Lane Cove Road, Macquarie Park

– Results: section adjacent to station concourse and cavern

Description	Displacement (mm)		Major Stress Distribution (MPa)	
	Vertical	Horizontal	Prior to Excavation	Prior to Excavation
Station concourse cavern (at crown)	2	1	3.20	3.90
Station concourse cavern (within rock bolt support)	2	1	3.20	3.90
Station main cavern (at crown)	2	0	5.60	5.70
Station main cavern (within rock bolt support)	1	1	3.20	3.00
Ground surface*	6	5	0.01	0.30
Bottom of excavation (Basement FFL)	6	2	1.60	1.20

* at the surface level adjacent to the completed basement excavation

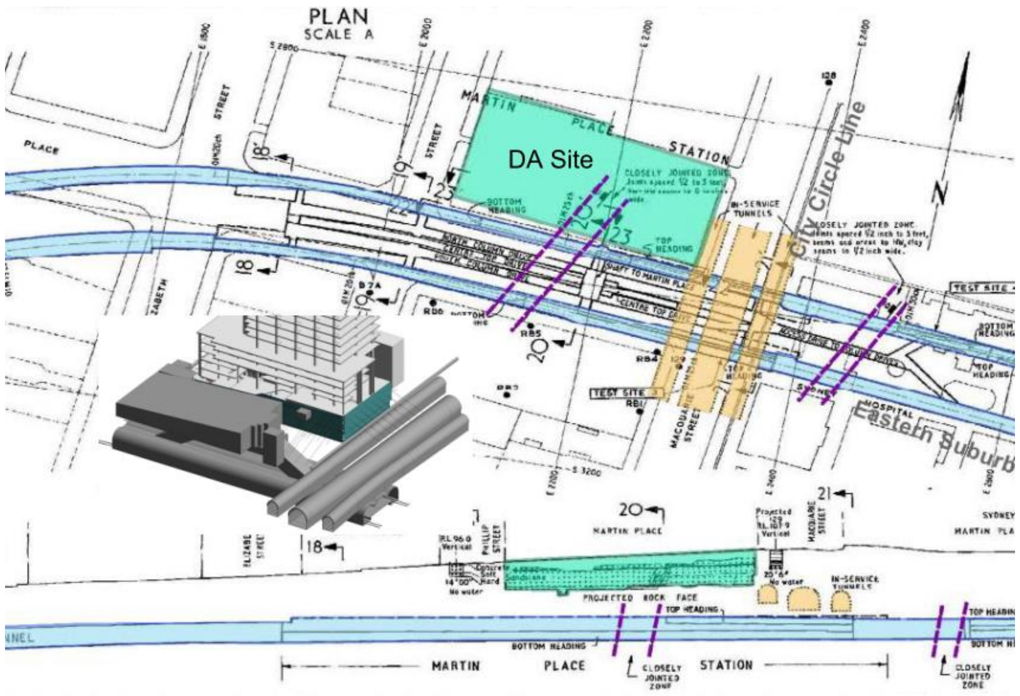
396 Lane Cove Road, Macquarie Park

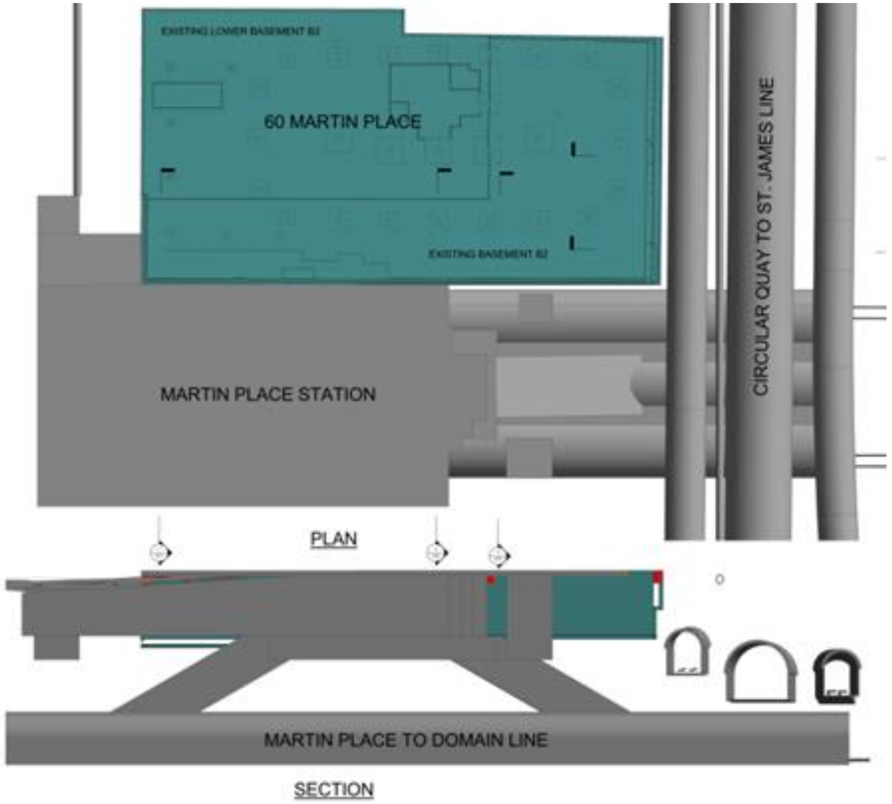
– Results: section adjacent to shaft and cavern

Description	Displacement (mm)		Major Stress Distribution (MPa)	
	Vertical	Horizontal	Prior to Excavation	Prior to Excavation
Station west entry shaft (at sidewall)	3	8	3.60	4.55
Station main cavern (at crown)	2	2	2.90	3.25
Station main cavern (within rock bolt support)	0	2	2.20	1.95
Ground surface*	9	34	0.10	0.00
Bottom of excavation (Basement FFL)	9	36	0.80	0.65

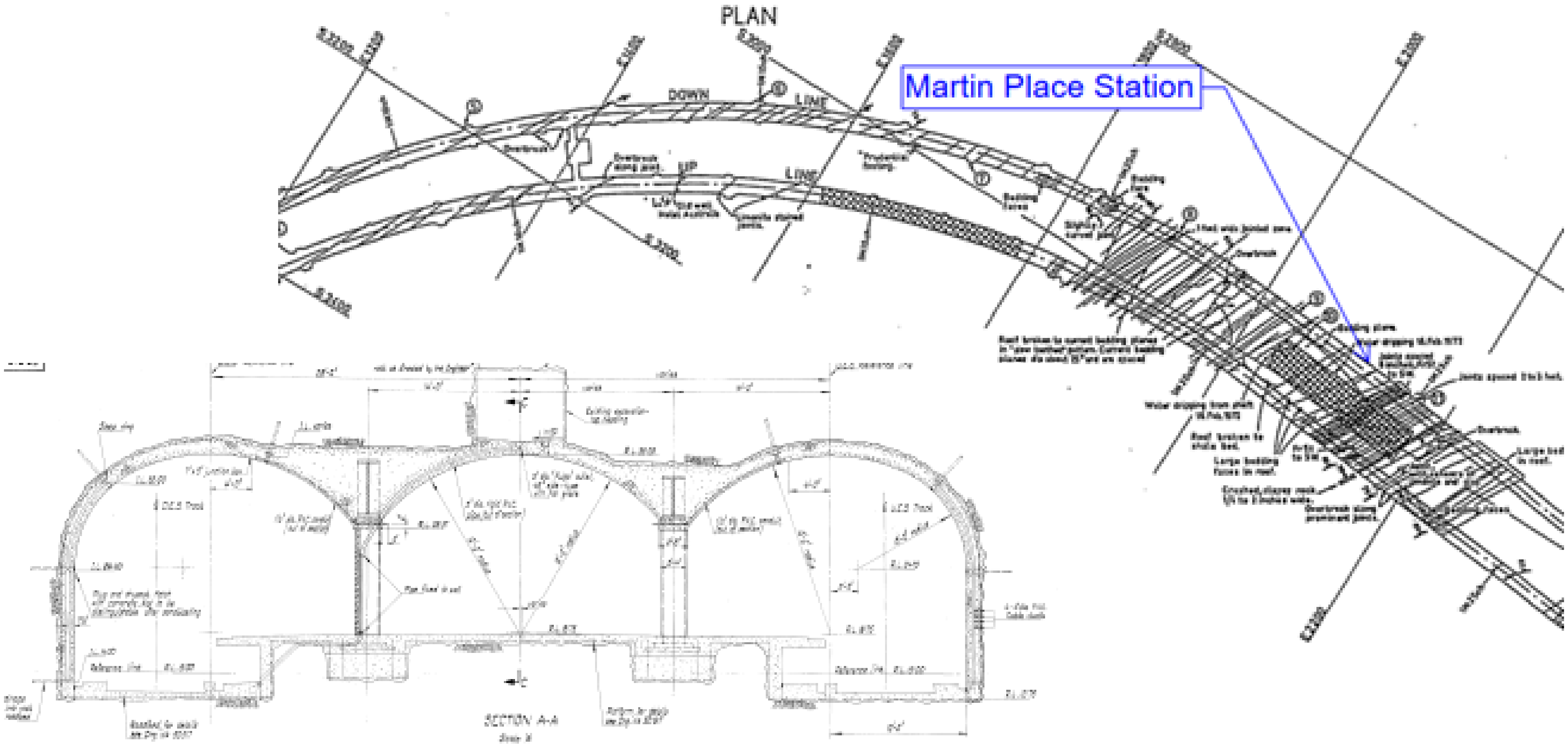
* at the surface level adjacent to the completed basement excavation

Sixty Martin Place, Sydney





Sixty Martin Place, Sydney



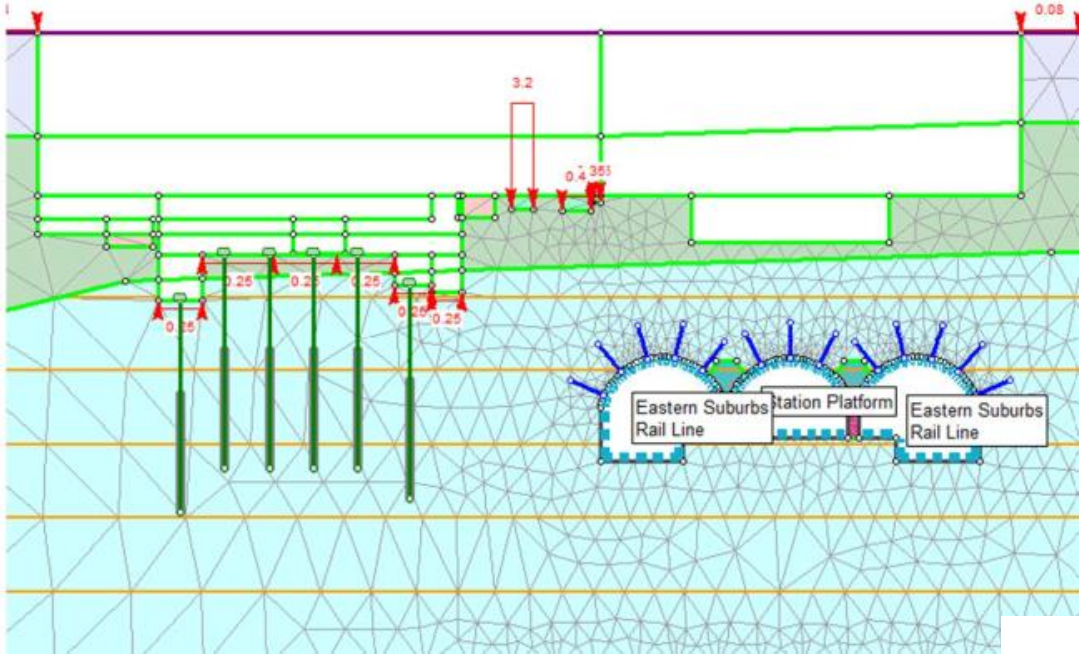
Sixty Martin Place, Sydney

- demolition of the existing 28 storey commercial building including basement levels, building footings
- construction of a 33-storey commercial office tower with lower-level retail use
- some minor excavation of the existing basement

Sixty Martin Place, Sydney

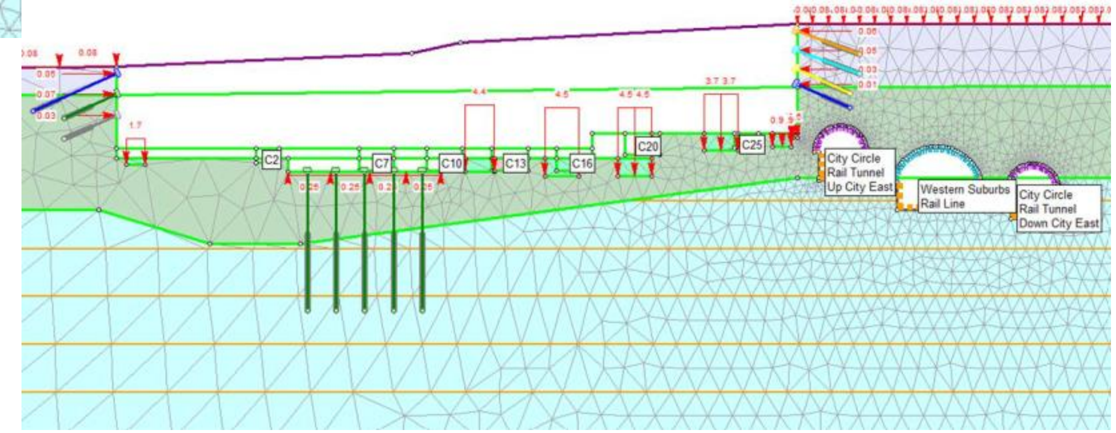
- Key considerations to protect rail assets
  - Assessment of the effects of the construction sequence using finite element and associated structural assessment to investigate the potential issue of cracking of the tunnel structure and the uplift that might be induced by ground unloading due to the demolition of the existing building
  - Additional localised basement excavation could cause some stress relief of the rock adjacent to the existing rail tunnels near their crown
  - The heightened sensitivity of impacts to the rail infrastructure due to their age from additional building loads within load influence zones
  - The requirement for temporary ground anchors to remain outside of the rail corridor

Sixty Martin Place, Sydney



Geotechnical model - section adjacent to Martin Place Station

Geotechnical model - section adjacent to Aged Tunnels (Macquarie Street)



Sixty Martin Place, Sydney

– Results: Section adjacent to Martin Place Station

Martin Place Station Section							
Stress Regime	Stages	Calculated Maximum Station Deformation (mm)			Maximum Stresses at Tunnel Crown (MPa)		
		Total	Vertical	Horizontal	ESR Down	Station	ESR Up
Upper bound, no joints	Demolition	3	2.5	1	2.62	4.31	4.23
	New development	4	-4.3	1	2.72	4.41	4.28
Lower bound, no joints	Demolition	2	1.8	1	0.73	0.69	0.69
	New development	5	-5.1	2	0.99	0.87	0.84
Upper bound, joints	Demolition	4	3.6	2	2.09	2.73	3.42
	New development	9	-8.5	1	2.06	2.6	3.49
Lower bound, joints	Demolition	2	2	1	0.71	0.65	0.64
	New development	6	-5.9	2	0.86	0.82	0.77

Sixty Martin Place, Sydney

– Results: section adjacent to Aged Tunnels

Macquarie Street Section							
Stress Regime	Stages	Calculated Maximum Tunnels Deformation (mm)			Maximum Stresses at Tunnel Crown (MPa)		
		Total	Vertical	Horizontal	CCL Up	WSL	CCL Down
Upper bound, no joints	Demolition	1	1	0	1.02	1.17	1.55
	New development	4	-3.1	3	0.79	1.11	1.39
Lower bound, no joints	Demolition	1	1	1	0.5	0.3	0.35
	New development	4	-3.4	2	0.35	0.32	0.36
Upper bound, joints	Demolition	2	1	2	1.72	1.55	0.95
	New development	5	-4.6	3	1.6	1.35	0.89
Lower bound, joints	Demolition	1	1	1	0.47	0.29	0.38
	New development	4	-3.5	2	0.29	0.31	0.4

CCL – City Circle rail tunnel, WSL – Western Suburbs rail line

Summary

- DA site, rail corridors & corresponding authorities
- Difference in defining protection corridors
- Key documents submit to relevant authorities
- Engineering impact assessment with case studies