OPERATIONAL NOISE AND VIBRATION

CHAPTER ELEVEN

11 Operational noise and vibration

This chapter assesses the potential impact of noise and vibration during the operation of the project. It describes the existing noise and vibration environment and identifies the potential significance of impacts to sensitive receivers. Mitigation measures to address the potential impacts are also identified. Technical paper 2 – Noise and vibration provides further details.

11.1 Secretary environmental assessment requirements

The Secretary's environmental assessment requirements relating to operational noise and vibration, and where these requirements are addressed in this Environmental Impact Statement, are outlined in Table 11-1.

Table 11-1 Secretary's environmental assessment requirements – operational noise and vibration

Ref.	Secretary's environmental assessment requirements	Where addressed
8. Noise and vibration – amenity		
8.1	The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to sensitive receivers including commercial premises, and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	Operational noise and vibration impacts are assessed in this chapter. Construction noise and vibration impacts are assessed in Chapter 10 (Construction noise and vibration).
9. Noise and vibration – structural		
9.1	The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage).	Operational noise and vibration impacts are assessed in this chapter. Construction noise and vibration impacts are assessed in Chapter 10 (Construction noise and vibration).

11.2 Assessment methodology

The following operational noise and vibration sources have been assessed:

- Ground-borne noise and vibration from trains operating within the project tunnels
- Airborne noise from metro trains operating between the Chatswood tunnel portal and just south of Chatswood Station, suburban and intercity trains operating between Brand Street Artarmon and just south of Chatswood Station, and metro trains operating immediately outside the Marrickville tunnel portal
- Airborne noise from mechanical plant and tunnel ventilation systems at stations and other ancillary facilities.

11.2.1 Terminology

The acoustic terminology used in this chapter is identified and defined in Table 11-2. The subscript 'A' indicates that the noise levels are filtered to match normal human hearing characteristics.

Table 11-2 Acoustic terminology

Term	Definition
Ground-borne noise	
$L_{Amax(slow),95\%}$	The 'typical maximum noise level' for a train passby event. For operational rail noise, the $L_{Amax(slow)}$ refers to the maximum noise level not exceeded for 95 per cent of rail passby events and is measured using the 'slow' response setting on a sound level meter.
Airborne noise	
$L_{Amax,95\%}$	The 'typical maximum noise level' for a train passby event. Refers to the maximum noise level not exceeded for 95 per cent of rail passby events and is measured using the 'fast' response setting on a sound level meter.
$L_{Aeq(24hour)}$	The 'energy averaged noise level' evaluated over a 24 hour period. Represents the cumulative effects of all the train noise events occurring in one day.
$L_{Aeq(15hour)}$	Represents the cumulative effects of all the train noise events occurring in the daytime period from 7 am to 10 pm.
$L_{Aeq(9hour)}$	Represents the cumulative effects of all the train noise events occurring in the night-time period from 10 pm to 7 am.
$L_{Aeq(1hour)}$	Represents the typical L_{Aeq} noise level from all the train noise events during the busiest 1-hour of the assessment period.

11.2.2 Ground-borne noise and vibration

Ground-borne vibration objectives

Ground-borne vibration levels have been assessed in accordance with the requirements of *Assessing Vibration – a technical guideline* (Department of Environment and Conservation, 2006a).

The impacts of ground-borne vibration in buildings fall into three main categories:

- Those in which the occupants or users of the building are inconvenienced or disturbed – termed human perception or human comfort vibration
- Those where the building contents may be affected
- Those in which the integrity of the building or structure itself may be prejudiced.

The vibration design objectives adopted for the project are based on human comfort (amenity) considerations, rather than the less stringent building damage (structural) risk criteria or potential effects on building contents. The proposed vibration design objectives for all sensitive receivers are listed in Table 11-3.

Table 11-3 Human comfort vibration design objectives

Receiver type	Time of day	Vibration design objective[1]
Residential	Day	106 dBv (0.2 mm/s)
	Night	103 dBv (0.14 mm/s)
Commercial (including offices, schools and places of worship)	When in use	112 dBv (0.4 mm/s)
Industrial	When in use	118 dBv (0.8 mm/s)
Theatres	When in use	106 dBv (0.2 mm/s)
Critical working areas[2]	When in use	100 dBv (0.1 mm/s)

1 *The vibration design objectives are based on the maximum 1 second rms vibration level not exceeded for 95% of train passbys*

2 *Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring*

In the case of rail tunnels, the ground-borne noise trigger levels (see Table 11-4 and Table 11-5) almost always require lower vibration levels than would otherwise be required by the vibration objectives as identified in Table 11-3. Hence other than at specific specialist facilities that would have particularly high sensitivity to vibration, compliance with the ground-borne noise trigger levels would ensure that the vibration design objectives would also be achieved.

Ground-borne noise objectives

The ground-borne noise and vibration assessment was carried out in accordance with the requirements of the *Rail Infrastructure Noise Guideline* (NSW Environment Protection Authority, 2013). The noise design objectives contained within this guideline are expressed as non-mandatory 'trigger levels' which, if exceeded, require consideration of feasible and reasonable mitigation measures.

The ground-borne noise levels refer to noise caused by the proposed rail operations only and do not include ambient noise from other sources such as major roads and industry. The train noise levels are evaluated inside buildings at the centre of the most affected habitable room (ie kitchens, bathrooms, laundries and the like are not considered "habitable"). The ground-borne noise trigger levels for residential and other sensitive receiver locations are provided in Table 11-4.

For commercial receivers, shopping centres and industrial buildings, the *Rail Infrastructure Noise Guideline* (EPA, 2013) does not provide guidance on acceptable levels. The previous *Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects* (Department of Environment and Climate Change, 2007a) outlines ground-borne noise design objectives for these other receivers (refer to Table 11-5) which have been adopted for the purposes of this assessment.

Table 11-4 Ground-borne noise design objectives – Rail Infrastructure Noise Guideline

Receiver	Time of day	Noise trigger levels (dBA)
		Development increases existing rail noise levels by 3.0 dB or more AND resulting rail noise levels exceed:
Residential	Day (7am to 10pm)	40 $L_{Amax(slow)}$
	Night (10pm to 7am)	35 $L_{Amax(slow)}$
Schools, educational institutions, places of worship	When in use	40-45 $L_{Amax(slow)}$[1]

1 *The lower value of the range is most applicable where low internal noise levels are expected, such as in areas assigned to studying, listening and praying.*

Table 11-5 Ground-borne noise design objectives – Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects

Receiver	Time of day	Noise trigger levels (dBA)[1]
Retail areas	When in use	40-50 dBA
General Office Areas	When in use	50 dBA
Private Offices and Conference Rooms	When in use	45 dBA
Cinemas, Public Halls and Lecture Theatres	When in use	35 dBA
Drama Theatres	When in use	NR 25[2]
Film/Television Studios and Sound Recording Studios	When in use	NR 15[2]
Workshops / Industrial Buildings	–	N/A

1 *The ground-borne noise design objectives are based on the maximum $L_{Amax(slow)}$ noise level, not to be exceeded for 95% of train passbys over any 24 hour period.*

2 *NR (Noise Rating) curves are used for rating noise levels and are a set of octave band curves which provide limiting sound pressure level values. NR 15 is equivalent to approximately 20 dBA and NR 25 is approximately 30 dBA.*

Ground-borne noise and vibration modelling

Train noise in buildings adjacent to rail tunnels is predominantly caused by the transmission of ground-borne vibration rather than the direct transmission of noise through the air. After entering a building, this vibration may cause the walls and floors to vibrate and hence to radiate audible noise, which is commonly termed ground-borne or regenerated noise.

International Standard ISO 14837;1 2005 *Mechanical vibration – Ground-borne noise and vibration arising from rail systems – Part 1: General Guidance* provides relevant guidance in relation to the extent of assessment that is normally required for new rail systems.

A computer noise model was developed to predict the ground-borne noise and vibration levels in nearby buildings above or close to the underground project alignment. The model takes into account the source vibration generated by trains operating in a similar rail tunnel environment, the proposed track design and operating speeds, the characteristics of the ground, the tunnel depth and typical building characteristics.

Given the expected similarities of the project to the Epping to Chatswood Rail Link project (in terms of geology, tunnel diameter, concrete lining, slab track design, etc), the source vibration levels for the new fleet of single deck, metro trains for use in the ground-borne noise and vibration modelling have been calibrated from measurements taken of the Epping to Chatswood Rail Link between 2009 and 2011.

In the absence of specific measured data relating to the proposed single-deck trains, source vibration levels have been assumed to be equivalent to A-Set (Waratah) trains – the most modern trains currently operating on the Sydney rail network. This assumption is considered to be conservative as the proposed single-deck passenger trains are likely to have reduced axle loads and unsprung mass compared to the Waratah train, resulting in marginally lower source vibration levels.

Further details on the ground-borne noise and vibration modelling methodology are provided in *Technical Paper 2 – Noise and vibration.*

11.2.3 Airborne noise

Noise emissions from suburban electric passenger trains are predominantly caused by the rolling contact of steel wheels on steel rails. Other noise sources on electric passenger trains (such as air-conditioning plant and air compressors) are generally insignificant in noise level when compared to the wheel rail interaction, unless the train is travelling at a very low speed or is stationary.

Airborne rail noise trigger levels

The NSW EPA provides guidance for the assessment and management of potential airborne noise from railways in the *Rail Infrastructure Noise Guideline* (EPA, 2013). To assess and manage potential noise from rail projects the guideline provides non-mandatory airborne noise triggers for residential and other sensitive receivers. Where rail noise levels are above the noise triggers feasible and reasonable noise mitigation should be identified to achieve the trigger levels.

The *Rail Infrastructure Noise Guideline* (EPA, 2013) requires noise to be assessed at opening and for a future design year (typically ten years after opening). For this project the two timeframes assessed are at opening scenario in 2024 and a future scenario based on forecasts for operations in 2034.

The project related surface track sections north of the Chatswood tunnel portal and south of Marrickville tunnel portal would be categorised as a redevelopment of an existing rail line.

The relevant airborne noise trigger levels for residential land uses surrounding the proposed surface track are presented in Table 11-6.

Table 11-6 Airborne rail noise triggers for residential land use

Sensitive land use	Noise trigger level (dBA)	
	Daytime 7am to 10pm	Night-time 10pm to 7am
Redevelopment of existing rail line	Development increases existing $L_{Aeq(period)}$ [1] rail noise levels by 2 dB or more, or existing L_{Amax} [2] rail noise levels by 3 dB or more AND Resulting rail noise levels exceed:	
	65 $L_{Aeq(15hour)}$ and 85 L_{Amax}	60 $L_{Aeq(9hour)}$ and 85 L_{Amax}

1 *$L_{Aeq(period)}$ means $L_{Aeq(15h)}$ for the day-time period and $L_{Aeq(9h)}$ for the night-time period*

2 *L_{Amax} refers to the maximum noise level not exceeded for 95 per cent of rail pass-by events and is measured using the 'fast' response setting on a sound level meter.*

The *Rail Infrastructure Noise Guideline* (EPA, 2013) noise triggers for non-residential sensitive receivers are shown in Table 11-7 and are applicable when the building or premise is in use. All noise trigger levels are external levels except where otherwise stated. Commercial receivers are not considered sensitive to operational airborne noise impacts.

Table 11-7 Airborne rail noise triggers for sensitive land uses other than residential

Sensitive land use	Noise trigger level (dBA)
	Development increases existing rail noise levels by 2 dB or more in L_{Aeq} in any hour AND Resulting rail noise levels exceed:
Schools, educational institutions and child care centres	45 $L_{Aeq(1hour)}$ internal
Places of worship	45 $L_{Aeq(1hour)}$ internal
Hospital wards	40 $L_{Aeq(1hour)}$ internal
Hospital other uses	65 $L_{Aeq(1hour)}$
Open space – passive use (eg parkland, bush reserves)	65 $L_{Aeq(15hour)}$
Open space – active use (eg sports field, golf course)	65 $L_{Aeq(15hour)}$

Approach to operational noise modelling

SoundPLAN version 7.0 was used to model airborne rail noise. The input data used in the modelling was chosen to reflect the likely metro fleet of single-deck trains. Noise levels for the T1 North Shore Line and T3 Bankstown Line were based on modern electric double-deck suburban passenger trains (similar to A-set 'Waratah' class). Other key inputs into the airborne noise model included:

- Concrete slab track within the dive structures and on the T1 North Shore Line bridge; ballast track in other surface track locations
- Sydney Metro would be constructed with continuously welded rail
- The horizontal radius of curves, especially those less than 600 metre radius
- The track geometry in relation to the adjacent ground terrain
- The Sydney Trains and Sydney Metro train speed profiles for the surface track sections
- Train numbers on metro lines and existing rail lines in the vicinity of the Chatswood and Marrickville dive structures
- The location of sensitive receivers.

The *Rail Infrastructure Noise Guideline* (EPA, 2013) specifies that the noise trigger levels apply both immediately after operations commence and for projected train numbers at an indicative period into the future to represent the expected typical maximum level of train use. To support the noise modelling predictions, estimated train numbers were assessed for the at-opening and 10-years after opening scenarios.

The train number estimates (for Sydney Metro and Sydney Trains) used in the modelling scenarios are provided in Table 11-8. These train numbers are indicative only and are based on estimated passenger demand, minimum service levels and the upper design limit of metro service frequency for future peak times.

Further details of the airborne noise modelling methodology and inputs are provided in *Technical Paper 2 – Noise and vibration*.

Table 11-8 Train numbers for noise assessment

Rail line	Scenario	Train type	Trains per weekday			
			Day (7 am to 10 pm)		Night (10 pm to 7 am)	
			Up	Down	Up	Down
T1 North Shore Line and future metro line	Existing 2015	A/H/M/T-Set	186	190	44	47
	Prior to opening 2024	A/H/M/T-Set	186	190	44	47
	After opening 2024	A/H/M/T-Set	186	190	44	47
		Metro Train	202	202	27	27
	Future 2034 with project	A/H/M/T-Set	186	190	44	47
		Metro Train	222	222	30	30
	Future 2034 without project	A/H/M/T-Set	186	190	44	47
		Metro train	0	0	0	0
T2 Airport Line	Existing 2015	A/H/M/T-Set	6	8	0	1
	Prior to opening 2024	A/H/M/T-Set	6	8	0	1
	After opening 2024	A/H/M/T-Set	6	8	0	1
	Future 2034 with project	A/H/M/T-Set	6	8	0	1
	Future 2034 without project	A/H/M/T-Set	6	8	0	1
T3 Bankstown Line and future metro line	Existing 2015	A/H/M/T-Set	78	84	17	20
	Prior to opening 2024	A/H/M/T-Set	78	84	17	20
	After opening 2024	A/H/M/T-Set	78	84	17	20
		Metro Train	184	184	27	27
	Future 2034 with project	A/H/M/T-Set	78	84	17	20
		Metro Train	202	202	30	30
	Future 2034 without project	A/H/M/T-Set	78	84	17	20
		Metro Train	0	0	0	0
T4 Eastern Suburbs and Illawarra Line	Existing 2015	A/H/M/T-Set	96	85	26	23
		C/K/S/R-Set	9	8	2	2
	Prior to opening 2024	A/H/M/T-Set	105	93	28	25
	After opening 2024	A/H/M/T-Set	105	93	28	25
	Future 2034 with project	A/H/M/T-Set	105	93	28	25
	Future 2034 without project	A/H/M/T-Set	105	93	28	25

11.2.4 Operational noise from stations and ancillary facilities

Noise criteria

The *Industrial Noise Policy* (INP) (Environment Protection Authority, 2000) sets two separate noise criteria to meet environmental noise objectives: one to account for intrusive noise and the other to protect the amenity of particular land uses. These criteria are to be met at the most-affected boundary of the receiver property. The more stringent of the criteria usually defines the proposal specific noise levels. For both amenity and intrusiveness, night-time criteria are more stringent than daytime or evening criteria.

In addition to intrusiveness and amenity, the risk of sleep disturbance must be assessed. Sleep disturbance is assessed in accordance with the screening criterion described in the online Application Notes to the INP and the more detailed review of sleep disturbance contained in the *Road Noise Policy* (RNP) (Department of Environment, Climate Change and Water, 2011a).

To provide for protection against intrusive noise, the INP states that the L_{Aeq} noise level of the source, measured over a period of 15 minutes, should not be more than five decibels above the ambient (background) L_{A90} noise level (or RBL), measured during the daytime, evening and night-time periods at the nearest sensitive residential receiver. In this case, the intrusiveness criteria are determined from the rating background levels, which are outlined in Chapter 10 (Construction noise and vibration), at sensitive receiver locations nearest to the facilities.

To provide protection against impacts on amenity, the INP specifies suitable maximum noise levels for particular land uses and activities during the daytime, evening and night-time periods. The relevant INP external amenity noise criteria are presented in Table 11-9.

Table 11-9 Industrial Noise Policy amenity criteria

Type of receiver	Indicative noise amenity area	Time of day	Recommended L_{Aeq} noise level (dBA)	
			Acceptable	Recommended maximum
Residence	Suburban [1]	Day	55	60
		Evening	45	50
		Night	40	45
Residence	Urban [2]	Day	60	65
		Evening	50	55
		Night	45	50
Commercial	All	When in use	65	70
Active recreation area	All	When in use	55	60
Educational	All	When in use	55 [1]	60 [1]
Place of worship	All	When in use	60 [1]	65 [3]

1 *Suburban area is characterised by local traffic with intermittent traffic flows, decreasing noise levels in the evening period, and/or evening ambient levels defined by the natural environment and infrequent human activity.*

2 *Urban areas are characterised by an acoustic environment dominated by 'urban hum' or industrial noise sources, through traffic with heavy and continuous traffic flows during peak hours, and/or located near commercial or industrial districts.*

3 *External levels, based on the internal levels specified in the INP plus 20 dB (assuming open windows).*

11.3 Existing environment

The existing noise environment varies considerably along the length of the project. The dominant noise sources that are likely to influence background noise levels include:

- Road traffic noise
- Suburban rail line operations and associated station activities
- Industrial activities occurring within existing industrial areas (such as at Artarmon and Marrickville)
- Other construction activities (such as the CBD and South East Light Rail, building redevelopments, road and housing construction)
- Sydney Harbour maritime traffic
- Aircraft noise.

The existing noise environment, including ambient noise levels, is described in Chapter 10 (Construction noise and vibration). This environment status would also be applicable to the operation stage of the project.

11.4 Potential impacts

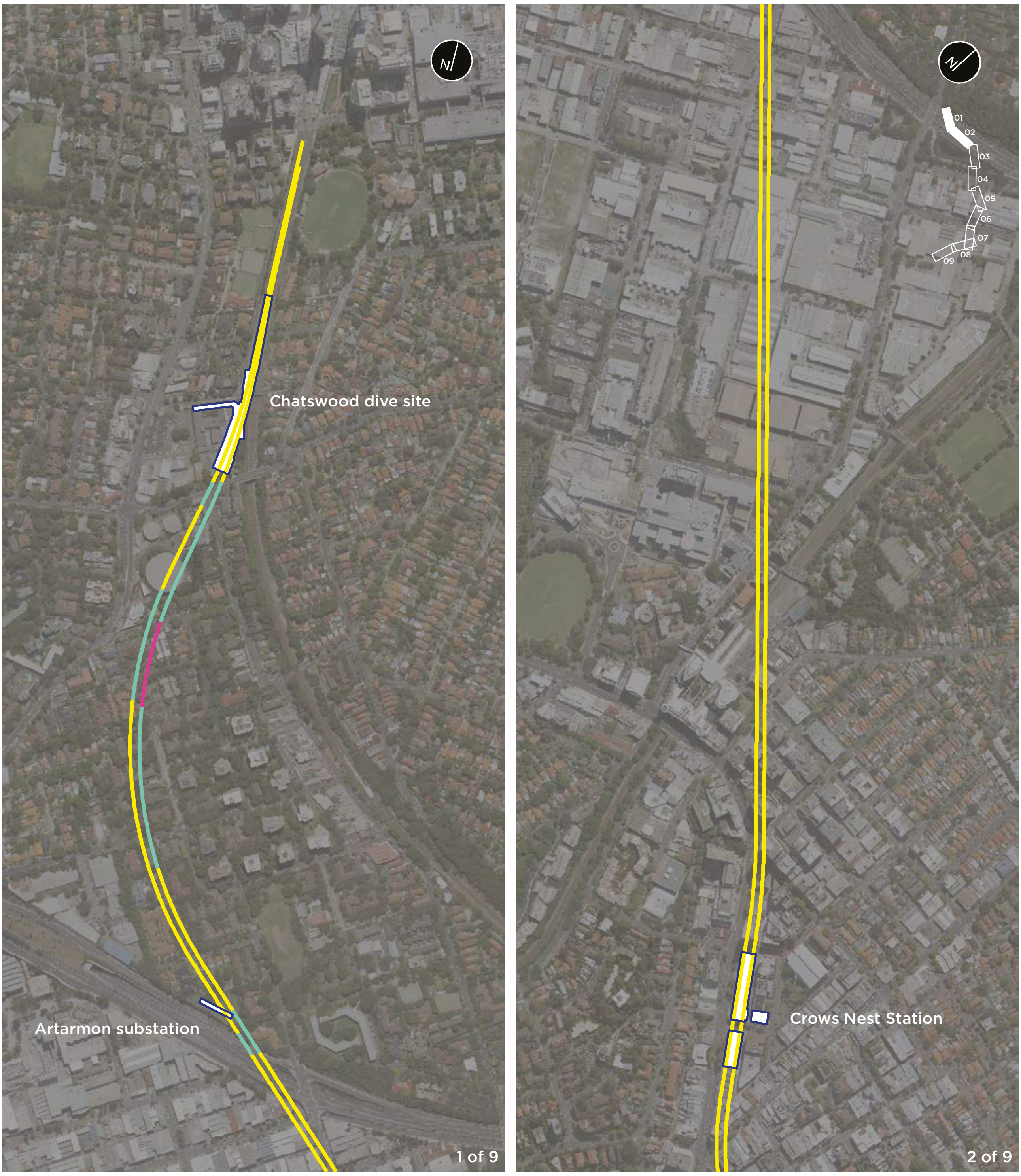
11.4.1 Ground-borne noise and vibration

Ground-borne noise and vibration impacts from operational rail lines in tunnels are generally mitigated by a resilient rubber layer between the rail and the tunnel foundation. This may take the form of resilient rail fasteners, booted sleepers, floating slab track or a combination of measures.

Initial ground-borne noise and vibration modelling was carried out to determine the indicative track form along the tunnel alignment to meet the design objectives at receivers above the tunnels. This modelling determined that the following three track forms would be required:

- **Standard attenuation track** – incorporating a hard resilient baseplates. This track form would be used for around 93 per cent of the tunnels and is the standard specification for Sydney Metro and would be used in areas with low sensitivity to ground-borne noise and vibration, or at locations where there is sufficient tunnel depth to the receivers
- **High attenuation track** – incorporating medium resilient baseplates. This track form would be used for around seven per cent of the tunnels, in sensitive areas where the standard attenuation track is not sufficient to meet the design objectives
- **Very high attenuation track** – incorporating soft resilient baseplates. This track form would only be required for less than one per cent of the tunnels, in very sensitive areas where the depth of the tunnel is particularly shallow.

The indicative track form for the current design of the tunnels, trains and operations are shown on Figure 11-1 (a-e). The proposed track form provides one option to meet the ground-borne noise and vibration objectives. As identified in Chapter 6, the tunnel alignment is indicative at this stage, and has been used for the purposes of the environmental impact assessment including all specialist investigations. During detailed design the alignment may change (horizontally and / or vertically). Any changes to the alignment would be reviewed for consistency with the assessment contained in this Environmental Impact Statement including relevant mitigation measures, performance outcomes and any future conditions of approval. The final track form would be confirmed as part of detailed design.



KEY

Standard Attenuation

High Attenuation

Very High Attenuation

Proposed operational area at surface

Indicative only, subject to design development

0 400 m

Figure 11-1a Extent of indicative track form in Sydney Metro Chatswood to Sydenham tunnels Map 1

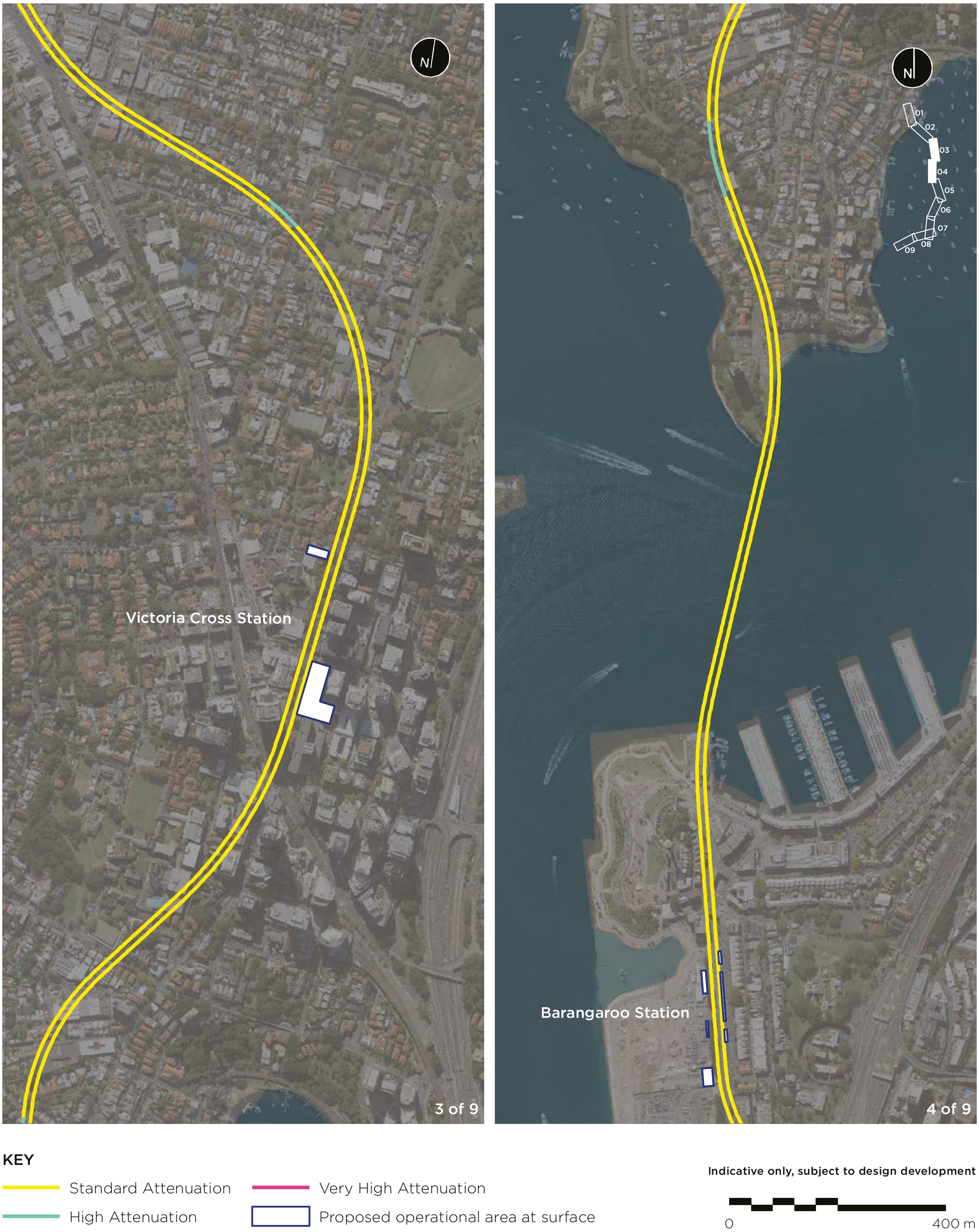
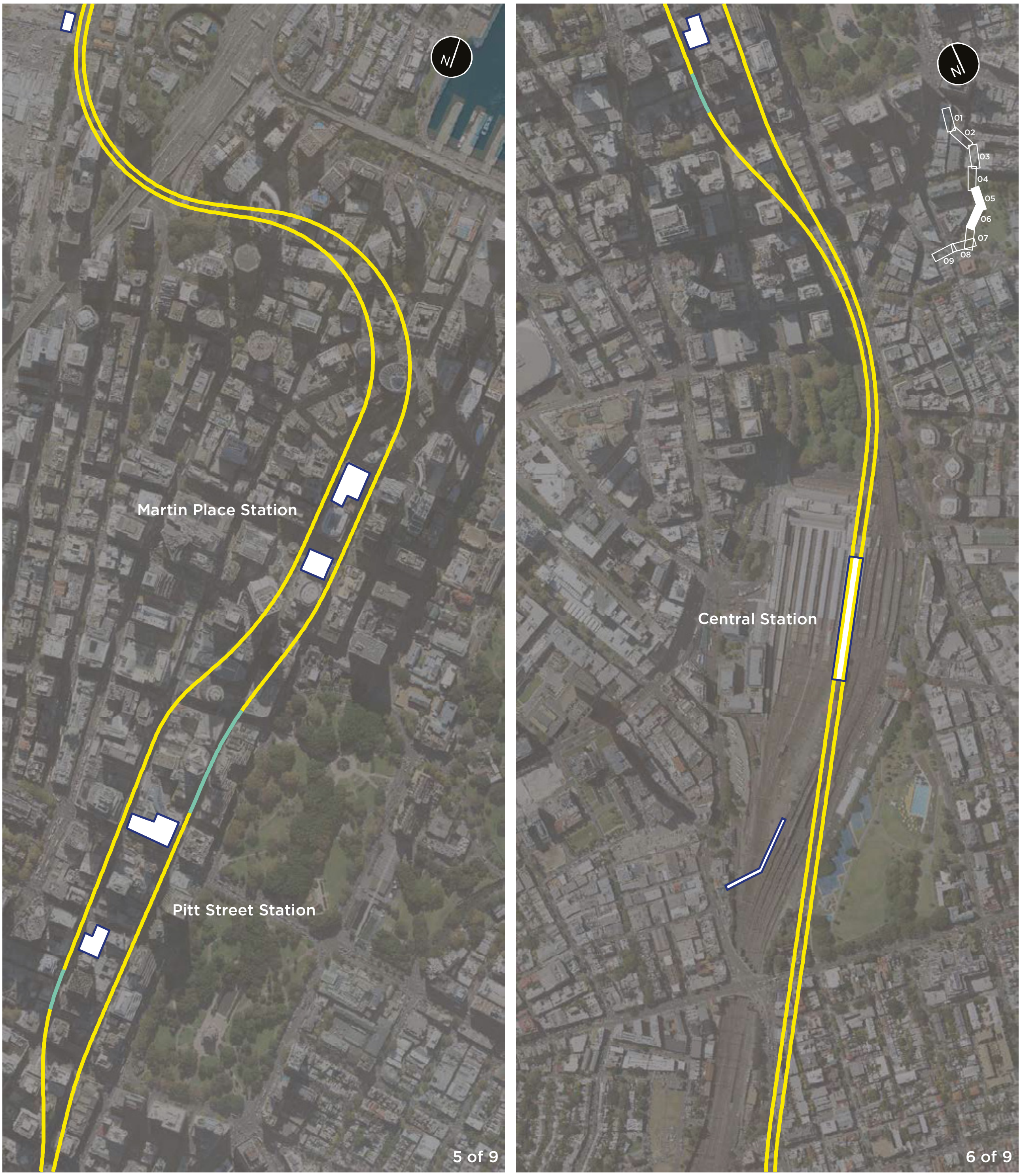


Figure 11-1b Extent of indicative track form in Sydney Metro Chatswood to Sydenham tunnels Map 2



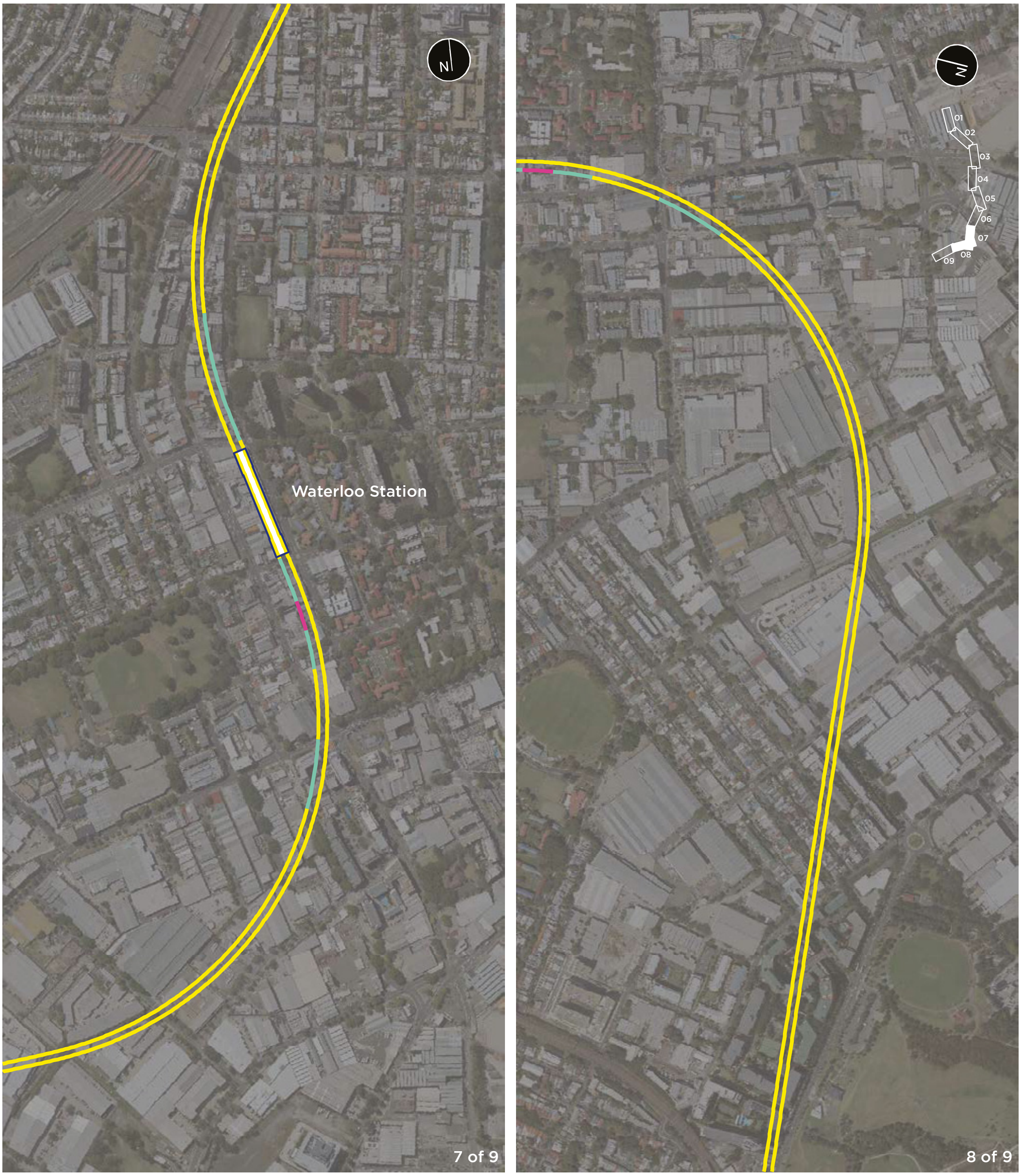
KEY

- Standard Attenuation
- High Attenuation
- Very High Attenuation
- Proposed operational area at surface

Indicative only, subject to design development

0 – 400 m

Figure 11-1c Extent of indicative track form in Sydney Metro Chatswood to Sydenham tunnels Map 3



KEY

Standard Attenuation

High Attenuation

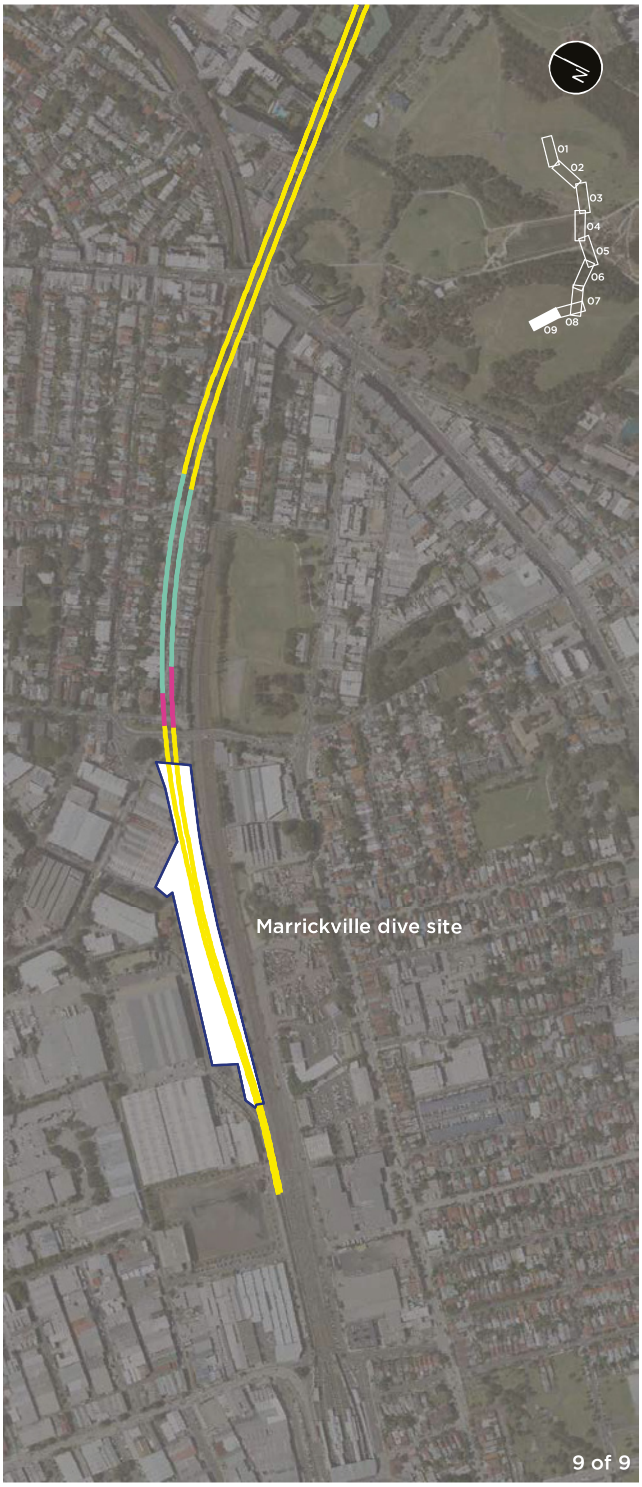
Very High Attenuation

Proposed operational area at surface

Indicative only, subject to design development

0 400 m

Figure 11-1d Extent of indicative track form in Sydney Metro Chatswood to Sydenham tunnels Map 4



KEY

Standard Attenuation

High Attenuation

Very High Attenuation

Proposed operational area at surface

Indicative only, subject to design development

0 400 m

Figure 11-1e Extent of indicative track form in Sydney Metro Chatswood to Sydenham tunnels Map 5

Ground-borne vibration predictions

Figure 11-2 presents a summary of the predicted ground-borne vibration levels for buildings located above or near the proposed tunnel alignment.

The predicted ground-borne vibration levels represent the maximum mid-floor vibration levels within multi-storey buildings.

At this stage it is not known whether any commercial premises contain highly sensitive measurement or fabrication equipment. For preliminary assessment purposes, it has been assumed that all nearby medical facilities may contain highly sensitive equipment such as lithography or optical / electronic inspection equipment with high resolution. Table 11-10 provides the results of ground-borne noise predictions for receivers containing highly sensitive equipment.

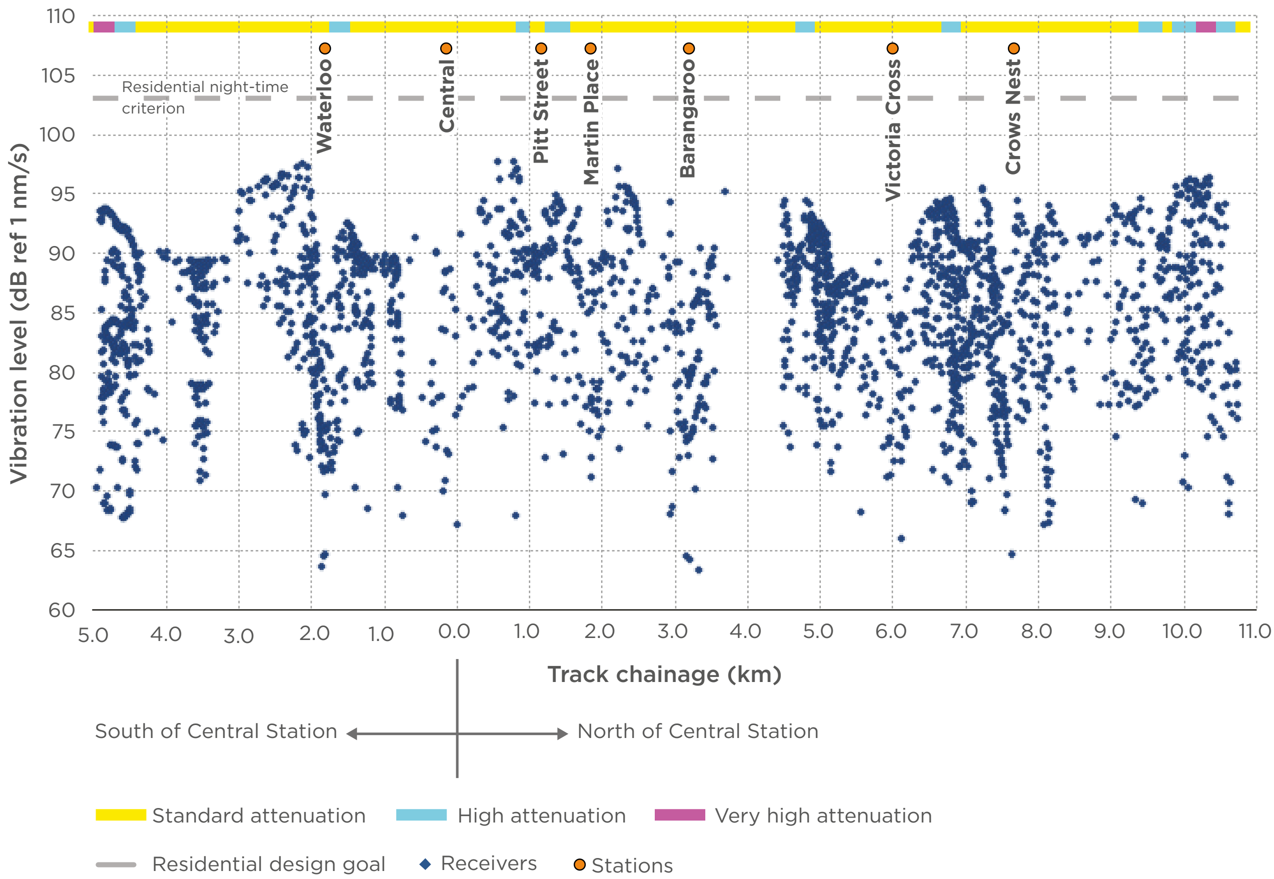


Figure 11-2 Predicted ground-borne vibration levels

Table 11-10 Ground-borne vibration predictions for receivers containing highly sensitive equipment

Receiver	Location	Maximum 1/3 Octave Band Vibration Level (dB ref 1 nm/s)	
		Design objective	Predicted
Royal North Shore Hospital	Near the tunnel alignment between Artarmon substation and Crows Nest Station	82	74
Health Care Imaging Services	Near the tunnel alignment between Pitt Street Station and Central Station	82	75

The human comfort objectives for ground-borne vibration are more stringent than other possible design limits related to building damage risk or the potential effects on building contents.

Compliance with the ground-borne vibration design objectives (and the human comfort vibration criteria from *Assessing Vibration: a technical guideline* – DEC, 2006) is predicted for all receivers located above or near to the proposed tunnel alignment.

Surface track ground-borne vibration

Some residential buildings located immediately adjacent to the surface rail track between Chatswood Station and Chatswood dive may experience an increase in train passby vibration levels. Residential receivers located on the western side of the rail corridor between Mowbray Road and Gordon Avenue, Chatswood are currently around 11 metres from the closest rail track. As a result of the realignment of the T1 North Shore Line, the surface track would be located around eight metres from these receivers (three metres closer). Based on previous investigations of vibration propagation from rail lines undertaken by the US Federal Transit Administration (2006), this change would equate to a potential increase in vibration level of around 2 dB. This increase is expected to be barely noticeable to the receivers.

Ground-borne noise predictions

Predictions of ground-borne noise levels are provided in Figure 11-3 for residential receivers and Figure 11-4 for commercial and other sensitive receivers. The predictions are based on a 'best estimate' plus a 5 dB safety factor. On average, the predicted ground-borne noise levels (for the highest 1 in 20 trains) at the nearest receivers would be around 30 dB which is well below the ground-borne noise design objectives. At most locations the noise levels would be much lower.

The proposed ground-borne noise levels are predicted to comply with the ground-borne noise objectives at all residential, commercial and other sensitive receiver locations.

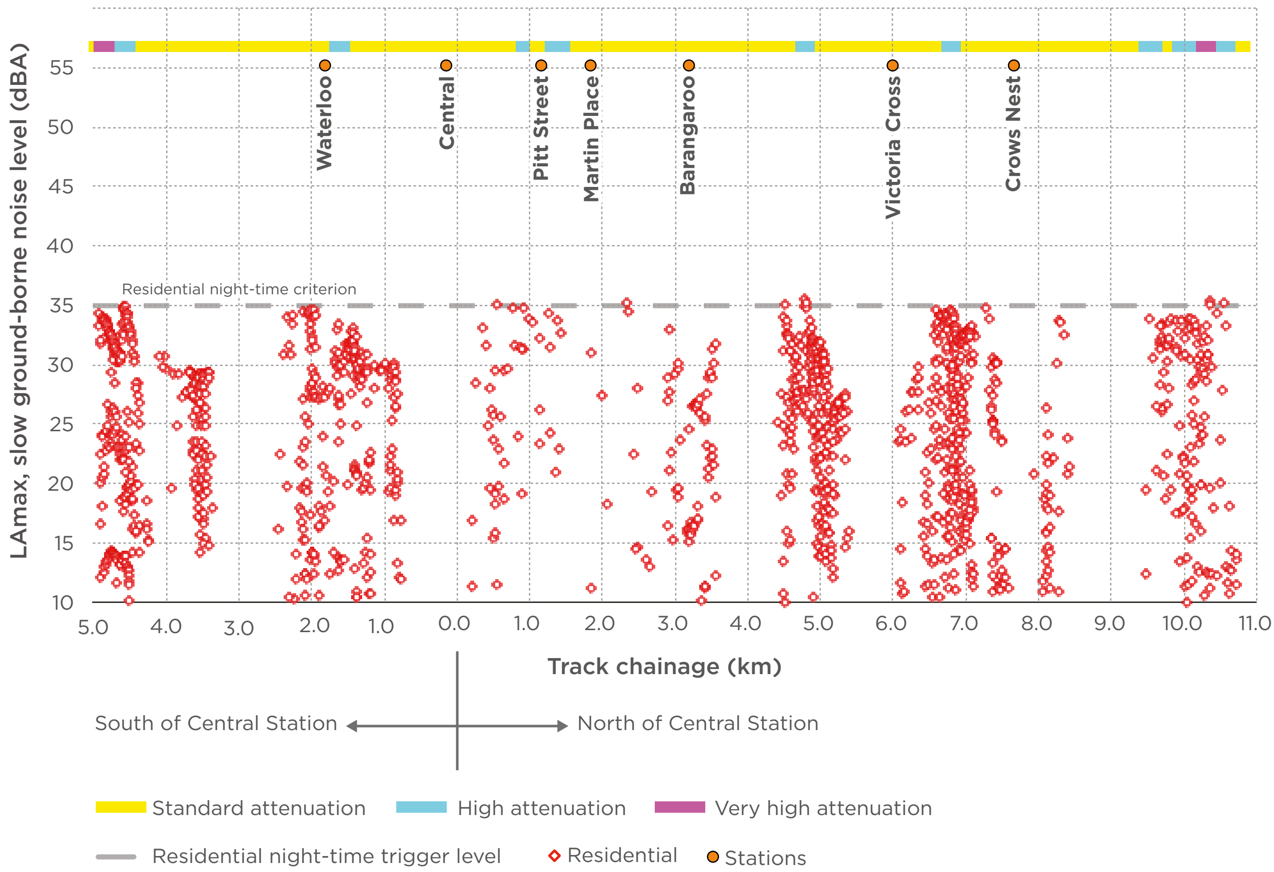


Figure 11-3 Predicted ground-borne noise levels – residential receivers

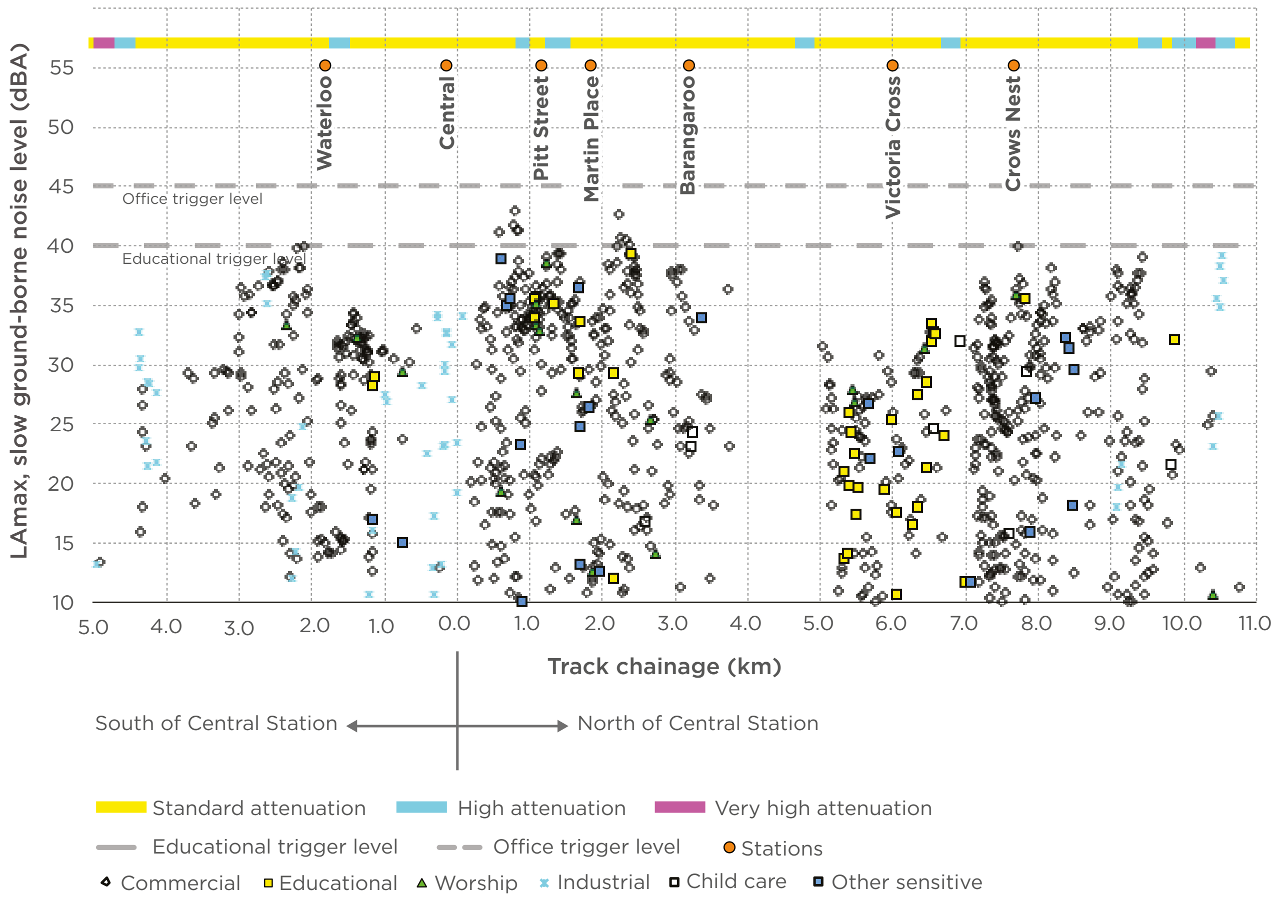


Figure 11-4 Predicted ground-borne noise levels – commercial and other sensitive receivers

11.4.2 Airborne noise

An operational airborne noise assessment has been carried out for the surface track sections at either end of the project, being:

- At the northern end of the project – metro trains operating between Chatswood Station and the Chatswood tunnel portal, and Sydney Trains trains operating on the realigned T1 North Shore Line between Chatswood Station and Brand Street, Artarmon
- At the southern end of the project – metro trains operating in the Marrickville dive structure.

For the purposes of assessment, receivers are broken into a number of noise catchment areas (NCAs). NCAs are determined to reflect the changing land uses and ambient noise environments adjacent to the project.

Northern surface works

In order to mitigate potential airborne noise impacts at the northern end of the project, the design has incorporated the following measures:

- An increase in the height (to four metres) of the noise barrier between Chapman Avenue and Nelson Street on the eastern side of the rail line
- An increase in the height (to four metres) of the noise barrier between the Frank Channon Walk pedestrian underpass and Albert Avenue on the western side the rail line
- An increase in the height (to four metres) of the noise barrier between Nelson Street and Gordon Avenue on the western side the rail line
- A two metre high noise barrier to the south of the Mowbray Road on the western side of the rail line
- Rail dampers and deck absorption within the Chatswood dive structure.

The exact height and extent of the noise barriers in these locations would be further refined during detailed design.

A summary of the predicted worst-case noise levels for residential receivers for the 2034 (future year) scenario are presented in Table 11-11. The future year 2034 scenario has been presented as it results in the highest noise level predictions. Results for the at opening 2024 scenario are provided in *Technical paper 2 – Noise and vibration*.

Table 11-11 Predicted 2034 airborne noise levels – residential receivers Chatswood dive

NCA	Side	Worst-case predicted noise level (dBA)								
		Without project			With project			Increase		RING triggers
		$L_{Aeq(15h)}$	$L_{Aeq(9h)}$	L_{Amax}	$L_{Aeq(15h)}$	$L_{Aeq(9h)}$	L_{Amax}	L_{Aeq}	L_{Amax}	
01	Up	50	46	68	52	47	68	1.6	-0.1	0
	Down	61	58	80	63	58	81	1.2	0.5	0
02	Up	**68**	**64**	**86**	**70**	**65**	**86**	1.9	-0.3	0
	Down	64	60	84	**67**	**62**	**85**	0	1.3	1
03	Up	**69**	**65**	**88**	**68**	**64**	**87**	0.7	0.8	0
	Down	63	59	81	65	60	81	1.8	0.7	0
04	Up	**69**	**65**	**87**	**69**	**65**	**87**	0.3	0	0
	Down	**68**	**64**	**85**	**68**	**64**	**85**	0.1	0	0

1 *Red bold indicates an exceedance of criteria*

2 *For reference the trigger levels are:*

development increases existing $L_{Aeq(period)}$ rail noise levels by 2 dB or more, or existing L_{Amax} rail noise levels by 3 dB or more and predicted rail noise levels exceed: daytime: 65 $L_{Aeq(15hour)}$ or 85 L_{Amax}, night-time: 60 $L_{Aeq(9hour)}$ or 85 L_{Amax}.

The results indicate that noise levels at residential receivers without the project are generally already close to, or exceeding, the overall noise criteria levels.

Comparing the 'with project' and 'without project' noise levels indicates that there is generally no change in noise levels from the project, primarily due to the measures incorporated into the design to minimise operational airborne noise impacts.

From the results it can be seen that there remains a predicted exceedance of the noise trigger levels at one residential receiver building (at address 1-3 Gordon Avenue, Chatswood) on the western side of the rail line. This residential receiver is a multi-storey apartment building and would consist of several dwellings. The upper floors of this receiver would have an unobstructed view of the rail tracks over the noise barrier, even with the proposed increase in barrier height. To break line of sight at the triggered receivers on the upper floor of this building would require a noise barrier in excess of six metres high. Noise barriers of this height are unlikely to be considered reasonable and may not be feasible, particularly since the barrier would need to be located in close proximity to the building facade. Based on the outcomes of noise modelling during detailed design, this property would be considered for at property treatment.

A summary of the predicted worst-case noise levels for other sensitive receivers for the 2034 (future year) scenario are presented in Table 11-12. The future year 2034 scenario has been presented as it results in the highest noise level predictions. Results for the at opening 2024 scenario are provided in *Technical paper 2 – Noise and vibration*.

Table 11-12 Predicted 2034 airborne noise levels – other sensitive receivers Chatswood dive

NCA	Side	Worst-case predicted noise level (dBA)					
		Without project		With project		Increase	RING triggers
		$L_{Aeq(1h)}$ Day	$L_{Aeq(1h)}$ Night	$L_{Aeq(1h)}$ Day	$L_{Aeq(1h)}$ Night	$L_{Aeq(1h)}$	
01	Up	59	55	61	56	2.2	0
	Down	61	58	62	58	1.2	0
02	Up	N/A	N/A	N/A	N/A	N/A	0
	Down	66	62	69	63	3.2	0
03	Up	N/A	N/A	N/A	N/A	N/A	0
	Down	63	59	64	60	1.8	0
04	Up	N/A	N/A	N/A	N/A	N/A	0
	Down	68	64	68	64	0.1	0

Southern surface works

A summary of the predicted worst-case noise levels for residential receivers for the 2034 (future year) scenario are presented in Table 11-13. The future year 2034 scenario has been presented as it results in the highest noise level predictions. Results for the at-opening 2024 scenario are provided in *Technical paper 2 – Noise and vibration*.

Table 11-13 Predicted 2034 airborne noise levels – residential receivers Marrickville dive

NCA	Side	Worst-case predicted noise level (dBA)								
		Without project			With project			Increase		RING triggers
		$L_{Aeq(15h)}$	$L_{Aeq(9h)}$	L_{Amax}	$L_{Aeq(15h)}$	$L_{Aeq(9h)}$	L_{Amax}	L_{Aeq}	L_{Amax}	
32	Up	**67**	**63**	**99**	**67**	**63**	**99**	0	0	0
	Down	**68**	**64**	**93**	**68**	**64**	**93**	0	0	0
33	Up	44	40	63	50	45	68	9.5	13.5	0
	Down	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
34	Up	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Down	58	54	76	58	54	76	0	0	0

1 *Red bold indicates an exceedance of criteria*

2 *For reference the trigger levels are:*
development increases existing $L_{Aeq(period)}$ rail noise levels by 2 dB or more, or existing L_{Amax} rail noise levels by 3 dB or more and predicted rail noise levels exceed: daytime: 65 $L_{Aeq(15hour)}$ or 85 L_{Amax}, night-time: 60 $L_{Aeq(9hour)}$ or 85 L_{Amax}.

The results indicate that noise levels at residential receivers without the project are generally already close to, or exceeding, the overall noise criteria levels.

Comparing the 'with project' and 'without project' noise levels indicates that there is generally no change in noise levels from the project, with the exception of NCA33 on the up side of the corridor where the distance to the dive tracks is shortest. However the predicted noise levels in this area are below the RING absolute noise level criteria.

From the results it can be seen that there are no RING noise level triggers for residential receivers surrounding the Marrickville dive structure.

A summary of the predicted worst-case noise levels for other sensitive receivers for the 2034 (future year) scenario are presented in Table 11-14. The future year 2034 scenario has been presented as it results in the highest noise level predictions. Results for the at-opening 2024 scenario are provided in *Technical paper 2 – Noise and vibration*.

Table 11-14 Predicted 2034 airborne noise levels – other sensitive receivers Marrickville dive

NCA	Side	Worst-case predicted noise level (dBA)					
		Without project		With project		Increase	RING triggers
		$L_{Aeq(1h)}$ Day	$L_{Aeq(1h)}$ Night	$L_{Aeq(1h)}$ Day	$L_{Aeq(1h)}$ Night	$L_{Aeq(1h)}$	
32	Up	67	63	67	63	0	0
	Down	68	64	68	64	0	0
33	Up	51	49	55	51	4.8	0
	Down	N/A	N/A	N/A	N/A	N/A	0
34	Up	69	64	69	64	0	0
	Down	68	64	68	64	0	0

The results indicate that there are no RING triggers for other sensitive receivers in the vicinity of the Marrickville dive structure.

Future developments

The future land use of the residual land at the Chatswood dive site is not currently known, however, this may include multi-storey residential developments overlooking the rail corridor. These developments may be exposed to levels of operational airborne rail noise in excess of the RING absolute noise level criteria. Accordingly any future developments on this site should adequately address the noise criteria in the *Infrastructure State Environment Planning Policy 2007*.

The future land use of the residual land at the Marrickville dive site is not currently known, however, this is likely to comprise commercial and industrial developments. In the event that residential developments are considered for this site, such developments should adequately address the noise criteria in the *Infrastructure State Environment Planning Policy 2007*.

11.4.3 Operational noise from stations and ancillary facilities

Mechanical, electrical and ventilation services

The approach to assessment of noise from services at station and ancillary facilities is to calculate the maximum acceptable sound power level at each location based on the location of the proposed facility and the location of the nearest receivers. These maximum acceptable sound power levels would be used to guide the detailed design to ensure compliance with the applicable criteria from the *Industrial Noise Policy* (EPA, 2000).

The nearest receiver type and relevant external noise criteria for each services location are presented in Table 11-15. Based on previous experience on projects such as Epping to Chatswood Rail Line, it is expected that these levels can be achieved through the use of appropriate noise attenuation measures such as equipment selection, positioning of plant and ventilation discharges, in-duct attenuators, and acoustic enclosures.

Table 11-15 External noise criteria applicable to stations and ancillary facilities

Site	Services location	Nearest receiver type	External noise criteria (dBA)
Artarmon substation	Traction substation	Residential	45
Crows Nest Station	North services building	Commercial	65
	South services building	Commercial	65
Victoria Cross Station	North services building	Residential	56
		Commercial	65
	South services building including traction substation	Commercial	65
Barangaroo Station	North services building	Residential	45
	South services building	Residential	45
	Traction substation	Residential	45
Martin Place Station	North services building	Commercial	65
	South services building	Commercial	65
Pitt Street Station	North services building	Hotel (residential)	58
		Commercial	65
	South services building including traction substation	Commercial	65
Central Station	Services building	Hotel (residential)	50
		Commercial	65
Waterloo Station	North services building including traction substation	Residential	44
	South services building	Residential	44
		Place of worship	60
Southern services facility	Water treatment plant	Residential	46
		Commercial	65
	Traction substation	Residential	46
		Commercial	65

Train breakout noise from draught relief shafts

Noise generated during train passbys in the tunnels has the potential to escape from the tunnels via the draught relief shafts.

The noise criteria adopted for train breakout noise from draught relief shafts is L_{Amax} 55 dBA for residential receivers and L_{Amax} 65 dBA for commercial receivers. These noise criteria are comparable with the design criteria adopted for the Sydney Metro Northwest, Epping to Chatswood Rail Line (ECRL) and Sydney Airport Rail Line. They are also more stringent than the maximum noise goal of 80 dBA) applied in the *Rail Infrastructure Noise Guidelines* (EPA, 2013) relating to airborne noise from the operation of trains on new surface track.

The breakout noise has been predicted using the in-tunnel maximum reverberant noise levels, based on noise measurements carried out within the Epping to Chatswood Rail Line tunnels.

Noise breakout from draught relief shafts is not expected to exceed the nominated noise criteria (L_{Amax} of 55 dBA for residential receivers) at any receiver surrounding the proposed stations, with appropriate attenuator selection in place.

11.5 Mitigation measures

The mitigation measures that would be implemented to address potential operational noise and vibration impacts are listed in Table 11-16.

Table 11-16 Mitigation measures – operational noise and vibration

Ref	Mitigation measure	Applicable location(s)[1]
OpNV1	The height and extent of noise barriers adjacent to the northern surface track works would be confirmed during detailed design with the aim of not exceeding trigger levels from the *Rail Infrastructure Noise Guidelines* (Environment Protection Authority, 2013). At property treatments would be offered where there are residual exceedances of the trigger levels.	STW
OpNV2	Track form would be confirmed during the detailed design process in order to meet the relevant ground-borne noise and vibration criteria from the *Rail Infrastructure Noise Guidelines* (EPA, 2013) and the *Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects* (DECC, 2007).	Metro rail tunnels
OpNV3	Stations and ancillary facilities including train breakout noise from draught relief shafts would be designed to meet the applicable noise criteria derived from the *Industrial Noise Policy* (EPA, 2000).	All except metro rail tunnels

1 *STW: Surface track works; CDS: Chatswood dive site; AS: Artarmon substation; CN: Crows Nest Station; VC: Victoria Cross Station; BP: Blues Point temporary site; GI: Ground improvement works; BN: Barangaroo Station; MP: Martin Place Station; PS: Pitt Street Station; CS: Central Station; WS: Waterloo Station; MDS: Marrickville dive site; Metro rail tunnels: Metro rail tunnel related not related to other sites (eg TBM works); PSR: Power supply routes.*