Table 32 Worst-affected residential NML exceedances - work area establishment

NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
								Worst-case Predicted at Nearby Receivers[1,2]	NML Exceedance[3]				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
NCA01	53	53	49	63	58	58	54	77 - >90	14 - >25	19 - >25	19 - >25	23 - >25	>90	64	>25
NCA02	53	52	46	63	58	57	51	76 - >90	13 - >25	18 - >25	19 - >25	25 - >25	>90	61	>25
NCA03	50	50	46	60	55	55	51	69 - 85	9 - 25	14 - >25	14 - >25	18 - >25	88	61	>25
NCA04	50	49	43	60	55	54	48	73 - 89	13 - >25	18 - >25	19 - >25	25 - >25	>90	58	>25
NCA05	56	56	48	66	61	61	53	74 - 90	8 - 24	13 - >25	13 - >25	21 - >25	>90	63	>25
NCA06	53	52	46	63	58	57	51	75 - >90	12 - >25	17 - >25	18 - >25	24 - >25	>90	61	>25
NCA07	61	57	42	71	66	62	47	76 - >90	5 - 21	10 - >25	14 - >25	>25	>90	57	>25
NCA08	48	47	42	58	53	52	47	76 - >90	18 - >25	23 - >25	24 - >25	>25	>90	57	>25
NCA09	41	41	38	51	46	46	43	70 - 86	19 - >25	24 - >25	24 - >25	>25	89	53	>25
NCA10	41	41	40	51	46	46	45	59 - 75	8 - 24	13 - >25	13 - >25	14 - >25	78	55	23
NCA11	55	54	47	65	60	59	52	74 - 90	9 - 25	14 - >25	15 - >25	22 - >25	>90	62	>25
NCA12	50	50	46	60	55	55	51	73 - 89	13 - >25	18 - >25	18 - >25	22 - >25	>90	61	>25
NCA13	46	46	38	56	51	51	43	73 - 89	17 - >25	22 - >25	22 - >25	>25	>90	53	>25
NCA14	58	58	52	68	63	63	57	73 - 89	5 - 21	10 - >25	10 - >25	16 - >25	>90	67	25
NCA15	58	55	44	68	63	60	49	73 - 89	5 - 21	10 - >25	13 - >25	24 - >25	>90	59	>25
NCA16	56	53	43	66	61	58	48	77 - >90	11 - >25	16 - >25	19 - >25	>25	>90	58	>25
NCA17	56	53	43	66	61	58	48	77 - >90	11 - >25	16 - >25	19 - >25	>25	>90	58	>25
NCA18	46	46	43	56	51	51	48	76 - >90	20 - >25	25 - >25	25 - >25	>25	>90	58	>25
NCA19	56	54	44	66	61	59	49	66 - 82	up to 16	5 - 21	7 - 23	17 - >25	85	59	>25
NCA20	54	52	41	64	59	57	46	71 - 87	7 - 23	12 - >25	14 - >25	>25	90	56	>25
NCA21	58	55	45	68	63	60	50	77 - >90	9 - 25	14 - >25	17 - >25	>25	>90	60	>25
Receivers east of works limit	47	47	39	57	52	52	44	51 - 67	up to 10	up to 15	up to 15	7 - 23	70	54	16

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**)

Note 2: Worst-case predictions in excess of 90 dBA are a result of high noise equipment being operated less than 5 m from a receiver. Such impacts would be of limited duration.

Note 3: Results are representative of the worst-affected receiver. Typically no impacts are predicted at the outer extents of the NCAs. Full extent of noise impacts at all adjacent receivers are shown in **Appendix R.**

Table 33 Median residential NML exceedances - work area establishment

NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
								Worst-case Predicted[1]	NML Exceedance				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
NCA01	53	53	49	63	58	58	54	55-71	up to 8	up to 13	up to 13	1 - 17	74	64	10
NCA02	53	52	46	63	58	57	51	50-66	up to 3	up to 8	up to 9	up to 15	69	61	8
NCA03	50	50	46	60	55	55	51	46-62	up to 2	up to 7	up to 7	up to 11	65	61	4
NCA04	50	49	43	60	55	54	48	47-63	up to 3	up to 8	up to 9	up to 15	66	58	8
NCA05	56	56	48	66	61	61	53	43-59	-	-	-	up to 6	62	63	-
NCA06	53	52	46	63	58	57	51	44-60	-	up to 2	up to 3	up to 9	63	61	2
NCA07	61	57	42	71	66	62	47	43-59	-	-	-	up to 12	62	57	5
NCA08	48	47	42	58	53	52	47	72-88	14 - 30	19 - 35	20 - 36	25 - 41	91	57	34
NCA09	41	41	38	51	46	46	43	35-51	-	up to 5	up to 5	up to 8	54	53	1
NCA10	41	41	40	51	46	46	45	40-56	up to 5	up to 10	up to 10	up to 11	59	55	4
NCA11	55	54	47	65	60	59	52	33-49	-	-	-	-	52	62	-
NCA12	50	50	46	60	55	55	51	35-51	-	-	-	-	54	61	-
NCA13	46	46	38	56	51	51	43	44-60	up to 4	up to 9	up to 9	1 - 17	63	53	10
NCA14	58	58	52	68	63	63	57	58-74	up to 6	up to 11	up to 11	1 - 17	77	67	10
NCA15	58	55	44	68	63	60	49	59-75	up to 7	up to 12	up to 15	10 - 26	78	59	19
NCA16	56	53	43	66	61	58	48	50-66	-	up to 5	up to 8	2 - 18	69	58	11
NCA17	56	53	43	66	61	58	48	42-58	-	-	-	up to 10	61	58	3
NCA18	46	46	43	56	51	51	48	52-68	up to 12	1 - 17	1 - 17	4 - 20	71	58	13
NCA19	56	54	44	66	61	59	49	43-59	-	-	-	up to 10	62	59	3
NCA20	54	52	41	64	59	57	46	45-61	-	up to 2	up to 4	up to 15	64	56	8
NCA21	58	55	45	68	63	60	50	48-64	-	up to 1	up to 4	up to 14	67	60	7
Receivers east of works limit	47	47	39	57	52	52	44	33-49	-	-	-	up to 5	52	54	-

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**)

Worst-affected receiver impacts

Where works are located directly adjacent to sensitive receivers, worst-case NML exceedances of greater than 25 dBA are predicted at the most potentially affected residential receivers during standard daytime hours. At the worst-affected receivers, worst-case predicted NML exceedances of over 25 dBA at residential receivers are common across the proposal area for Work area establishment works during standard daytime hours.

Out of hours works would be expected to result in higher noise impacts than works during standard daytime hours at all locations. Predicted construction noise levels at the most affected residential receivers in each NCA would typically be greater than 25 dBA during out of hours works during noise intensive periods where works are located immediately adjacent to these receivers.

Typical receiver impacts

The median impacts (**Table 33**) are predicted to be significantly less than those at the worst-affected receiver (**Table 32**).

The median predicted NML exceedances during standard daytime hours are typically minor (less than 10 dB). It is noted that NCA08, NCA15 and NCA18 are relatively small catchments bounded by other NCAs and would therefore tend to have higher median impacts compared to the typical NCA. High median NML exceedances in NCA08 are predicted as the majority of the existing properties are acquired leaving only a small number of receivers located close to the works.

Median OOHW impacts are typically minor (up to 10 dBA) or moderate (up to 20 dBA). The exception is found in NCA08 and NCA15 for which high (more than 20 dBA) NML exceedances are predicted on account of the near vicinity to the works.

Other sensitive receiver impacts

Other sensitive receivers are generally predicted to be subject to moderate NML exceedances of up to 15 dBA (refer to **Appendix Q**), with the exception of the following receivers which have higher predicted noise impacts when in use:

- Place of Worship in NCA04 immediately adjacent Underwood Road tunnel and civil site (greater than 25 dBA exceedance of NML)
- Place of Worship in NCA06 near Concord Road civil and tunnel site (up to 22 dBA exceedance of NML)
- Place of Worship in NCA07 immediately adjacent Concord Road civil and tunnel site (greater than 25 dBA exceedance of NML)
- Medical Facilities in NCA12 immediately adjacent Cintra Park tunnel site (greater than 25 dBA exceedance of NML)
- Place of Worship in NCA14 immediately adjacent Wattle Street and Walker Avenue civil site (greater than 25 dBA exceedance of NML)
- Passive Recreation Area in NCA16 immediately adjacent Wattle Street and Walker Avenue civil site (greater than 25 dBA exceedance of NML)
- Educational Facility in NCA19 immediately adjacent Parramatta Road civil site (greater than 25 dBA exceedance of NML)
- Childcare Centre in NCA20 immediately adjacent Parramatta Road civil site (greater than 25 dBA exceedance of NML)
- Active Recreation Area east of works limit immediately adjacent Parramatta Road civil site (up to 22 dBA exceedance of NML)

Further information

Maps indicating the worst-case NML exceedances at all receivers for the work area establishment works are shown in **Appendix R1**.

Impacts for all receivers are also summarised by NCA in **Section 14**.

10.6.3 Temporary road and intersection modifications

Temporary Road and Intersection Modification works may be required during out-of-hours periods due to the traffic control requirements of the works.

Table 34 presents a summary of the worst-case predicted noise impacts at residential receivers during Temporary Road and Intersection Modification works.

Table 34 Worst-affected residential NML exceedances - temporary road and intersection modifications

NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
								Worst-case Predicted at Nearby Receivers[1,2]	NML Exceedance[3]				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
NCA01	53	53	49	63	58	58	54	<30	-	-	-	-	4	64	-
NCA02	53	52	46	63	58	57	51	<30	-	-	-	-	4	61	-
NCA03	50	50	46	60	55	55	51	<30	-	-	-	-	4	61	-
NCA04	50	49	43	60	55	54	48	<30	-	-	-	-	31	58	-
NCA05	56	56	48	66	61	61	53	<30	-	-	-	-	4	63	-
NCA06	53	52	46	63	58	57	51	55 - 58	-	-	up to 1	4 - 7	62	61	1
NCA07	61	57	42	71	66	62	47	61 - 64	-	-	up to 2	14 - 17	68	57	11
NCA08	48	47	42	58	53	52	47	50 - 53	-	-	up to 1	3 - 6	57	57	-
NCA09	41	41	38	51	46	46	43	52 - 55	1 - 4	6 - 9	6 - 9	9 - 12	59	53	6
NCA10	41	41	40	51	46	46	45	41 - 44	-	-	-	-	48	55	-
NCA11	55	54	47	65	60	59	52	49 - 52	-	-	-	-	56	62	-
NCA12	50	50	46	60	55	55	51	62 - 65	2 - 5	7 - 10	7 - 10	11 - 14	69	61	8
NCA13	46	46	38	56	51	51	43	55 - 58	up to 2	4 - 7	4 - 7	12 - 15	62	53	9
NCA14	58	58	52	68	63	63	57	69 - 72	1 - 4	6 - 9	6 - 9	12 - 15	76	67	9
NCA15	58	55	44	68	63	60	49	62 - 65	-	up to 2	2 - 5	13 - 16	69	59	10
NCA16	56	53	43	66	61	58	48	77 - 80	11 - 14	16 - 19	19 - 22	>25	84	58	>25
NCA17	56	53	43	66	61	58	48	68 - 71	2 - 5	7 - 10	10 - 13	20 - 23	75	58	17
NCA18	46	46	43	56	51	51	48	65 - 68	9 - 12	14 - 17	14 - 17	17 - 20	72	58	14
NCA19	56	54	44	66	61	59	49	46 - 49	-	-	-	-	53	59	-
NCA20	54	52	41	64	59	57	46	61 - 64	-	2 - 5	4 - 7	15 - 18	68	56	12
NCA21	58	55	45	68	63	60	50	66 - 69	up to 1	3 - 6	6 - 9	16 - 19	73	60	13
Receivers east of works limit	47	47	39	57	52	52	44	38 - 41	-	-	-	-	45	54	-

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**)
Note 2: Worst-case predictions in excess of 90 dBA are a result of high noise equipment being operated less than 5 m from a receiver. Such impacts would be of limited duration.
Note 3: Results are representative of the worst-affected receiver. Typically no impacts are predicted at the outer extents of the NCAs. Full extent of noise impacts at all adjacent receivers are shown in **Appendix R.**

Table 35 Median residential NML exceedances - temporary road and intersection modifications

NCA	RBL			NML				Noise Level - $L_{Aeq(15minute)}$ (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
								Worst-case Predicted[1]	NML Exceedance				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
NCA01	53	53	49	63	58	58	54	<30	-	-	-	-	<30	64	-
NCA02	53	52	46	63	58	57	51	<30	-	-	-	-	<30	61	-
NCA03	50	50	46	60	55	55	51	<30	-	-	-	-	<30	61	-
NCA04	50	49	43	60	55	54	48	<30	-	-	-	-	<30	58	-
NCA05	56	56	48	66	61	61	53	<30	-	-	-	-	<30	63	-
NCA06	53	52	46	63	58	57	51	<30	-	-	-	-	31	61	-
NCA07	61	57	42	71	66	62	47	36-39	-	-	-	-	43	57	-
NCA08	48	47	42	58	53	52	47	45-48	-	-	-	up to 1	52	57	-
NCA09	41	41	38	51	46	46	43	<30	-	-	-	-	30	53	-
NCA10	41	41	40	51	46	46	45	<30	-	-	-	-	33	55	-
NCA11	55	54	47	65	60	59	52	<30	-	-	-	-	<30	62	-
NCA12	50	50	46	60	55	55	51	<30	-	-	-	-	31	61	-
NCA13	46	46	38	56	51	51	43	35-38	-	-	-	-	42	53	-
NCA14	58	58	52	68	63	63	57	45-48	-	-	-	-	52	67	-
NCA15	58	55	44	68	63	60	49	42-45	-	-	-	-	49	59	-
NCA16	56	53	43	66	61	58	48	42-45	-	-	-	-	49	58	-
NCA17	56	53	43	66	61	58	48	36-39	-	-	-	-	43	58	-
NCA18	46	46	43	56	51	51	48	38-41	-	-	-	-	45	58	-
NCA19	56	54	44	66	61	59	49	34-37	-	-	-	-	41	59	-
NCA20	54	52	41	64	59	57	46	34-37	-	-	-	-	41	56	-
NCA21	58	55	45	68	63	60	50	36-39	-	-	-	-	43	60	-
Receivers east of works limit	47	47	39	57	52	52	44	<30	-	-	-	-	<30	54	-

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**)

Worst-affected receiver impacts

Noise predictions presented in **Table 34** indicate Temporary Road and Intersection Modification works are unlikely to produce significant noise impacts at residential receivers during standard daytime hours except for NCA18 and NCA16 where worst-case NML exceedances of up to 12 dBA and 14 dBA are predicted respectively due to the close proximity of the works to nearby residential receivers.

If Temporary Road and Intersection Modification works are required to be undertaken during the night time out-of-hours period, NML exceedances of more than 10 dBA are predicted for several NCAs adjacent the works. NCAs that include residential receivers located immediately adjacent the intersections show larger worst case impacts than NCAs far from the works. Worst case night-time NML exceedances of greater than 25 dBA are predicted for NCA16 which includes receiver buildings immediately adjacent the works.

Typical receiver impacts

Median NML exceedances (**Table 35**) are predicted to be negligible, indicating that these works affect a small proportion of the study area.

Other sensitive receiver impacts

Other sensitive receivers are generally predicted to be subject to moderate NML exceedances of up to 15 dBA when in use (refer to **Appendix Q**).

Further information

Maps indicating the worst-case NML exceedances for the Temporary Road and Intersection Modification works are shown in **Appendix R2**.

Impacts for all receivers are also summarised by NCA in **Section 14**.

10.6.4 Construction ancillary facilities

Construction ancillary facilities are located within several key construction areas within the proposal footprint. The construction ancillary facilities include the below sites:

- C1 - Homebush Bay Drive civil site
- C2 – Pomeroy Street civil site
- C3 - Underwood Road civil and tunnel site
- C4 – Powells Creek civil site
- C5 - Concord Road civil and tunnel site
- C6 – Cintra Park tunnel site
- C7 - Northcote Street tunnel site
- C8 - Eastern ventilation facility site
- C9 – Wattle Street and Walker Avenue civil site
- C10 - Parramatta Road civil site.

Construction activities proposed to be undertaken within these areas are listed in **Table 31**. Activities associated with works within the construction ancillary facilities are anticipated to be undertaken within the extents of the proposal boundary. Construction civil site works may be undertaken at property boundaries immediately adjacent sensitive receivers. Acoustic shielding provided by property boundary fencing has not been included in the construction noise prediction methodology, as such results are considered conservative as boundary fencing may provide some degree of construction noise mitigation in most circumstances

Table 36 presents a summary of the worst-case predicted noise impacts at residential receivers during the construction of the ancillary facilities. Construction ancillary facilities (civil sites) are proposed to operate during the standard daytime construction periods only. Tunnel sites are assessed in **Section 10.6.6**.

Table 36 Worst-affected residential NML exceedances - construction ancillary facilities: general worksites

Compound	NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
									Worst-case Predicted at Nearby Receivers[1,2]	NML Exceedance[3]				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
		Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
C1 Homebush Bay Drive Civil	NCA01	53	53	49	63	58	58	54	59 - 79	up to 16	n/a	n/a	n/a	n/a	64	-
C2 Pomeroy Street civil	NCA02	53	52	46	63	58	57	51	64 - 84	1 - 21	n/a	n/a	n/a	n/a	61	-
	NCA03	50	50	46	60	55	55	51	53 - 73	up to 13	n/a	n/a	n/a	n/a	61	-
C3 Underwood Road tunnel and civil	NCA04	50	49	43	60	55	54	48	60 - 80	up to 20	n/a	n/a	n/a	n/a	58	-
C4 Powells Creek civil	NCA05	56	56	48	66	61	61	53	63 - 83	up to 17	n/a	n/a	n/a	n/a	63	-
C5 Concord Road civil and tunnel	NCA06	53	52	46	63	58	57	51	59 - 79	up to 16	n/a	n/a	n/a	n/a	61	-
	NCA07	61	57	42	71	66	62	47	51 - 71	-	n/a	n/a	n/a	n/a	57	-
	NCA08	48	47	42	58	53	52	47	62 - 82	4 - 24	n/a	n/a	n/a	n/a	57	-
	NCA09	41	41	38	51	46	46	43	52 - 72	1 - 21	n/a	n/a	n/a	n/a	53	-
	NCA10	41	41	40	51	46	46	45	46 - 66	up to 15	n/a	n/a	n/a	n/a	55	-
	NCA11	55	54	47	65	60	59	52	58 - 78	up to 13	n/a	n/a	n/a	n/a	62	-
C6 Cintra Park tunnel site	NCA12	50	50	46	60	55	55	51	60 - 80	up to 20	n/a	n/a	n/a	n/a	61	-
C7 Northcote Street tunnel	NCA13	46	46	38	56	51	51	43	59 - 79	3 - 23	n/a	n/a	n/a	n/a	53	-
	NCA14	58	58	52	68	63	63	57	58 - 78	up to 10	n/a	n/a	n/a	n/a	67	-

Compound	NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
		Day	Eve	Night	Day	Day OOH	Eve	Night	Worst-case Predicted at Nearby Receivers[1,2]	NML Exceedance[3] Day	Day OOH	Eve	Night	Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
C9 Wattle Street and Walker Avenue civil[4] and C8 Eastern ventilation facility site	NCA15	58	55	44	68	63	60	49	58 - 78	up to 10	n/a	n/a	n/a	n/a	59	-
	NCA16	56	53	43	66	61	58	48	61 - 81	up to 15	n/a	n/a	n/a	n/a	58	-
	NCA17	56	53	43	66	61	58	48	60 - 80	up to 14	n/a	n/a	n/a	n/a	58	-
C10 Parramatta Road civil site	NCA18	46	46	43	56	51	51	48	65 - 85	9 - >25	n/a	n/a	n/a	n/a	58	-
	NCA19	56	54	44	66	61	59	49	50 - 70	up to 4	n/a	n/a	n/a	n/a	59	-
	NCA20	54	52	41	64	59	57	46	53 - 73	up to 9	n/a	n/a	n/a	n/a	56	-
	NCA21	58	55	45	68	63	60	50	64 - 84	up to 16	n/a	n/a	n/a	n/a	60	-
	Receivers east of works limit	47	47	39	57	52	52	44	35 - 55	-	n/a	n/a	n/a	n/a	54	-

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**)
Note 2: Worst-case predictions in excess of 90 dBA are a result of high noise equipment being operated less than 5 m from a receiver . Such impacts would be of limited duration
Note 3: Results are representative of the worst-affected receiver. Typically no impacts are predicted at the outer extents of the NCAs. Full extent of noise impacts at all adjacent receivers are shown in **Appendix R**.

Table 37 Median residential NML exceedances - construction ancillary facilities: general worksites

Compound	NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
									Worst-case Predicted[1]	NML Exceedance				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
		Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
C1 Homebush Bay Drive Civil	NCA01	53	53	49	63	58	58	54	40-60	-	n/a	n/a	n/a	n/a	64	-
C2 Pomeroy Street civil	NCA02	53	52	46	63	58	57	51	33-53	-	n/a	n/a	n/a	n/a	61	-
	NCA03	50	50	46	60	55	55	51	30-50	-	n/a	n/a	n/a	n/a	61	-
C3 Underwood Road tunnel and civil	NCA04	50	49	43	60	55	54	48	34-54	-	n/a	n/a	n/a	n/a	58	-
C4 Powells Creek civil	NCA05	56	56	48	66	61	61	53	31-51	-	n/a	n/a	n/a	n/a	63	-
C5 Concord Road civil and tunnel	NCA06	53	52	46	63	58	57	51	30-50	-	n/a	n/a	n/a	n/a	61	-
	NCA07	61	57	42	71	66	62	47	up to 49	-	n/a	n/a	n/a	n/a	57	-
	NCA08	48	47	42	58	53	52	47	59-79	1 - 21	n/a	n/a	n/a	n/a	57	-
	NCA09	41	41	38	51	46	46	43	up to 43	-	n/a	n/a	n/a	n/a	53	-
	NCA10	41	41	40	51	46	46	45	up to 49	-	n/a	n/a	n/a	n/a	55	-
	NCA11	55	54	47	65	60	59	52	up to 43	-	n/a	n/a	n/a	n/a	62	-
C6 Cintra Park tunnel site	NCA12	50	50	46	60	55	55	51	up to 44	-	n/a	n/a	n/a	n/a	61	-
C7 Northcote Street tunnel	NCA13	46	46	38	56	51	51	43	31-51	-	n/a	n/a	n/a	n/a	53	-
	NCA14	58	58	52	68	63	63	57	43-63	-	n/a	n/a	n/a	n/a	67	-
C9 Wattle Street and Walker Avenue civil[4] and C8 Eastern ventilation facility site	NCA15	58	55	44	68	63	60	49	45-65	-	n/a	n/a	n/a	n/a	59	-
	NCA16	56	53	43	66	61	58	48	37-57	-	n/a	n/a	n/a	n/a	58	-
	NCA17	56	53	43	66	61	58	48	up to 49	-	n/a	n/a	n/a	n/a	58	-

Compound	NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
		Day	Eve	Night	Day	Day OOH	Eve	Night	Worst-case Predicted[1]	NML Exceedance Day	Day OOH	Eve	Night	Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
C10 Parramatta Road civil site	NCA18	46	46	43	56	51	51	48	39-59	up to 3	n/a	n/a	n/a	n/a	58	-
	NCA19	56	54	44	66	61	59	49	31-51	-	n/a	n/a	n/a	n/a	59	-
	NCA20	54	52	41	64	59	57	46	31-51	-	n/a	n/a	n/a	n/a	56	-
	NCA21	58	55	45	68	63	60	50	36-56	-	n/a	n/a	n/a	n/a	60	-
	Receivers east of works limit	47	47	39	57	52	52	44	up to 43	-	n/a	n/a	n/a	n/a	54	-

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**)

Worst-affected receiver impacts

Works activities undertaken within construction ancillary facilities are anticipated to generate NML exceedances of greater than 10 dBA during standard daytime hours at residential receivers located immediately adjacent to most compound locations. Worst case NML exceedances are predicted to vary significantly between NCAs depending on the proximity of the potentially most affected receiver to the construction compounds noise producing plant. NCAs with receivers immediately adjacent a construction ancillary facility are predicted to receive higher worst-case NML exceedances than NCAs further from the works.

As the construction ancillary facilities are at fixed locations, it is likely that mitigation measures such as temporary noise walls, in combination with judicious selection of works areas within the site would assist in reducing impacts. These are discussed further in **Section 10.8.3**.

Typical receiver impacts

Median NML exceedances (**Table 37**) are predicted to be negligible, indicating that these works affect a small proportion of the study area. The exception is found in NCA08 for which high (more than 20 dBA) worst-case NML exceedances are predicted on account of the near vicinity to the works.

Other sensitive receiver impacts

Other sensitive receivers are generally predicted to be subject to moderate NML exceedances of up to 10 dBA during standard daytime hours (refer to **Appendix Q**), with the exception of the following receivers which have higher predicted noise impacts:

- Place of Worship in NCA04 immediately adjacent Underwood Road tunnel and civil site (up to 20 dBA exceedance of NML)
- Place of Worship in NCA07 immediately adjacent Concord Road civil and tunnel site (up to 17 dBA exceedance of NML)
- Medical Facilities in NCA12 immediately adjacent Cintra Park tunnel site (up to 21 dBA exceedance of NML)
- Active Recreation Area in NCA12 immediately adjacent Cintra Park tunnel site (up to 10 dBA exceedance of NML)
- Place of Worship in NCA14 immediately adjacent Wattle Street and Walker Avenue civil site (up to 17 dBA exceedance of NML)
- Passive Recreation Area in NCA16 immediately adjacent Wattle Street and Walker Avenue civil site (greater than 25 dBA exceedance of NML)
- Educational Facility in NCA19 immediately adjacent Parramatta Road civil site (up to 17 dBA exceedance of NML)
- Childcare Centre in NCA20 immediately adjacent Parramatta Road civil site (up to 22 dBA exceedance of NML)
- Active Recreation Area east of works limit immediately adjacent Parramatta Road civil site (up to 3 dBA exceedance of NML)

Further information

Maps indicating the worst-case NML exceedance at each of the proposed sites are shown in **Appendix R3**.

These impacts are also summarised by NCA in **Section 14**.

10.6.5 Roads works

Activities associated with Road Works are anticipated to be undertaken within the extents of the carriageway areas nominated for pavement modifications and areas of new carriageway. Construction activities proposed to be undertaken within these areas are listed in **Table 31**. Some Road Works activities may be required during out-of-hours periods due to the traffic control requirements of the works in some areas.

Table 38 presents a summary of the worst-case predicted noise impacts at residential receivers during Road Works.

Table 38 Worst-affected residential NML exceedances - roads/cut-and-cover/dive structures and approach roads and ramps

NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
								Worst-case Predicted at Nearby Receivers[1,2]	NML Exceedance[3]				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
NCA01	53	53	49	63	58	58	54	>90	>25	>25	>25	>25	>90	64	>25
NCA02	53	52	46	63	58	57	51	86 - >90	23 - >25	>25	>25	>25	>90	61	>25
NCA03	50	50	46	60	55	55	51	84 - >90	24 - >25	>25	>25	>25	>90	61	>25
NCA04	50	49	43	60	55	54	48	74 - 88	14 - >25	19 - >25	20 - >25	>25	>90	58	>25
NCA05	56	56	48	66	61	61	53	76 - 90	10 - 24	15 - >25	15 - >25	23 - >25	>90	63	>25
NCA06	53	52	46	63	58	57	51	84 - >90	21 - >25	>25	>25	>25	>90	61	>25
NCA07	61	57	42	71	66	62	47	86 - >90	15 - >25	20 - >25	24 - >25	>25	>90	57	>25
NCA08	48	47	42	58	53	52	47	83 - >90	25 - >25	>25	>25	>25	>90	57	>25
NCA09	41	41	38	51	46	46	43	82 - >90	>25	>25	>25	>25	>90	53	>25
NCA10	41	41	40	51	46	46	45	55 - 69	4 - 18	9 - 23	9 - 23	10 - 24	72	55	17
NCA11	55	54	47	65	60	59	52	82 - >90	17 - >25	22 - >25	23 - >25	>25	>90	62	>25
NCA12	50	50	46	60	55	55	51	54 - 68	up to 8	up to 13	up to 13	3 - 17	71	61	10
NCA13	46	46	38	56	51	51	43	73 - 87	17 - >25	22 - >25	22 - >25	>25	90	53	>25
NCA14	58	58	52	68	63	63	57	82 - >90	14 - >25	19 - >25	19 - >25	25 - >25	>90	67	>25
NCA15	58	55	44	68	63	60	49	84 - >90	16 - >25	21 - >25	24 - >25	>25	>90	59	>25
NCA16	56	53	43	66	61	58	48	87 - >90	21 - >25	26 - >25	>25	>25	>90	58	>25
NCA17	56	53	43	66	61	58	48	86 - >90	20 - >25	25 - >25	>25	>25	>90	58	>25
NCA18	46	46	43	56	51	51	48	>90	>25	>25	>25	>25	>90	58	>25
NCA19	56	54	44	66	61	59	49	74 - 88	8 - 22	13 - >25	15 - >25	25 - >25	>90	59	>25
NCA20	54	52	41	64	59	57	46	79 - >90	15 - >25	20 - >25	22 - >25	>25	>90	56	>25
NCA21	58	55	45	68	63	60	50	85 - >90	17 - >25	22 - >25	25 - >25	>25	>90	60	>25
Receivers east of works limit	47	47	39	57	52	52	44	65 - 79	8 - 22	13 - >25	13 - >25	21 - >25	82	54	>25

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**)

Note 2: Worst-case predictions in excess of 90 dBA are a result of high noise equipment being operated less than 5 m from a receiver. Such impacts would be of limited duration.

Note 3: Results are representative of the worst-affected receiver. Typically no impacts are predicted at the outer extents of the NCAs. Full extent of noise impacts at all adjacent receivers are shown in **Appendix R**

Table 39 Median residential NML exceedances - roads/cut-and-cover/dive structures and approach roads and ramps

NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
								Worst-case Predicted[1]	NML Exceedance				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
NCA01	53	53	49	63	58	58	54	64-78	1 - 15	6 - 20	6 - 20	10 - 24	81	64	17
NCA02	53	52	46	63	58	57	51	54-68	up to 5	up to 10	up to 11	3 - 17	71	61	10
NCA03	50	50	46	60	55	55	51	51-65	up to 5	up to 10	up to 10	up to 14	68	61	7
NCA04	50	49	43	60	55	54	48	50-64	up to 4	up to 9	up to 10	2 - 16	67	58	9
NCA05	56	56	48	66	61	61	53	43-57	-	-	-	up to 4	60	63	-
NCA06	53	52	46	63	58	57	51	45-59	-	up to 1	up to 2	up to 8	62	61	1
NCA07	61	57	42	71	66	62	47	49-63	-	-	up to 1	2 - 16	66	57	9
NCA08	48	47	42	58	53	52	47	68-82	10 - 24	15 - 29	16 - 30	21 - 35	85	57	28
NCA09	41	41	38	51	46	46	43	39-53	up to 2	up to 7	up to 7	up to 10	56	53	3
NCA10	41	41	40	51	46	46	45	42-56	up to 5	up to 10	up to 10	up to 11	59	55	4
NCA11	55	54	47	65	60	59	52	40-54	-	-	-	up to 2	57	62	-
NCA12	50	50	46	60	55	55	51	<30	-	-	-	-	17	61	-
NCA13	46	46	38	56	51	51	43	45-59	up to 3	up to 8	up to 8	2 - 16	62	53	9
NCA14	58	58	52	68	63	63	57	54-68	-	up to 5	up to 5	up to 11	71	67	4
NCA15	58	55	44	68	63	60	49	64-78	up to 10	1 - 15	4 - 18	15 - 29	81	59	22
NCA16	56	53	43	66	61	58	48	54-68	up to 2	up to 7	up to 10	6 - 20	71	58	13
NCA17	56	53	43	66	61	58	48	48-62	-	up to 1	up to 4	up to 14	65	58	7
NCA18	46	46	43	56	51	51	48	56-70	up to 14	5 - 19	5 - 19	8 - 22	73	58	15
NCA19	56	54	44	66	61	59	49	47-61	-	-	up to 2	up to 12	64	59	5
NCA20	54	52	41	64	59	57	46	49-63	-	up to 4	up to 6	3 - 17	66	56	10
NCA21	58	55	45	68	63	60	50	52-66	-	up to 3	up to 6	2 - 16	69	60	9
Receivers east of works limit	47	47	39	57	52	52	44	41-55	-	up to 3	up to 3	up to 11	58	54	4

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**)

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Worst-affected receiver impacts

Activities associated with Road Works during standard daytime hours are predicted to produce worst-case NML exceedances of more than 10 dBA at residential receivers in most NCAs. Road Works are located near residential receivers in all NCAs except NCA12. The Road Works construction activities are likely to come within close proximity to some residential receivers, resulting in significant NML exceedances of greater than 25 dBA during the daytime and night time periods. Exceedances of this nature are a result of works being undertaken very near the residential property boundary.

Predicted worst-case noise impacts are higher in noise catchment areas that include road works close to residential and other sensitive receivers. In many cases the works are proposed to be undertaken on new and existing road sections within 15 m of a sensitive receiver building facade.

Noise mitigation measures, including construction of the design noise walls (for mitigating operational noise impacts) at an early stage in the construction are discussed in **Section 10.8.3**.

Out of hours works would be expected to result in higher noise impacts than works during standard daytime hours at all locations. Predicted worst-case NML exceedances at the most affected residential receivers in each NCA would typically be greater than 25 dBA during out of hours works for noise intensive periods where works are located immediately adjacent to these receivers.

Typical receiver impacts

The median impacts (**Table 39**) are predicted to be significantly less than those at the worst-affected receiver (**Table 38**).

The median predicted NML exceedances during standard daytime hours are typically minor (less than 10 dB). It is noted that NCA08, NCA15 and NCA18 are relatively small catchments bounded by other NCAs and would therefore tend to have higher median impacts compared to the typical NCA. Moderate (up to 20 dBA) median NML exceedances in NCA01 and NCA18 and high (over 20 dBA) NML exceedances in NCA08 are predicted as the majority receivers are located close to the works.

Median OOHW impacts are typically minor (up to 10 dBA) or moderate (up to 20 dBA). The exception is found in NCA01, NCA08, NCA15 and NCA18 for which high (more than 20 dBA) NML exceedances are predicted on account of the near vicinity to the works.

Other sensitive receiver impacts

Other sensitive receivers are generally predicted to be subject to moderate NML exceedances of up to 15 dBA (refer to **Appendix Q**), with the exception of the following receivers which have higher predicted noise impacts during standard daytime hours:

- Place of Worship in NCA04 adjacent M4 Road Works (up to 25 dBA exceedance of NML)
- Place of Worship in NCA06 adjacent Concord Road Works (up to 25 dBA exceedance of NML)
- Place of Worship in NCA07 immediately adjacent Concord Road Works (greater than 25 dBA exceedance of NML)
- Place of Worship in NCA11 near M4 and Parramatta Road Works (up to 19 dBA exceedance of NML)
- Place of Worship in NCA14 immediately adjacent Wattle Street Road Works (greater than 25 dBA exceedance of NML)
- Passive Recreation Area in NCA16 immediately adjacent Wattle Street Road Works site (greater than 25 dBA exceedance of NML)
- Educational Facility in NCA19 immediately adjacent Parramatta Road Works site (greater than 25 dBA exceedance of NML)
- Childcare Centre in NCA20 immediately adjacent Parramatta Road Works site (greater than 25 dBA exceedance of NML)
- Active Recreation Area east of works limit immediately adjacent Parramatta Road Works site (greater than 25 dBA exceedance of NML)

It is noted that wherever practical, piling activities shall be undertaken using quieter alternative methods than impact or percussion piling, such as bored piles or vibrated piles. If a requirement for impact piling is identified, this will be assessed further during detailed design. Indicatively, predicted noise levels may be up to 20 dBA higher for impact piling compared to other piling methods for works undertaken in close vicinity to noise sensitive receivers.

Further information

Maps indicating the worst-case NML exceedances for the Road Works construction scenario are shown in **Appendix R4**.

These impacts are also summarised by NCA in **Section 14**.

10.6.6 Tunnelling site operations

Tunnelling site operations are anticipated to be undertaken on a 24/7 basis for all tunnelling sites. As such, the most sensitive assessment period that is likely to result in the greatest noise impacts is the night-time out-of-hours period.

Table 40 presents a summary of the worst-case predicted noise impacts at residential receivers during Tunnelling Site Operations without mitigation. Refer to **Section 10.8** for a discussion of noise mitigation proposed at the tunnel sites.

Table 40 Worst-affected residential NML exceedances - tunnelling site operations, including excavation and ground support, civil, mechanical, and electrical

Tunnelling Site	NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
									Worst-case Predicted at Nearby Receivers[1]	NML Exceedance				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
		Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
Underwood Road	NCA01	53	53	49	63	58	58	54	<30	-	-	-	-	7	64	-
	NCA02	53	52	46	63	58	57	51	55 - 59	-	up to 1	up to 2	4 - 8	64	61	3
	NCA03	50	50	46	60	55	55	51	52 - 56	-	up to 1	up to 1	1 - 5	61	61	-
	NCA04	50	49	43	60	55	54	48	39 - 79	up to 19	up to 24	up to 25	>25	84	58	>25
	NCA05	56	56	48	66	61	61	53	41 - 64	-	up to 3	up to 3	up to 11	69	63	6
	NCA06	53	52	46	63	58	57	51	57 - 66	up to 3	up to 8	up to 9	6 - 15	71	61	10
Concord Road civil and tunnel	NCA07	61	57	42	71	66	62	47	64 - 78	up to 7	up to 12	2 - 16	17 - >25	83	57	>25
	NCA08	48	47	42	58	53	52	47	73 - 90	15 - >25	20 - >25	21 - >25	>25	>90	57	>25
	NCA09	41	41	38	51	46	46	43	60 - 77	9 - >25	14 - >25	14 - >25	17 - >25	82	53	>25
	NCA10	41	41	40	51	46	46	45	51 - 60	up to 9	5 - 14	5 - 14	6 - 15	65	55	10
	NCA11	55	54	47	65	60	59	52	55 - 67	up to 2	up to 7	up to 8	3 - 15	72	62	10
Cintra Park	NCA12	50	50	46	60	55	55	51	68 - 74	8 - 14	13 - 19	13 - 19	17 - 23	79	61	18
Northcote Street	NCA13	46	46	38	56	51	51	43	58 - 66	2 - 10	7 - 15	7 - 15	15 - 23	71	53	18
	NCA14	58	58	52	68	63	63	57	61 - 76	up to 8	up to 13	up to 13	4 - 19	81	67	14
	NCA15	58	55	44	68	63	60	49	52 - 57	-	-	-	3 - 8	62	59	3
	NCA16	56	53	43	66	61	58	48	38 - 50	-	-	-	up to 2	55	58	-
	NCA17	56	53	43	66	61	58	48	34 - 43	-	-	-	-	48	58	-
	NCA18	46	46	43	56	51	51	48	54 - 68	up to 12	3 - 17	3 - 17	6 - 20	73	58	15
	NCA19	56	54	44	66	61	59	49	46 - 52	-	-	-	up to 3	57	59	-
	NCA20	54	52	41	64	59	57	46	39 - 43	-	-	-	-	48	56	-
	NCA21	58	55	45	68	63	60	50	44 - 51	-	-	-	up to 1	56	60	-
	Receivers east of works limit	47	47	39	57	52	52	44	<30	-	-	-	-	7	54	-

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**)
Note 2: Results are representative of the worst-affected receiver. Typically no impacts are predicted at the outer extents of the NCAs. Full extent of noise impacts at all adjacent receivers are shown in **Appendix R**.

Table 41 Median residential NML exceedances - tunnelling site operations, including excavation and ground support, civil, mechanical, and electrical

Tunnelling Site	NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
									Worst-case Predicted[1]	NML Exceedance				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
		Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
Underwood Road	NCA01	53	53	49	63	58	58	54	<30	-	-	-	-	7	64	-
	NCA02	53	52	46	63	58	57	51	34-38	-	-	-	-	43	61	-
	NCA03	50	50	46	60	55	55	51	up to 33	-	-	-	-	38	61	-
	NCA04	50	49	43	60	55	54	48	50-54	-	-	-	up to 6	59	58	1
	NCA05	56	56	48	66	61	61	53	32-36	-	-	-	-	41	63	-
	NCA06	53	52	46	63	58	57	51	up to 45	-	-	-	-	50	61	-
Concord Road civil and tunnel	NCA07	61	57	42	71	66	62	47	33-41	-	-	-	-	43	57	-
	NCA08	48	47	42	58	53	52	47	52-67	up to 9	up to 14	up to 15	up to 20	72	57	15
	NCA09	41	41	38	51	46	46	43	33-40	-	-	-	-	45	53	-
	NCA10	41	41	40	51	46	46	45	39-47	-	up to 1	up to 1	up to 2	52	55	-
	NCA11	55	54	47	65	60	59	52	34-41	-	-	-	-	46	62	-
Cintra Park	NCA12	50	50	46	60	55	55	51	31-41	-	-	-	-	46	61	-
Northcote Street	NCA13	46	46	38	56	51	51	43	41-49	-	-	-	up to 6	54	53	1
	NCA14	58	58	52	68	63	63	57	43-58	-	-	-	up to 1	63	67	-
	NCA15	58	55	44	68	63	60	49	36-49	-	-	-	-	54	59	-
	NCA16	56	53	43	66	61	58	48	31-42	-	-	-	-	47	58	-
	NCA17	56	53	43	66	61	58	48	<30	-	-	-	-	7	58	-
	NCA18	46	46	43	56	51	51	48	34-40	-	-	-	-	45	58	-
	NCA19	56	54	44	66	61	59	49	<30	-	-	-	-	34	59	-
	NCA20	54	52	41	64	59	57	46	<30	-	-	-	-	7	56	-
	NCA21	58	55	45	68	63	60	50	<30	-	-	-	-	7	60	-
	Receivers east of works limit	47	47	39	57	52	52	44	<30	-	-	-	-	7	54	-

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**)

Worst-affected receiver impacts

Where works are located directly adjacent residential receivers, worst-case NML exceedances of greater than 25 dBA are predicted at the most potentially affected receivers during the night-time out-of-hours period.

Significant exceedances of the night-time NMLs are restricted to areas where residential receivers are located immediately adjacent tunnelling sites. These residential receivers should be considered for construction noise mitigation. As the tunnelling site operations are at fixed locations, it is recommended that mitigation measures such as acoustic building enclosures, temporary noise walls and judicious selection of works areas within the site be considered to assist in reducing impacts. These options are discussed further in **Section 10.8.3**.

Typical receiver impacts

Median NML exceedances (**Table 41**) are predicted to be negligible in most NCAs, indicating that these works affect a small proportion of the study area. Generally, median NML exceedances in NCAs immediately to the tunnel sites are minor (less than 10 dBA). The exception is found in NCA08 for which moderate (up to 20 dBA) worst-case NML exceedances are predicted on account of the near vicinity to the works and small number of receivers.

Other sensitive receiver impacts

Other sensitive receivers are generally predicted to be subject to moderate NML exceedances of up to 15 dBA (refer to **Appendix Q**), with the exception of the following receivers which have higher predicted noise impacts during standard daytime hours:

- Place of Worship in NCA07 immediately adjacent Concord Road Works (moderate exceedance of NML up to 19 dBA)

Further information

Maps indicating the worst-case NML exceedance at each of the proposed tunnelling sites are shown in **Appendix R5**.

These impacts are also summarised by NCA in **Section 14**.

10.6.7 Demolition of acquisition properties

Demolition of acquisition properties works are anticipated to be undertaken during standard daytime construction hours only. Demolition of acquisition properties works are unlikely to take longer than a week at single residential acquisition building.

Activities associated with demolition of acquisition properties works are anticipated to be undertaken within the extents of the acquisition property boundary. Demolition works may be undertaken at property boundaries immediately adjacent sensitive receivers, resulting in a short noise source to receiver distance. Acoustic shielding provided by property boundary fencing has not been included in the construction noise prediction methodology as the effective acoustic properties of such constructions can vary significantly, hence the predictions are considered conservative.

Table 40 presents a summary of the worst-case predicted noise impacts at residential receivers for Demolition of Acquisition Properties works. Demolition of acquisition properties will be undertaken during the standard daytime construction periods only.

Table 42 Worst-affected residential NML exceedances - demolition of acquisition properties

NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
								Worst-case Predicted at Nearby Receivers[1,2]	NML Exceedance[3]				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
NCA01	53	53	49	63	58	58	54	51 - 65	up to 2	n/a	n/a	n/a	n/a	64	-
NCA02	53	52	46	63	58	57	51	74 - 88	11 - 25	n/a	n/a	n/a	n/a	61	-
NCA03	50	50	46	60	55	55	51	59 - 73	up to 13	n/a	n/a	n/a	n/a	61	-
NCA04	50	49	43	60	55	54	48	84 - >90	24 - >25	n/a	n/a	n/a	n/a	58	-
NCA05	56	56	48	66	61	61	53	63 - 77	up to 11	n/a	n/a	n/a	n/a	63	-
NCA06	53	52	46	63	58	57	51	84 - >90	21 - >25	n/a	n/a	n/a	n/a	61	-
NCA07	61	57	42	71	66	62	47	87 - >90	16 - >25	n/a	n/a	n/a	n/a	57	-
NCA08	48	47	42	58	53	52	47	83 - >90	25 - >25	n/a	n/a	n/a	n/a	57	-
NCA09	41	41	38	51	46	46	43	84 - >90	>25	n/a	n/a	n/a	n/a	53	-
NCA10	41	41	40	51	46	46	45	54 - 68	3 - 17	n/a	n/a	n/a	n/a	55	-
NCA11	55	54	47	65	60	59	52	72 - 86	7 - 21	n/a	n/a	n/a	n/a	62	-
NCA12	50	50	46	60	55	55	51	54 - 68	up to 8	n/a	n/a	n/a	n/a	61	-
NCA13	46	46	38	56	51	51	43	71 - 85	15 - >25	n/a	n/a	n/a	n/a	53	-
NCA14	58	58	52	68	63	63	57	86 - >90	18 - >25	n/a	n/a	n/a	n/a	67	-
NCA15	58	55	44	68	63	60	49	77 - >90	9 - 23	n/a	n/a	n/a	n/a	59	-
NCA16	56	53	43	66	61	58	48	78 - >90	12 - >25	n/a	n/a	n/a	n/a	58	-
NCA17	56	53	43	66	61	58	48	86 - >90	20 - >25	n/a	n/a	n/a	n/a	58	-
NCA18	46	46	43	56	51	51	48	83 - >90	27 - >25	n/a	n/a	n/a	n/a	58	-
NCA19	56	54	44	66	61	59	49	62 - 76	up to 10	n/a	n/a	n/a	n/a	59	-
NCA20	54	52	41	64	59	57	46	75 - 89	11 - 25	n/a	n/a	n/a	n/a	56	-
NCA21	58	55	45	68	63	60	50	90 - >90	22 - >25	n/a	n/a	n/a	n/a	60	-
Receivers east of works limit	47	47	39	57	52	52	44	54 - 68	up to 11	n/a	n/a	n/a	n/a	54	-

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**)

Note 2: Worst-case predictions in excess of 90 dBA are a result of high noise equipment being operated less than 5 m from a receiver. Such impacts would be of limited duration.

Note 3: Results are representative of the worst-affected receiver. Typically no impacts are predicted at the outer extents of the NCAs. Full extent of noise impacts at all adjacent receivers are shown in **Appendix R**

Table 43 Median residential NML exceedances - demolition of acquisition properties

NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
								Worst-case Predicted[1]	NML Exceedance				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
NCA01	53	53	49	63	58	58	54	48-62	-	-	-	-	n/a	64	-
NCA02	53	52	46	63	58	57	51	43-57	-	-	-	-	n/a	61	-
NCA03	50	50	46	60	55	55	51	34-48	-	-	-	-	n/a	61	-
NCA04	50	49	43	60	55	54	48	50-64	up to 4	-	-	-	n/a	58	-
NCA05	56	56	48	66	61	61	53	33-47	-	-	-	-	n/a	63	-
NCA06	53	52	46	63	58	57	51	44-58	-	-	-	-	n/a	61	-
NCA07	61	57	42	71	66	62	47	48-62	-	-	-	-	n/a	57	-
NCA08	48	47	42	58	53	52	47	68-82	10 - 24	-	-	-	n/a	57	-
NCA09	41	41	38	51	46	46	43	37-51	-	-	-	-	n/a	53	-
NCA10	41	41	40	51	46	46	45	42-56	up to 5	-	-	-	n/a	55	-
NCA11	55	54	47	65	60	59	52	38-52	-	-	-	-	n/a	62	-
NCA12	50	50	46	60	55	55	51	<30	-	-	-	-	n/a	61	-
NCA13	46	46	38	56	51	51	43	48-62	up to 6	-	-	-	n/a	53	-
NCA14	58	58	52	68	63	63	57	63-77	up to 9	-	-	-	n/a	67	-
NCA15	58	55	44	68	63	60	49	62-76	up to 8	-	-	-	n/a	59	-
NCA16	56	53	43	66	61	58	48	51-65	-	-	-	-	n/a	58	-
NCA17	56	53	43	66	61	58	48	43-57	-	-	-	-	n/a	58	-
NCA18	46	46	43	56	51	51	48	57-71	1 - 15	-	-	-	n/a	58	-
NCA19	56	54	44	66	61	59	49	46-60	-	-	-	-	n/a	59	-
NCA20	54	52	41	64	59	57	46	47-61	-	-	-	-	n/a	56	-
NCA21	58	55	45	68	63	60	50	51-65	-	-	-	-	n/a	60	-
Receivers east of works limit	47	47	39	57	52	52	44	37-51	-	-	-	-	n/a	54	-

Note 1: Worst-case predicted noise levels presented in red text indicate presence of highly noise affected receivers as described by the ICNG (refer **Section 10.4.1**).

Worst-affected receiver impacts

Noise predictions presented in **Table 42** indicate works associated with the Demolition of Acquisition Properties are likely to produce significant noise impacts at adjacent residential receivers during standard daytime hours. NML exceedances are understood to be directly related to the operation of high noise producing plant (including rockbreakers) in close proximity to existing residential and other sensitive receivers.

Demolition works would likely be restricted to standard daytime hours and would not require the use of a rockbreaker for the full duration of the works.

For activities during the daytime OOH period (ie 1.00 pm to 6.00 pm Saturdays or 8.00 am to 6.00 pm Sundays) NML exceedances at adjacent receivers would be 5 dBA higher than those predicted during standard hours due to the more stringent OOH noise goal.

Typical receiver impacts

Median NML exceedances (**Table 43**) are predicted to be negligible in most NCAs, indicating that these works affect a small proportion of the study area. Generally, median NML exceedances in NCAs immediately to the works are minor (less than 10 dBA). The exception is found in NCA08 and NCA15 for which high (more than 20 dBA) and moderate (up to 20 dBA) worst-case NML exceedances are predicted respectively. This is due to the near vicinity to the works and smaller number of receivers in these NCAs.

Other sensitive receiver impacts

Other sensitive receivers are generally predicted to be subject to moderate NML exceedances of up to 15 dBA (refer to **Appendix Q**), with the exception of the following receivers which have higher predicted noise impacts during standard daytime hours:

- Place of Worship in NCA04 adjacent M4 Road Works (greater than 25 dBA exceedance of NML)
- Place of Worship in NCA06 adjacent Concord Road Works (up to 23 dBA exceedance of NML)
- Place of Worship in NCA07 immediately adjacent Concord Road Works (greater than 25 dBA exceedance of NML)
- Place of Worship in NCA14 immediately adjacent Wattle Street Road Works (greater than 25 dBA exceedance of NML)
- Passive Recreation Area in NCA16 immediately adjacent Wattle Street Road Works site (up to 22 dBA exceedance of NML)
- Educational Facility in NCA19 immediately adjacent Parramatta Road Works site (greater than 25 dBA exceedance of NML)
- Childcare Centre in NCA20 immediately adjacent Parramatta Road Works site (greater than 25 dBA exceedance of NML)

Further information

Maps indicating the worst-case NML exceedances for the Demolition of Acquisition Properties works are shown in **Appendix R6**.

10.6.8 Ventilation facilities construction

Ventilation facilities construction works are anticipated to be undertaken primarily within the area surrounding the tunnel ventilation buildings.**Table 44** presents a summary of the worst-case predicted noise impacts at residential receivers for Ventilation facilities construction works.

Table 44 Worst-affected residential NML exceedances - ventilation facilities construction

NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
								Worst-case Predicted at Nearby Receivers	NML Exceedance[1]				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
NCA01	53	53	49	63	58	58	54	36 - 43	-	-	-	-	45	64	-
NCA02	53	52	46	63	58	57	51	63 - 70	up to 7	5 - 12	6 - 13	12 - 19	72	61	11
NCA03	50	50	46	60	55	55	51	52 - 59	-	up to 4	up to 4	1 - 8	61	61	-
NCA04	50	49	43	60	55	54	48	63 - 70	3 - 10	8 - 15	9 - 16	15 - 22	72	58	14
NCA05	56	56	48	66	61	61	53	66 - 73	up to 7	5 - 12	5 - 12	13 - 20	75	63	12
NCA06	53	52	46	63	58	57	51	37 - 44	-	-	-	-	46	61	-
NCA07	61	57	42	71	66	62	47	<30	-	-	-	-	2	57	-
NCA08	48	47	42	58	53	52	47	<30	-	-	-	-	2	57	-
NCA09	41	41	38	51	46	46	43	36 - 43	-	-	-	-	45	53	-
NCA10	41	41	40	51	46	46	45	35 - 42	-	-	-	-	44	55	-
NCA11	55	54	47	65	60	59	52	36 - 43	-	-	-	-	45	62	-
NCA12	50	50	46	60	55	55	51	63 - 70	3 - 10	8 - 15	8 - 15	12 - 19	72	61	11
NCA13	46	46	38	56	51	51	43	50 - 57	up to 1	up to 6	up to 6	7 - 14	59	53	6
NCA14	58	58	52	68	63	63	57	57 - 64	-	up to 1	up to 1	up to 7	66	67	-
NCA15	58	55	44	68	63	60	49	52 - 59	-	-	-	3 - 10	61	59	2
NCA16	56	53	43	66	61	58	48	39 - 46	-	-	-	-	48	58	-
NCA17	56	53	43	66	61	58	48	37 - 44	-	-	-	-	46	58	-
NCA18	46	46	43	56	51	51	48	59 - 66	3 - 10	8 - 15	8 - 15	11 - 18	68	58	10
NCA19	56	54	44	66	61	59	49	43 - 50	-	-	-	up to 1	52	59	-
NCA20	54	52	41	64	59	57	46	36 - 43	-	-	-	-	45	56	-
NCA21	58	55	45	68	63	60	50	41 - 48	-	-	-	-	50	60	-
Receivers east of works limit	47	47	39	57	52	52	44	<30	-	-	-	-	2	54	-

Note 1: Results are representative of the worst-affected receiver. Typically no impacts are predicted at the outer extents of the NCAs. Full extent of noise impacts at all adjacent receivers are shown in **Appendix R**.

Table 45 Median residential NML exceedances - ventilation facilities construction

NCA	RBL			NML				Noise Level - LAeq(15minute) (dBA) (least noise intensive scenario - most noise intensive scenario)					Noise Level – LA1(60second) (dBA)		
								Worst-case Predicted at Nearby Receivers	NML Exceedance[1]				Worst-case Predicted (night-time)	Screening Crit. (RBL+15 dBA)	Exceed.
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night			
NCA01	53	53	49	63	58	58	54	<30	-	-	-	-	<30	64	-
NCA02	53	52	46	63	58	57	51	up to 35	-	-	-	-	37	61	-
NCA03	50	50	46	60	55	55	51	up to 32	-	-	-	-	34	61	-
NCA04	50	49	43	60	55	54	48	40-47	-	-	-	-	49	58	-
NCA05	56	56	48	66	61	61	53	up to 33	-	-	-	-	35	63	-
NCA06	53	52	46	63	58	57	51	<30	-	-	-	-	<30	61	-
NCA07	61	57	42	71	66	62	47	<30	-	-	-	-	<30	57	-
NCA08	48	47	42	58	53	52	47	<30	-	-	-	-	<30	57	-
NCA09	41	41	38	51	46	46	43	<30	-	-	-	-	<30	53	-
NCA10	41	41	40	51	46	46	45	<30	-	-	-	-	<30	55	-
NCA11	55	54	47	65	60	59	52	<30	-	-	-	-	<30	62	-
NCA12	50	50	46	60	55	55	51	<30	-	-	-	-	30	61	-
NCA13	46	46	38	56	51	51	43	34-41	-	-	-	-	43	53	-
NCA14	58	58	52	68	63	63	57	39-46	-	-	-	-	48	67	-
NCA15	58	55	44	68	63	60	49	33-40	-	-	-	-	42	59	-
NCA16	56	53	43	66	61	58	48	30-37	-	-	-	-	39	58	-
NCA17	56	53	43	66	61	58	48	<30	-	-	-	-	<30	58	-
NCA18	46	46	43	56	51	51	48	30-37	-	-	-	-	39	58	-
NCA19	56	54	44	66	61	59	49	up to 30	-	-	-	-	32	59	-
NCA20	54	52	41	64	59	57	46	<30	-	-	-	-	30	56	-
NCA21	58	55	45	68	63	60	50	<30	-	-	-	-	26	60	-
Receivers east of works limit	47	47	39	57	52	52	44	<30	-	-	-	-	<30	54	-

Worst-affected receiver impacts

For works during standard daytime hours, minor worst-case NML exceedances of 10 dBA or less are predicted at most residential receivers. Predicted worst-case noise impacts are higher for works undertaken outside standard daytime hours.

Typical receiver impacts

Median NML exceedances (**Table 45**) are predicted to be negligible, indicating that these works affect a small proportion of the study area.

Other sensitive receiver impacts

Other sensitive receivers are generally predicted to be subject to moderate NML exceedances of up to 15 dBA when in use (refer to **Appendix Q**).

Further information

Maps indicating the worst-case NML exceedances for the Ventilation facilities construction works are shown in **Appendix R7**.

Impacts for all receivers also summarised by NCA in **Section 14**.

10.6.9 Sleep disturbance

Review of the predicted $L_{A1(1minute)}$ noise levels at the nearest noise sensitive receivers provided in **Table 32** through **Table 44** indicates that the sleep disturbance screening criterion is likely to be exceeded when night works are occurring adjacent to residential receivers for the majority of works scenarios. This level of noise is typical for construction works using noise intensive equipment in urban areas.

The term 'screening criterion' indicates a noise level that is intended as a guide to identify the likelihood of sleep disturbance. The RNP contains a section on sleep disturbance that includes a summary of current literature; concluding that:

- Maximum internal noise levels below 50 dBA to 55 dBA L_{AFmax} are unlikely to cause awakening reactions
- One or two events per night, with maximum internal noise levels of 65 dBA to 70 dBA L_{AFmax}, are not likely to affect health and wellbeing significantly.

The works activities have the potential to significantly exceed the screening criterion and the above levels at nearby residential receivers indicating potential for adverse reactions at these receivers.

At this early stage in the approval process, the assessment has included predictions of maximum noise impacts for assessment of potential sleep disturbance, however, it is noted that the ICNG only requires the proposal to consider maximum noise levels where construction works are planned to extend over more than two consecutive nights.

It is anticipated that the finalised requirements for OOHWs would be determined at a later design stage.

10.7 Cumulative noise impacts

The indicative construction program shown in **Table 3** shows a number of overlapping construction phases, however these are representative of the works phase rather than the specific location of the works within each area at any given time. Cumulative noise impacts warrant assessment where more than one works scenario operates at the same time and in the same location such that the same receiver is impacted by noise from more than one works scenario in comparable magnitudes. The assessment presented in **Section 10.6** includes concurrent operation of multiple plant items within the same construction scenario where these may be operating at the same time, in the same location.

The prediction of cumulative noise levels from more than one construction scenario operating close to another scenario within the proposal area is a complex matter given the number of sources and possible locations of a particular combination of construction works. In practice, it is not always possible to specify the precise location of more than one works scenario for the same 15-minute period and the assessment becomes overly conservative to calculate the cumulative impacts based on all nearby works operating on a worst-case basis at the same time.

Since the works are anticipated to be of a similar nature, the effect of concurrent construction works is likely only to increase the number of 15-minute periods during construction where the predicted worst-case noise impacts are apparent. In practice, the noise levels will vary due to the fact that plant and equipment will move about the worksites and will not all be operating concurrently at the worst-case scenario used in the assessment (ie there are times where equipment is not operating).

Construction scenarios with the potential to generate cumulative impacts include construction civil and tunnelling sites which may operate simultaneously during the daytime period. These construction areas are anticipated to include reasonably stationary noise sources which operate for the majority of the construction period. The worst case impacts at the most potentially affected receivers from the combination of construction civil and tunnelling sites operating concurrently are not anticipated to increase significantly due to concurrent site operations. Cumulative noise impacts generated by concurrent operation of civil and tunnel sites are therefore concluded to be of minor impact on the worst-case construction noise levels. Cumulative noise impacts of the tunnel and civil sites are displayed in **Appendix S**.

Other major construction projects within the vicinity of the project have been identified. The M4 widening project has a construction compound in the south east corner of the Homesbush Bay Drive interchange and G-loop ramp works at Homebush Bay Drive. These works are located at the western end of NCA01. The scheduling of this project and the M4 Widening project means that there is some potential for overlapping construction periods up to the indicative M4 Widening completion date in 2017. Whilst it is anticipated that the frequency of potential construction noise impacts may increase during this overlapping period there are no predicted increases in the worst-case construction noise impacts as presented in this report due to the relative offset distances between plant items (for either project) and the affected receivers. Therefore, no further consideration of cumulative noise impacts due to other nearby projects is required.

10.8 Construction noise mitigation

The ICNG describes strategies for construction noise mitigation and control that are applicable to this proposal. The strategies are designed to minimise, to the fullest extent practicable, noise during construction.

10.8.1 Restriction of construction hours

Where feasible and reasonable, preference would be given to scheduling construction works within the standard construction hours of:

- Monday to Friday 7.00 am to 6.00 pm.
- Saturday 8.00 am to 1.00 pm.
- No work on Sundays or public holidays

The nature of the project means evening and night work would also be required. Construction works would be required outside of standard hours where:

- Temporary road closures and other measures are required by the Police and other regulatory authorities for the safe delivery of material/ equipment.
- Works have the potential to disrupt commuter services and road networks.
- Works are required to be completed to maintain health and safety, avoid loss of life or injury and to prevent environmental damage.
- Works are undertaken 24/7 with minimal community impact to significantly reduce the delivery time of the proposal, including tunnelling works.

Working 24 hours would allow contractors to spread the workload from peak to non-peak periods where there are less traffic impacts. It would allow the works to be less constrained which would reduce the impacts to businesses and residents in that the overall duration of the works would be reduced.

Where works are proposed during the night-time period (10:00 pm to 7:00 am) site specific Construction Noise and Vibration Management Plans (CNVMPs) would be developed in the detailed design phase. Construction works proposed, at times, during the night-time periods include:

- Work area establishment (including clearing within the road corridor)
- Temporary Road and intersection modifications
- Roads/Cut-and-cover/Dive Structures and Approach Roads and Ramps
- Tunnelling site operations, including excavation and ground support, civil, mechanical, and electrical
- Ventilation Facilities Construction

The CNVMPs would provide a detailed assessment of potential noise levels and site specific measures to control potential noise impacts and minimise the potential for disturbance at affected receivers. It is understood that any OOHW (excluding 24 hour tunnelling sites) would be subject to a separate approval on a case-by-case basis and would likely require approval under the project's EPL. A range of feasible and reasonable construction noise mitigation measures are provided in **Section 10.8.4**.

10.8.2 Restriction of construction noise levels

The ICNG acknowledges that due to the nature of construction activities it is inevitable there would be some noise impacts from construction sites. The NMLs identified in this report have been applied to prescribe measures for the control of potential construction noise impacts at sensitive receivers. Where exceedances of the NMLs have been predicted during the daytime (standard construction hours), receivers are considered to be noise affected.

The proponent should apply all feasible and reasonable work practices to meet the NMLs and inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels, duration of noise generating construction works, and the contact details for the proposal.

Receivers are considered to be highly noise affected if noise levels from construction exceed 75 dBA L_{Aeq}. This relates to daytime works only. **Table 46** presents a worst-case summary of highly noise affected receivers.

Table 46 Summary of highly noise affected residential receivers

Scenario	Number of worst-case highly noise affected residential receivers[1]																				
	NCA01	NCA02	NCA03	NCA04	NCA05	NCA06	NCA07	NCA08	NCA09	NCA10	NCA11	NCA12	NCA13	NCA14	NCA15	NCA16	NCA17	NCA18	NCA19	NCA20	NCA21
Work area establishment - All Areas	7	43	14	22	8	21	11	8	15	-	10	15	5	26	34	15	21	19	3	11	38
Temporary Road and intersection modifications	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Construction ancillary facility - General Worksites	2	9	-	7	1	6	-	6	-	-	1	3	4	3	11	6	5	4	-	-	20
Roads/Cut-and-cover/Dive Structures and Approach Roads and Ramps	14	41	33	18	8	27	19	8	23	-	7	-	4	19	39	18	49	31	7	28	43
Tunnelling site operations, including Excavation and ground support, civil, mechanical, and electrical	-	-	-	1	-	-	2	1	2	-	-	-	-	2	-	-	-	-	-	-	-
Demolition of acquisition properties	-	5	-	30	1	23	19	8	22	-	5	-	10	35	38	13	14	34	1	11	52
Ventilation facilities Construction	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note 1: Count is based on the total number of receiver buildings predicted to be subject to worst-case construction noise levels above the highly noise affected level (75 dBA) at any time in the entire construction schedule. This is generally limited to periods when noise intensive activities are located immediately adjacent to residences. It is therefore expected that the number of noise affected receivers on a typical day to day basis would be considerably less than presented in this table. Note that the ICNG definition of 'highly noise affected' applies to the standard construction (daytime) period only– refer to **Table 28**.

The information presented in **Table 46** indicates that, due to the close vicinity of the works, worst case construction works may result in daytime noise levels above 75 dBA $L_{Aeq(15minute)}$ during noise intensive activities at immediately adjacent residences during the works.

Consequently, site-specific CNVMPs should be developed in the detailed design phase when more information is available on the schedule for the works and the equipment to be used. The proponent and construction contractor(s) should schedule work (where necessary) to provide respite periods from the noisiest activities, and communicate with the impacted residents by clearly explaining the duration and noise level of the works. A potential approach would be to schedule high noise generating works to less sensitive times of 9:00 am to 12:00 pm or 2:00 pm to 5:00 pm, if this is agreed by the affected community.

Where OOHWs are required, these may be predicted to result in exceedances of the NMLs. The proponent should identify all feasible and reasonable work practices in the CNVMPs to reduce potential noise impacts. Where all feasible and reasonable practices have been applied and noise would be more than 5 dBA above the noise affected level, the proponent should negotiate with the community to determine the schedule for the works or provide respite to occupants where sleep disturbance is likely to occur.

10.8.3 Construction noise mitigation measures

Based on the assessment of construction noise impacts in this report, a range of noise mitigation measures have been recommended to reduce and control potential construction noise impacts. The construction noise mitigation measures are recommended to, where feasible and reasonable, minimise potential for disturbance at receivers, preserve the acoustic amenity of the surrounding environment and aim to control noise levels within the construction NMLs.

The reasonableness of the identified feasible mitigation measures would be considered during the construction planning and work area establishment phases of the proposal, and in the development of CNVMPs. In general, mitigation measures that should be considered are summarised below.

Temporary Acoustic Hoarding

For construction concentrated in a single area, such as at the civil and tunnelling sites, temporary acoustic hoarding/barriers around the site perimeter should be considered where feasible and reasonable to mitigate off-site noise levels.

The installation of temporary acoustic hoarding along the perimeter of construction ancillary facilities is predicted to reduce NML exceedances from construction works undertaken within the sites (typically by 5 to 10 dBA) and is expected to reduce the number of highly noise affected receivers by more than 60 percent as presented in **Table 47**. Temporary acoustic hoarding heights vary between 2.1 metres and 4.5 metres across the study area (refer to **Table 49**) depending on site topography and other construction constraints with the general aim of reducing direct line of sight from source to receiver as far as reasonably practicable.

Table 47 Construction ancillary facilities highly noise affected residential receivers - with acoustic hoarding

Scenario	NCA	Type	Reduction of worst-case highly noise affected receivers through implementation of acoustic hoarding	Number of residual worst-case highly noise affected receivers with hoarding
Construction ancillary facility - General Worksites Including Acoustic Hoarding	NCA01	Residential	1	1
	NCA02	Residential	7	2
	NCA03	Residential	-	-
	NCA04	Residential	6	1
	NCA05	Residential	-	1
	NCA06	Residential	5	1
	NCA07	Residential	-	-
	NCA08	Residential	5	1
	NCA09	Residential	-	-
	NCA10	Residential	-	-
	NCA11	Residential	-	1
	NCA12	Residential	3	-
	NCA13	Residential	-	4
	NCA14	Residential	3	-
	NCA15	Residential	8	3
	NCA16	Residential	5	1
	NCA17	Residential	4	1
	NCA18	Residential	4	-
	NCA19	Residential	-	-
	NCA20	Residential	-	-
	NCA21	Residential	5	15
	Receivers east of works limit	Residential	-	-

Noise barriers are effective for receivers at or near ground level and not effective for receivers overlooking the sites.

Maps indicating the worst-case NML exceedance at each of the proposed civil sites, with mitigation (temporary noise barriers) is shown in **Appendix R3**.

Acoustic building enclosures at tunnelling sites

Tunnelling Site Operations are anticipated to be undertaken on a 24 hour, seven day per week basis. noise impacts are predicted during the night-time out-of-hours period.

In order to sufficiently mitigate noise from these construction activities during all periods, a combination of acoustic hoarding and acoustic building enclosures may be required.

Indicative NML exceedances have been predicted for the tunnel sites including acoustic sheds as a mitigation measure. An insertion loss for the acoustic sheds of up to 22 dBA has been assumed such that worst-case NML exceedances are typically reduced to NML + 10 dBA.

The installation of an acoustic shed around the tunnelling shaft and works areas in combination with temporary acoustic hoarding at the site boundary is predicted to significantly reduce NML exceedances from construction works undertaken within tunnelling sites and is expected to remove almost all highly noise affected receivers.

The detailed design of the tunnelling enclosures would need to be considered during the construction planning and site establishment phases of the proposal, when the final site layout is known.

The position of nearby sensitive receivers, and spectral performance of the material should be considered when planning the site layout and designing the acoustic enclosure to ensure sufficient noise mitigation is achieved for all surrounding receivers.

Maps indicating the predicted worst-case NML exceedance at each of the proposed tunnelling sites, with mitigation (acoustic sheds and temporary noise barriers) is shown in **Appendix R5**.

Priority construction of noise barriers

Priority construction of noise barriers proposed to mitigate operational noise impacts of the project at the earliest practicable stage in the construction period is highly recommended in order to provide noise screening to adjacent receivers during the subsequent construction activities. Locations where priority construction of noise barriers would provide mitigation of construction works would include:

- Receivers located north of the M4 carriageway between Homebush Bay Drive and Underwood Road
- Receivers located South of the M4 carriageway between Homebush Bay Drive and Powell Street
- Receivers surrounding the Concord Road civil and tunnel site
- Receivers east of the Northcote Street tunnel site
- Receivers south of Wattle Street between Parramatta Road and Waratah Street

Construction methods and scheduling

Given the potential high noise levels at residential receivers, adherence to daytime construction hours is recommended for excavation, demolition or rock breaking activities, and for activities concentrated in a single area (ie activities that do not move along the alignment, and do not require out of hours activities for safety reasons or to minimise disruption to road networks). An exception to this recommendation is provided for tunnelling works which are proposed to operate continuously 24 hours a day, seven days a week to minimise the overall length of construction and the duration of the potential impacts on the local community.

Other construction noise mitigation measured associated with construction methods and scheduling include:

- Night works should be programmed to minimise the number of consecutive nights work impacting the same receivers – likely to only apply to the moving corridor works and not the civil and tunnel sites..
- When working adjacent to schools, particularly noisy activities should be scheduled outside normal school hours, where practicable.
- Scheduling works to avoid the coincidence of noisy plant working simultaneously close together and adjacent to sensitive receivers would result in reduced noise emissions.
- Equipment which is used intermittently is to be shut down when not in use.
- Where practicable, heavy vehicle movements should be limited to daytime hours.
- Where practicable, the offset distance between noisy plant items and nearby noise sensitive receivers should be as great as possible.
- Where practicable, equipment with directional noise emissions should be oriented away from sensitive receivers.

- Regular compliance checks on the noise emissions of all plant and machinery used for the proposal would indicate whether noise emissions from plant items were higher than predicted. This also identifies defective silencing equipment on the items of plant.
- Ongoing noise monitoring during construction at sensitive receivers during critical periods to identify and assist in managing high risk noise events.
- Reversing of equipment should be minimised so as to prevent nuisance caused by reversing alarms. Use of non-tonal reversing alarms (Quackers) may be implemented to reduce the nuisance caused by reversing alarms.
- Loading and unloading should be carried out away from sensitive receivers, where practicable.

Mitigation during out of hours works

Additional noise mitigation measures during OOHW should be determined on a case-by-case basis from individual receiver predictions during the construction phase and may consist of offers of alternative accommodation, monitoring, individual briefings, letter box drops, project specific respite offers, phone calls and specific notifications.

10.8.4 General mitigation summary

A summary of the potential noise benefits from application of the proposed project noise mitigation measures as described in this report (refer to **Section 10.8.1**, **Section 10.8.2** and **Section 10.8.3** is presented in **Table 48.**

Table 48 Construction noise mitigation summary (ranked by noise reduction)

Construction Noise Mitigation Measures to be implemented where practicable and appropriate	Potential Noise Reduction
Acoustic enclosure around tunnelling shafts – subject to detailed construction planning	Typically around 15 to 22 dBA
Portable temporary enclosures	Up to around 15 dBA
Temporary acoustic fencing/barriers – subject to detailed construction planning	Typically around 5 to 10 dBA
Construct operational noise walls early in the construction program where feasible and reasonable	5-10 dBA
Maximise offset distance between noisy plant items and nearby noise sensitive receivers where practicable	Approximately 6 dBA reduction per doubling of offset distance
Loading and unloading should be carried out away from sensitive receivers where practicable	Approximately 6 dBA reduction per doubling of offset distance
Avoid the coincidence of noisy plant working simultaneously close together, where practicable	Up to 3 dBA for halving the number of similar dominant plant items working together
Install operational property treatments where required	Improved reduction of internal noise levels within habitable rooms of dwellings
Schedule construction works within the standard construction hours	No reduction during standard construction hours Minimises Out of Hours noise impacts
Shut down equipment when not in use	Negligible reduction in comparison to worst-case predictions, however eliminates noise source during less noise intensive works
Schedule a respite period (eg one hour for every three hours of continuous construction activity) where appropriate	n/a
Schedule high noise generating works to less sensitive times of 9:00 am to 12:00 pm or 2:00 pm to 5:00 pm where appropriate and agreed with the community.	n/a
Minimise the number of consecutive nights work impacting the same receivers where practicable – likely to only apply to the moving corridor works and not the civil and tunnel sites.	n/a
Noisy activities should be scheduled outside normal school hours, where practicable	n/a
Regular compliance checks on the noise emissions	n/a
Ongoing noise monitoring during construction at sensitive receivers	n/a
Where practicable, heavy vehicle movements should be limited to daytime hours	n/a
Non-tonal reversing alarms where practicable	n/a

10.8.5 Construction ancillary facilities mitigation summary

Proposed mitigation measures for construction civil and tunnelling sites included this project are summarised in **Table 49**.

Table 49 Construction ancillary facilities noise mitigation summary

Site	NCA	Proposed Mitigation
Homebush Bay Drive civil site	NCA01	Hoarding: 3 metres high compound boundary excluding access gates 3 metres high between compound and Verley Drive
Pomeroy Street civil site	NCA02 NCA03	Hoarding: 4 metres high on northern boundary Installation of operational noise barriers at an early stage in construction as far as practicable
Underwood Road tunnel and civil site	NCA04	Hoarding: 4.5 metres high on northern boundary Acoustic shed
Powells Creek civil site	NCA05	Management measures
Concord Road civil and tunnel site	NCA06 to NCA11	Hoarding: 4 metres high on northern boundary 4.5 metres high on eastern boundary Installation of operational noise barriers at an early stage in construction as far as practicable Acoustic shed
Cintra park tunnel site	NCA12	Hoarding: 4.5 metres high on northern boundary of complex 4.5 metres high on southern boundary of complex 3 metres high on western boundary 4.5 metres high on eastern boundary of complex 3 metres high on carpark boundary Acoustic shed
Northcote Street tunnel site	NCA13 NCA14	Hoarding: 4.5 metres high on perimeter boundary Acoustic shed Installation of operational noise barriers at an early stage in construction as far as practicable
Eastern ventilation facility site	NCA13 NCA14 NCA18	Hoarding 4 metres high on northern boundary 4 metres high on southern boundary 3 metres high on western boundary 4 metres high on eastern boundary
Wattle Street and Walker Avenue civil site	NCA15 to NCA18	Hoarding 3 metres high on southern boundary 2.1 metres high on northern boundary 3 metres high on western boundary 2.1 metres high on eastern boundary Installation of operational noise barriers at an early stage in construction as far as practicable
Parramatta Road civil site	NCA19 to NCA21	Hoarding 3 metres high on western boundary 2.1 metres high on eastern boundary

10.8.6 Construction environmental management plan

A Construction Environmental Management Plan (CEMP) would be prepared during the detailed design phase and implemented through all construction activities. A CNVMP would be included in the CEMP to provide the framework and mechanisms for the management and mitigation of all potential noise and vibration impacts from the construction works. The CNVMP would include restrictions on the hours of construction for specific sites and the construction noise levels at sensitive receivers.

This would address each major stage of the construction works and identify the appropriate mitigation and management measures, consistent with the requirements of the ICNG

The objectives of the CNVMP are as follows:

- Assist in ensuring that the noise emissions during the construction works comply with the noise management levels and goals nominated in **Section 10.4**.
- Determine noise and vibration monitoring, reporting and response procedures.
- Describe specific mitigation treatments, management methods and procedures to be implemented to control noise and vibration during construction.
- Describe construction timetabling to minimise noise impacts including time and duration restrictions, respite periods and frequency.
- Describe procedures for notifying residents of construction activities likely to affect their amenity through noise and vibration.
- Define contingency plans to be implemented in the event of non-compliances and/or noise complaints.

11 Assessment of construction noise - public road network

This section provides an assessment of the construction related traffic on the public road network. When trucks and other vehicles are operating within the boundaries of the various construction sites, noise levels are assessed as outlined in **Section 10**. When construction related traffic moves onto the public road network, vehicle movements would be regarded as 'additional road traffic' rather than as part of the construction site.

11.1 Construction road traffic noise goals

The ICNG does not provide specific guidance in relation to acceptable noise levels associated with construction traffic. For assessment purposes, guidance is taken from the RNP however it is noted that these are taken as noise goals only and are not mandatory.

One of the objectives of the RNP is to apply relevant permissible noise increase criteria to protect sensitive receivers against excessive decreases in amenity as the result of a proposal. In assessing feasible and reasonable mitigation measures, an increase of up to 2 dBA represents a minor impact that is considered barely perceptible to the average person.

On this basis, construction traffic NMLs set at 2 dBA above the existing road traffic noise levels during the daytime and night-time periods are considered appropriate to identify the onset of potential noise impacts. Where the road traffic noise levels are predicted to increase by more than 2 dBA as a result of construction traffic, consideration would be given to applying feasible and reasonable noise mitigation measures to reduce the potential noise impacts and preserve acoustic amenity.

In considering feasible and reasonable mitigation measures where the relevant noise increase is greater than 2 dBA, consideration would also be given to the actual noise levels associated with construction traffic and whether or not these levels comply with the following road traffic noise criteria in the RNP:

- 60 dBA $L_{Aeq(15hour)}$ day and 55 dBA $L_{Aeq(9hour)}$ night for existing freeway / arterial / sub-arterial roads.
- 55 dBA $L_{Aeq(1hour)}$ day and 50 dBA $L_{Aeq(1hour)}$ night for existing local roads.

Sleep disturbance and maximum noise events

In addition to the current legislative guidance on potential sleep disturbance outlined in **Section 4.6** the RNP refers to Practice Note iii of the ENMM for specific impacts from road traffic. The ENMM recommends an evaluation of the number and distribution of night-time passby events where the L_{AFmax} - $L_{Aeq(1hour)}$ difference is greater than 15 dBA, and the maximum noise level of that event is greater than 65 dBA L_{AFmax}.

On the basis of the current guidance, an external sleep disturbance screening criterion of RBL + 15 dBA and sleep disturbance NML of L_{Amax} 55 dBA (internal) have been adopted - the latter equates to an external NML of 65 dBA L_{AFmax} (assuming open windows).

11.2 Construction traffic noise assessment

At this stage in the assessment, it is assumed that additional heavy construction vehicle movements on public roads may be required 24 hours a day, up to seven days a week.

The forecast maximum daily heavy vehicles during the construction works are presented in **Table 50**. The maximum daily flows have been used at this stage in the assessment in order to provide a conservative assessment for each site. Night-time volumes are based on the hourly vehicle numbers for each hour of the night-time period.

Table 50 Construction traffic forecast

Site	Maximum daily construction road traffic movements forecast during works[1]		Heavy vehicles per hour outside of standard hours	
	Heavy	Light	Evening (6.00 pm – 10.00 pm)	Night (10.00 pm – 7.00 am)
Homebush Bay Drive civil site (C1) and Pomeroy Street civil site (C2)	110	160	-	-
Underwood Road tunnel and civil site (C3)	80	30	2	2
Powells Creek civil site (C4)	40	50	-	-
Concord Road civil and tunnel site (C5)	260	80	18	18
Cintra Park tunnel site (C6)	200	330 (on weekdays)	14	14
Northcote Street tunnel site (C7)	300	30	18	18
Eastern ventilation facility site (C8)	60	30	10	2
Wattle Street civil site (C9)	120	70	-	-
Parramatta Road civil site (C10)	90	90	-	-

Note 1: One direction flows. The assessment assumes all movements require an additional return trip.

The proposed haulage routes are presented in **Table 51** along with the assessment of predicted increase in noise impacts, based on the maximum daily forecast number of heavy vehicle movements in a day added to the existing vehicle volume data, where this data is available for the road in question.

Table 51 Construction road traffic noise assessment

Site	Haulage Route	Road	Predicted Traffic Noise Increase (dB)	
			Daytime	Night-time
Homebush Bay Drive civil site (C1) and Pomeroy Street civil site (C2)	Heavy vehicles – via existing M4 Light vehicles – via existing M4 and Pomeroy Street	M4	<0.5	n/a[3]
		Pomeroy Street	<0.5	
Underwood Road tunnel and civil site (C3)	Underwood Road and Short Street East	Underwood Road	<0.5	<0.5
		Short Street East	>2.0[2]	>2.0[2]
Powells Creek civil site (C4)	Heavy vehicles – Powell Street and Underwood Road Light vehicles – Powell Street and Parramatta Road	Powell Street	>2.0[2]	n/a[3]
		Underwood Road	<0.5	
		Parramatta Road	<0.5	
Concord Road civil and tunnel site (C5)	Heavy vehicles – Sydney Street (M4 off-ramp) and Concord Road Light vehicles – Alexandra Street and Ada Street	Sydney Street (M4 off-ramp)	<0.5	1.8
		Concord Road	<0.5	0.9
		Alexandra Street	Refer to note 4	
		Ada Street	Refer to note 4	

Site	Haulage Route	Road	Predicted Traffic Noise Increase (dB)	
			Daytime	Night-time
Cintra Park tunnel site (C6)	Heavy vehicles – Parramatta Road Light vehicles – Gipps Street	Parramatta Road	<0.5	<0.5
		Gipps Street	<0.5	<0.5
Northcote Street tunnel site (C7)	Parramatta Road and Wattle Street	Parramatta Road	<0.5	<0.5
		Wattle Street	<0.5	<0.5
Eastern ventilation facility site (C8)	Heavy vehicles – Parramatta Road and Wattle Street Light vehicles – Walker Avenue	Parramatta Road	<0.5	<0.5
		Wattle Street	<0.5	<0.5
		Walker Avenue	Refer to note 4	Refer to note 4
Wattle Street civil site (C9)	Wattle Street	Wattle Street	<0.5	n/a[3]
Parramatta Road civil site (C10)	Heavy vehicles – Parramatta Road Light vehicles – Orpington Street	Parramatta Road	<0.5	n/a[3]
		Orpington Street	Refer to note 4	

Note 1: Existing traffic noise levels based on traffic modelling undertaken by WDA and/or AADTs where available.

Note 2: Estimate at the worst-affected receiver (ie with least existing road traffic noise exposure) based on the assumption that minimal heavy vehicles currently use these local roads. Existing traffic flows on this road are not currently available.

Note 3: Proposed operations daytime only.

Note 4: As no heavy vehicles are proposed to use these roads, the contribution due to the proposed construction traffic (light vehicles only) is predicted to be lower than the nominated criteria for local roads, and below the existing noise level predicted from nearby major roads. Existing traffic flows on this road are not currently available.

The information presented in **Table 51** indicates that construction traffic is unlikely to result in a noticeable increase in L_{Aeq} noise levels at receivers along the proposed routes with the exception of the following local roads which are proposed to carry heavy vehicles at times during construction:

- Underwood Road tunnel and civil site (C3) - Short Street East (daytime and night-time)
- Powells Creek civil site (C4) - Powell Street (daytime only)

With regard to potential night-time maximum noise events, construction traffic on the major roads are unlikely to significantly increase the number of maximum noise events due to the relatively high existing traffic volumes on these roads.

The traffic management plan and site inductions should cover instructions for operation of vehicles entering and leaving the sites in order to minimise noise. It is recommended that planned truck queues be located away from residences in order to minimise noise impacts due to trucks idling near the sites.

11.3 Proposed local road use

Proposed haul traffic on local roads is considered likely to cause a noticeable increase in the number of maximum noise events on local road Short Street East where heavy vehicles are proposed at night. Further assessment of night-time maximum noise events on local roads is therefore recommended to be undertaken during detailed design, once the requirements for night-time local road access are finalised and more information is available with regard to likely night-time vehicle numbers on the proposed roads. It is anticipated that this would occur during preparation of the CNVMP.

11.4 Mitigation and management measures

The following measures are recommended, and should be confirmed during detailed design:

- As far as practicable, restrict construction vehicle movements during the night-time along local roads to light vehicles only, subject to further investigation of potential night-time maximum noise events during detailed design

- As far as practicable, limit heavy vehicle movements outside of standard construction hours associated with tunnel support works (spoil removal, concrete delivery and other heavy vehicle movements) to access and egress directly to and from the major road network.
- Appropriate training should be provided to contractors in order to minimise noise when entering and leaving the sites.

12 Construction ground-borne noise assessment

12.1 Ground-borne noise from tunnelling during roadheader activity

The potential ground-borne noise impacts associated with the construction of the underground tunnels have been assessed for the section of the alignment to the east of the main M4E portals near Homebush Bay Drive. The assessment includes the excavation of the main road M4E tunnels together with all access ramp connections to the various surface intersections (Concord Road, Wattle Street and Parramatta Road).

At this stage, most of the underground sections of the alignment are proposed to be excavated using roadheaders however the lower bench of the tunnels are proposed to be excavated by a drill and blast method. Criteria for assessing impacts from blasting are discussed in **Section 13.8**.

12.2 Ground-borne noise management levels

The ICNG provides residential NMLs for ground-borne noise, which are applicable when ground-borne noise levels are higher than the corresponding airborne construction noise levels. The ICNG provides ground-borne noise levels at residences for evening and night-time periods only, as the objectives are to protect the amenity and sleep of people when they are at home. The following ground-borne noise levels are applicable for residences:

- Evening 40 dBA $L_{Aeq(15minute)}$
- Night-time 35 dBA $L_{Aeq(15minute)}$

For commercial receivers such as offices and retail areas, the ICNG does not provide guidance in relation to acceptable ground-borne noise levels. For the purpose of this assessment, an internal NML of 60 dBA $L_{Aeq(15minute)}$ has been adopted in order to assist in identifying potential impacts.

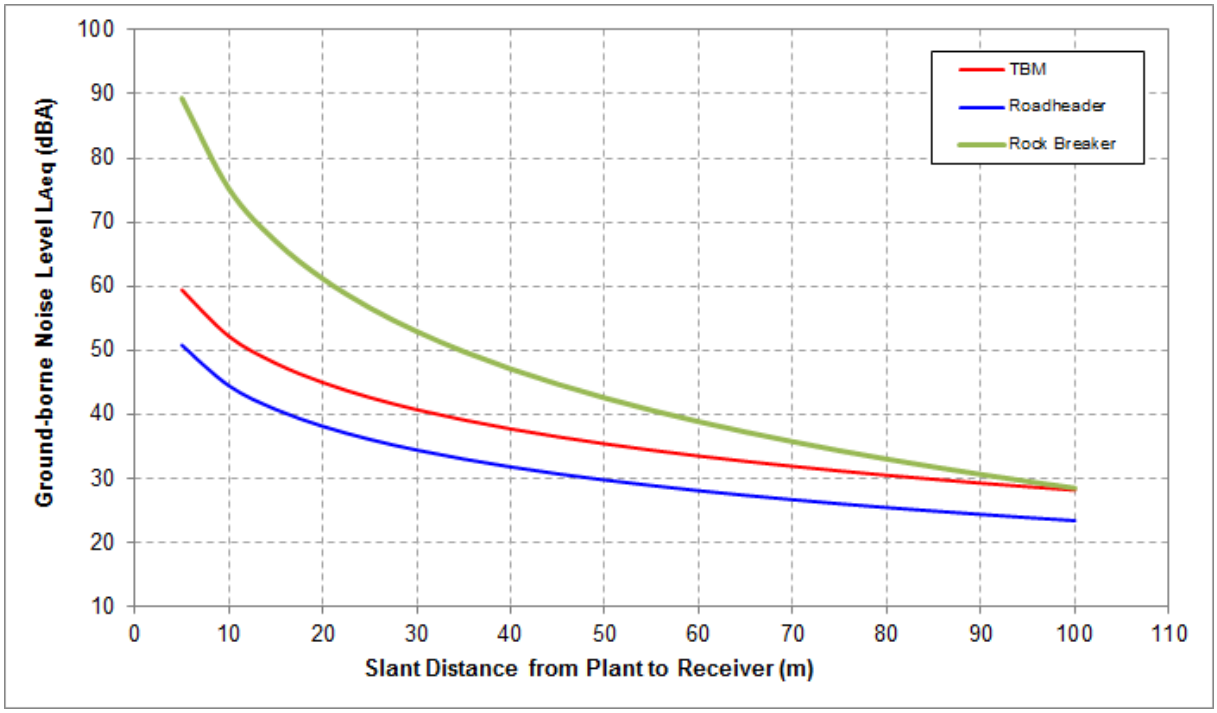
These NMLs are applicable to residences and commercial receivers located above tunnelling works, and would also apply to other construction activities such as rock breaking where ground-borne noise levels are higher than airborne noise levels. This situation may occur at construction sites where airborne noise levels are shielded by noise barriers or other structures, or sensitive areas within residential or commercial buildings which are removed from the airborne noise source.

12.3 Ground-borne construction noise modelling

Ground-borne noise impacts at the various sensitive receivers above the proposed tunnelling works have been predicted using a three-dimensional model which utilises the receiver location and elevation data for all receivers in the study area, together the horizontal and vertical information supplied for the underground section of the road alignment.

Figure 13 presents indicative ground-borne noise levels for TBMs, roadheaders and rockbreakers as measured on other Sydney tunnelling projects. As the figure demonstrates, ground-borne noise levels reduce as the distance between plant and the receiver increases.

Figure 13 Indicative ground-borne noise levels from TBMs, roadheaders and rockbreakers



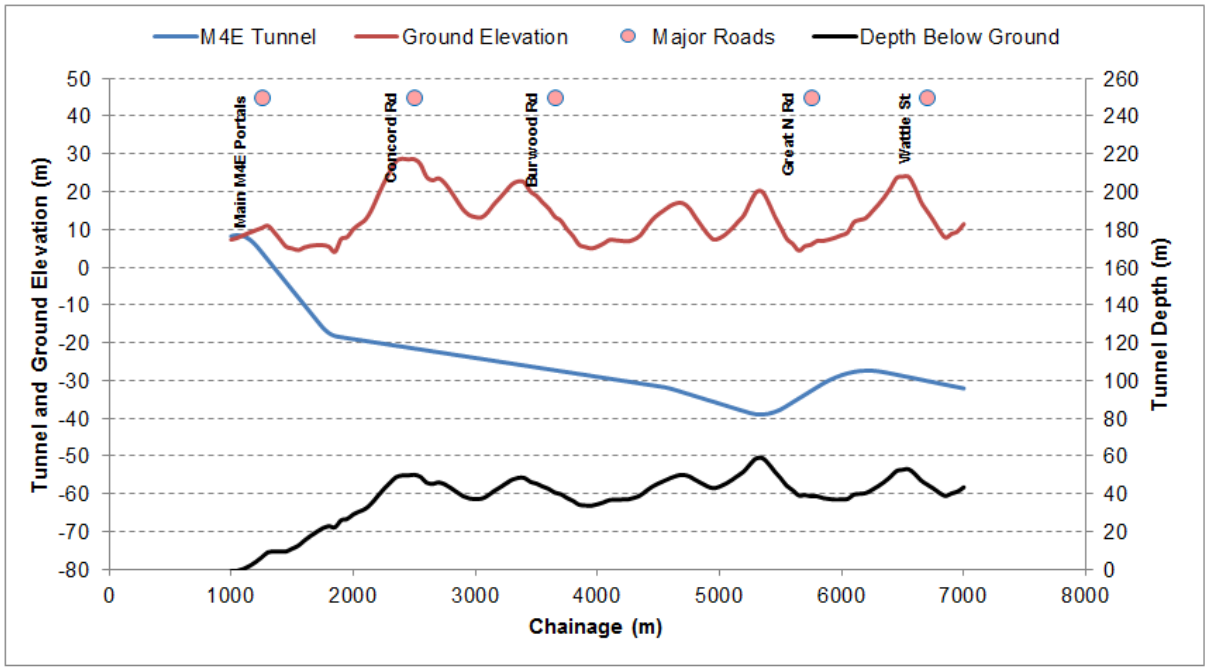
Source: TBM and roadheader data is from *Australian Acoustical Society Technical Meeting – Tunnelling Noise and Vibration Management*, Wilkinson Murray, December 2003. Rockbreaker data was obtained from SLR Consulting's noise database.

The ground-borne noise model calculates the three-dimensional slant distance from the tunnel crown to each sensitive receiver situated above the alignment, where tunnelling works are proposed. A conservative offset distance of 10 m from the road level to the tunnel crown has been incorporated into the model for the calculations.

12.4 Excavation of main tunnels

Figure 14 provides a chart showing the proposed tunnel depth (from ground elevation to the tunnel crown) for the entire alignment and illustrates that the tunnel depth varies from approximately 0 metres to up to around 60 metres below ground at the shallowest and deepest points respectively.

Figure 14 Proposed mainline tunnel depth and existing ground elevation



Note: Tunnel depth is from ground elevation to the mainline tunnel crown and has been determined on the basis of the tunnel being 10 m in height.

The ground-borne noise assessment is based on the worst-case predicted L_{Aeq} internal ground-borne noise level when the tunnelling works are directly below each receiver and the tunnelling works are at their closest point.

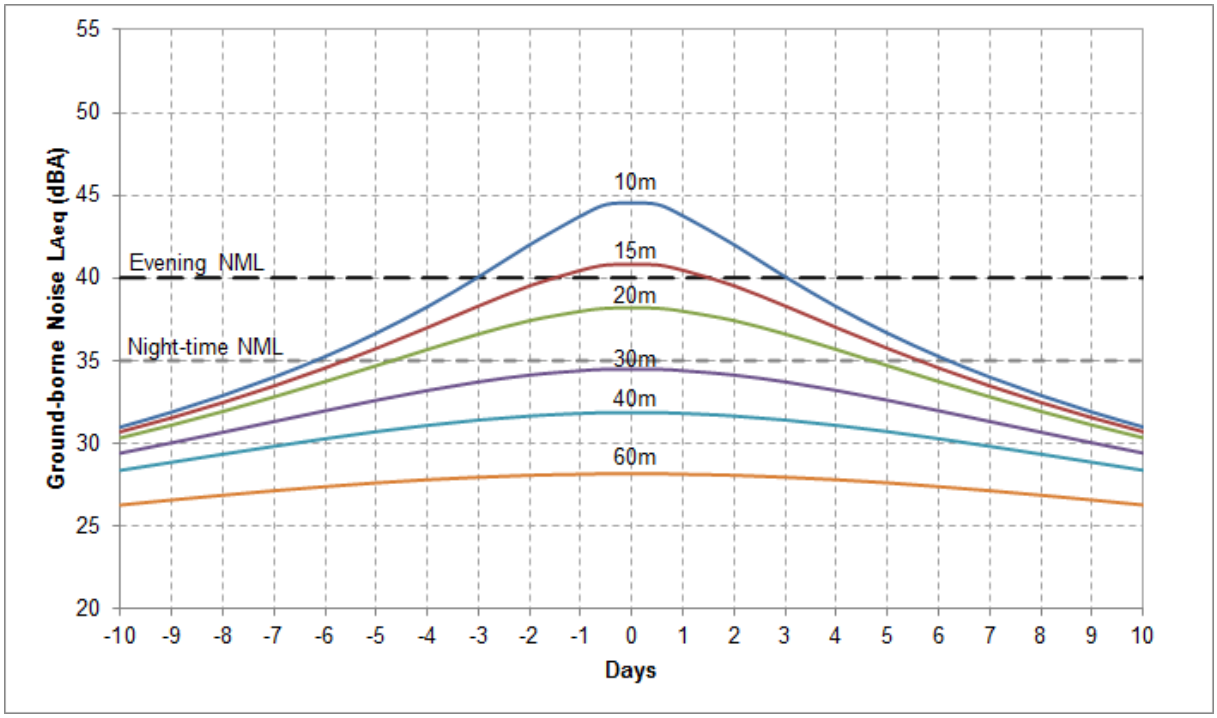
Given the progression rate of the roadheader works (assumed to be around 30 metres per week), it is anticipated that the worst-case ground-borne noise impacts along the majority of the alignment would only be apparent for a relatively short period of time (ie several days for each roadheader) whilst the tunnelling works are directly beneath a particular receiver.

As the works progress and move away, a particular receiver's exposure to ground-borne noise would notably reduce. This concept is illustrated in **Figure 15**, which shows the likely internal ground-borne noise levels from roadheader excavation works as they progresses past a particular location.

The figure indicates that the night-time NML of 35 dBA $L_{Aeq(15minute)}$ is likely to be exceeded at a particular location as each roadheader passes for the following approximate durations:

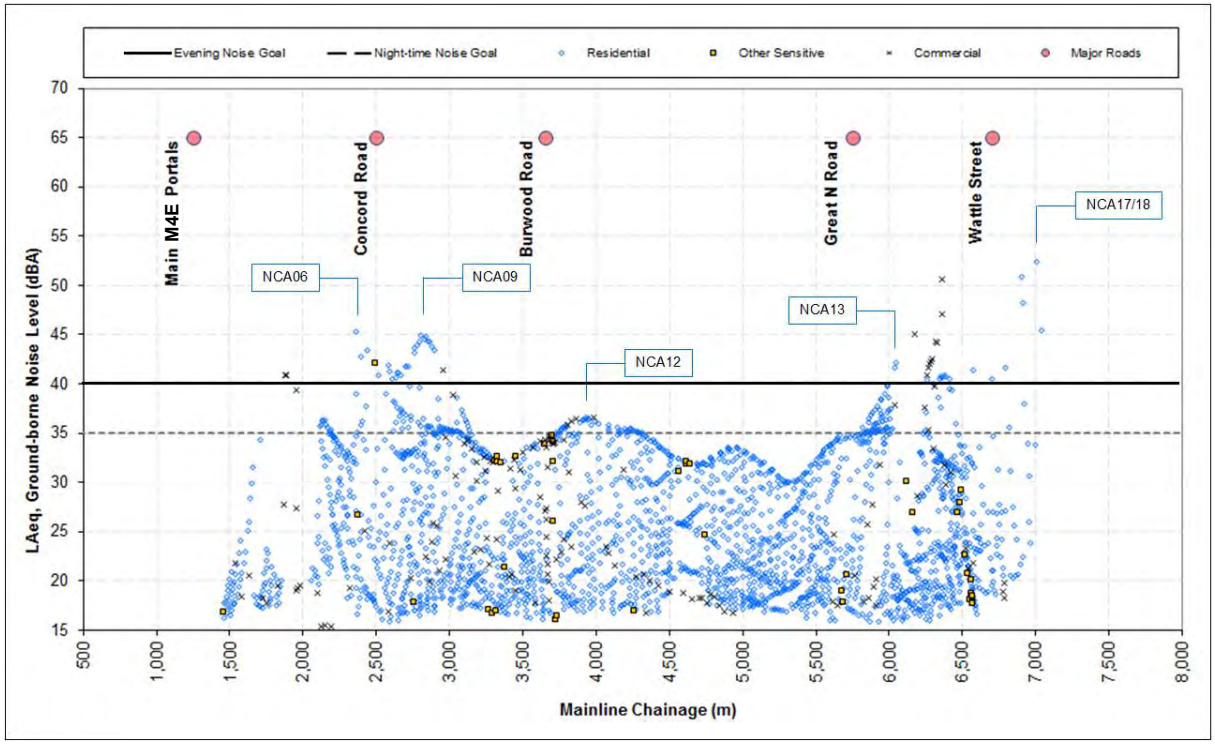
- 10 days where a slant distance of approximately 20 metres from the tunnels is apparent.
- 11 days where a slant distance of approximately 15 metres from the tunnels is apparent.
- 13 days where a slant distance of approximately 10 metres from the tunnels is apparent.

Figure 15 Ground-borne noise levels at slant distances from roadheading (progress = 30 m/week)



A graph showing the maximum ground-borne noise levels from roadheader excavation works is presented in **Figure 16**.

Figure 16 Worst-case predicted ground-borne noise levels during tunnelling (roadheader)



12.5 Discussion

The worst-case ground-borne noise levels are predicted to be compliant with the more stringent 35 dBA $L_{Aeq(15minute)}$ night-time criterion at the majority of receivers which are potentially affected by ground-borne noise from tunnelling works.

At residential locations greater than a slant distance of 40 m from the nearest tunnel (ie taking into account the tunnel depth and the horizontal offset distance), exceedances of the ground-borne NML of 35 dBA $L_{Aeq(15minute)}$ during night-time periods are unlikely. At several locations however, the tunnel depth at receivers directly above the proposed alignment is less than 40 m. The potential ground-borne noise impacts at these locations are discussed below:

- In NCA06, NCA07 and NCA09, in the vicinity of Concord Road, where the access ramps to/from the main M4E tunnels climb to meet with Concord Road at ground elevation, receivers above the tunnels in these catchments between approximate chainage 2,300 – 2,700 (around Concord Road interchange, Concord) are predicted to be subject to ground-borne levels up to around 45 dBA $L_{Aeq(15minute)}$, which exceeds both the evening and night-time criteria. Based on a progress rate of 30 metres per week, the most affected receivers are likely to experience noise levels above the night-time criterion for up to around ten days.
- In NCA12, at approximate chainage 3,900 (just east of Burwood Road, Burwood), marginal exceedances of the night-time criterion are predicted, with ground-borne noise levels of up to 37 dBA $L_{Aeq(15minute)}$ being predicted. The relative depth of the tunnel is less in this location due to a lower ground elevation than the surrounding areas of receivers.
- In NCA13, at approximate chainage 6,000 (to the south of Parramatta Road, Ashfield), receivers are predicted to be subject to ground-borne levels up to around 43 dBA $L_{Aeq(15minute)}$, which exceeds both the evening and night-time criteria. This area of receivers is above the location where the mainline tunnels rise in elevation and become shallower. Based on a progress rate of 30 metres per week, the most affected receivers are likely to experience noise levels above the night-time criterion for up to around six days.
- In NCA17 and NCA18, in the vicinity of Wattle Street, where the access ramps to/from the main M4E tunnels climb to meet with Wattle Street and Parramatta Road at ground elevation, receivers above these sections are predicted to be subject to ground-borne levels up to around 53 dBA $L_{Aeq(15minute)}$, which exceeds both the evening and night-time criteria. Based on a progress rate of 30 metres per week, the most affected receivers are likely to experience noise levels above the night-time criterion for up to around two weeks.

At all of the above locations, the ground-borne noise predictions are based on the nearest sensitive receivers above or adjacent to the proposed tunnel alignment. The ground-borne noise impacts would reduce for sensitive receivers offset horizontally from the proposed alignment due to the increased slant distance.

12.6 Rockbreaking and Blasting

It is understood that the contractor is proposing to use blasting and potentially rockbreaking to excavate benches and cross passages within the tunnel sections of the project. There is potential for ground-borne noise impacts from these activities where receivers are situated above the tunnel.

Reference to **Figure 14** shows a maximum tunnel depth of around 60 metres below surface level. As such, with reference to **Figure 13**, all cross passage locations excavated by rockbreakers are likely to exceed the night-time ground-borne noise criterion of 35 dBA where residential receivers are located above. As a guide, the following ground-borne noise levels are likely from rockbreakers working at various distances from receivers:

- A slant distance of 20 metres results in around 61 dBA
- A slant distance of 40 metres results in around 47 dBA
- A slant distance of 60 metres results in around 39 dBA

Detailed ground-borne noise predictions would be undertaken by the contractor during detailed design to determine the likely impacts from these activities. These assessments would form part of site specific Construction Noise and Vibration Impact Assessments.

Whilst blasting is proposed and may generate audible ground-borne noise at receivers above the tunnelling works assessment of impulsive blasting, typically conducted as a single event, against the ICNG slow weighted 15-minute L_{Aeq} criteria is not appropriate. Criteria for assessing impacts from blasting are discussed in **Section 13.8**. The procedures for managing and mitigating the potential impacts from blasting would be addressed in the contractor's blasting plan which would form part of the project's CEMP.

12.7 Ground-borne Noise Mitigation

Depending on the specific construction equipment, and where vibration intensive construction activities are proposed in relation to nearby sensitive receivers the general, mitigation measures that should be considered are summarised as follows:

- Vibration intensive construction works should be confined to the less sensitive daytime period as far as reasonably practicable.
- The potential impacts from vibration are to be considered with more detailed and localised geotechnical conditions ie establish the vibration *site law* for the assessment location.
- Detailed design to include site-specific CNVMPs where necessary.

13 Construction vibration assessment

13.1 Vibration damage criteria overview

Most commonly specified “safe” structural vibration limits are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have potential to cause damage to the main structure.

In terms of the most recent relevant vibration damage criteria, British Standard 7385:Part 2-1993 *Evaluation and Measurement for Vibration in Buildings Part 2*[xiv] is an internationally accepted standard against which the likelihood of building damage from ground vibration can be assessed. This is the Standard recommended in Australian Standard AS 2187: Part 2-2006 *Explosives - Storage and Use - Part 2: Use of Explosives* as the vibration guideline values and assessment methods “are applicable to Australian conditions”.

Another reference, German Standard DIN 4150: Part 3-1999[xv] also provides guidelines for evaluating the effects of vibration on structures. For vibration frequencies of less than 10 Hz, the DIN Standard gives a “safe limit” of peak vibration for dwellings of 5 mm/s and for historic buildings (with preservation orders or the like) of 3 mm/s. As opposed to the “minimal risk of cosmetic damage” approach adopted in BS 7385, the “safe limits” given in DIN 4150 are the vibration levels up to which no damage due to vibration effects has been observed. Hence the guideline limits in DIN 4150 are somewhat lower than those in BS 7385.

13.2 Vibration damage goals

13.2.1 Australian Standard AS 2187 and British Standard BS 7385

Australian standard AS 2187: Part 2-2006 *Explosives - Storage and Use - Part 2: Use of Explosives* recommends the frequency dependent vibration guideline values and assessment methods given in British Standard BS 7385 Part 2-1993 *Evaluation and measurement for vibration in buildings Part 2* as they “are applicable to Australian conditions”.

The standard sets guide values for vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk is usually taken as 95 per cent probability of no effect.

The recommended guideline limits for transient vibration to minimise risk of cosmetic damage to residential and industrial buildings are presented in **Table 52** and graphically in **Figure 17**.

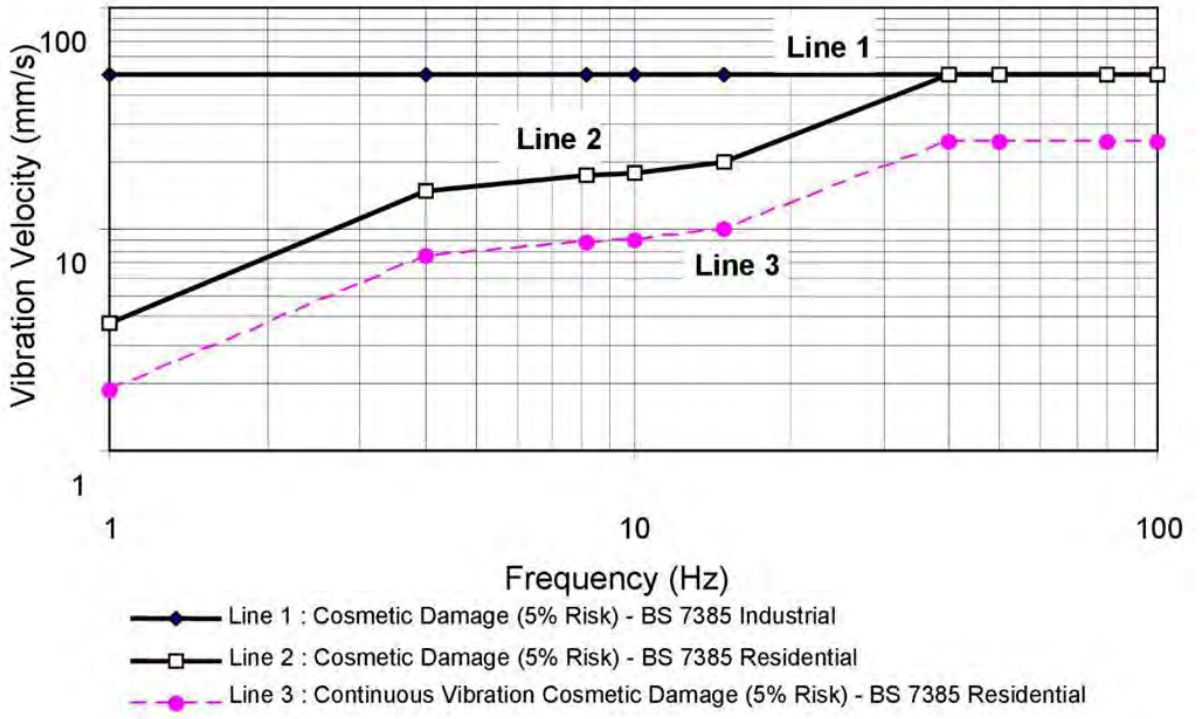
Table 52 AS 2187 Transient Vibration Guide Values - Minimal Risk of Cosmetic Damage

Line	Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	15 Hz and Above
1	Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures. Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

The guide values in **Table 52** relate predominately to transient vibration which does not give rise to resonant responses in structures and low-rise buildings. In the event continuous vibration gives rise to magnification of vibration by resonance (specific conditions where the structure can readily store and transfer vibration energy), then the guide values in **Table 52** may need to be reduced by up to 50 percent

Rockbreaking, rock hammering and sheet piling are considered to have the potential to cause dynamic loading in some structures and it may therefore be appropriate to reduce the transient values by 50 per cent for these construction activities.

Figure 17 Transient vibration guide values for cosmetic damage



13.2.2 German Standard DIN 4150

For continuous long-term vibration or repetitive vibration with the potential to cause fatigue effects, DIN 4150 provides the following Peak Particle Velocity (PPV) values as safe limits, below which superficial cosmetic damage is not to be expected:

- 10 mm/s for commercial buildings and buildings of similar design.
- 5 mm/s for dwellings and buildings or similar design.
- 2.5 mm/s for buildings of particular sensitivity (structurally unsound).

For short-term vibration events (ie those unlikely to cause resonance or fatigue), DIN 4150 offers the criteria shown in **Table 53**. These are maximum levels measured in any direction at the foundation or in the horizontal axes in the plane of the uppermost floor.

The minimum "safe limit" of peak vibration velocity at low frequencies for commercial buildings and buildings of similar design is 20 mm/s (Group 1). For dwellings and buildings of similar design and/or use it is 5 mm/s (Group 2) and for structures which may be particularly sensitive to ground vibration, such as historic buildings which are structurally unsound (Group 3), it is 3 mm/s. This latter criterion could also be applied to buried archaeological artefacts.

Table 53 DIN 4150 structural damage - safe limits for short-term building vibration

Group	Type of Structure	Peak Particle Velocity (mm/s)			
		At Foundation			Plane of Floor of Uppermost Storey
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz[1]	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 at 10 Hz increasing to 40 at 50 Hz	40 at 50 Hz increasing to 50 at 100 Hz	40
2	Dwellings and buildings of similar design and/or use	5	5 at 10 Hz increasing to 15 at 50 Hz	15 at 50 Hz increasing to 20 at 100 Hz	15
3	Structures that because of their particular sensitivity to vibration (structurally unsound), do not correspond to those listed in Lines 1 or 2	3	3 at 10 Hz increasing to 8 at 50 Hz	8 at 50 Hz increasing to 10 at 100 Hz	8

Note 1: For frequencies above 100 Hz the upper value in this column should be used.

As opposed the “minimal risk of cosmetic damage” approach adopted in BS 7385 (95% probability of no effect), the “safe limits” given in DIN 4150 are the levels up to which no damage due to vibration effects has been observed for the particular class of building. “Damage” is defined by DIN 4150 to include even minor non-structural effects such as superficial cracking in cement render, the enlargement of cracks already present, and the separation of partitions or intermediate walls from load bearing walls.

13.3 Project vibration goals

Residential and commercial locations

Most sources of intermittent vibration during construction, such as rockbreakers, piling rigs, vibratory rollers and excavators, the predominant vibration energy occurs at frequencies usually in the 10 Hz to 100 Hz range. On this basis, and with reference to **Table 52**, a vibration damage screening level of 7.5 mm/s has been adopted for the purpose of assessing potential impacts from continuous vibration.

In the lower frequency region below 4 Hz the guide values for building types are reduced as a high displacement is associated with relatively low peak component particle velocity. To minimise risk of structural damage a guide value of 3.7 mm/s has been adopted.

Heritage buildings

BS 7385 states that “a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive”.

Heritage buildings are to be considered on a case by case bases. Where a historic building is deemed to be sensitive to damage from vibration (following inspection), the more conservative DIN 4150 superficial cosmetic damage criteria of 2.5 mm/s should be considered as a screening criterion. Where heritage buildings of a typical residential-type construction are not found to be structurally unsound, DIN 4150 superficial cosmetic damage criteria of 5 mm/s may be more suitable as a screening criterion.

It should be noted from **Table 53** that levels higher than these minimum figures for low frequencies may be quite "safe", depending on the frequency content of the vibration.

13.4 Human comfort goals for construction vibration

13.4.1 Perception of vibration

Humans are far more sensitive to vibration than is commonly realised. They can detect vibration levels well below those required to cause any risk of damage to a building or its contents.

The actual perception of motion or vibration may not in itself be disturbing or annoying. An individual's response to that perception and whether the vibration is 'normal' or 'abnormal' depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as normal in a car, bus or train is considerably higher than what is perceived as normal in a shop, office or dwelling. The vibration caused in a home by a child running across a timber floor may be acceptable to most people, but similar vibration caused by nearby road construction may be considered unacceptable.

Human tactile perception of random motion, as distinct from human comfort considerations, was investigated by Diekmann and subsequently updated in German Standard DIN 4150 Part 2-1975. On this basis, the resulting degrees of perception for humans are suggested by the vibration level categories given in **Table 54**.

Table 54 Peak Vibration Levels and Human Perception of Motion

Approximate Vibration Level		**Degree of Perception**
Peak Vibration Level	**RMS Vibration Level**	
0.10 mm/s	0.07 mm/s	Not felt
0.15 mm/s	0.1 mm/s	Threshold of perception
0.35 mm/s	0.25 mm/s	Barely noticeable
1 mm/s	0.7 mm/s	Noticeable
2 mm/s	1.4 mm/s	Easily noticeable
6 mm/s	4.2 mm/s	Strongly noticeable
14 mm/s	10 mm/s	Very strongly noticeable

Note: These approximate vibration levels (in floors of building) are for vibration having a frequency content in the range of 8 Hz to 80 Hz. The RMS vibration levels assume a crest factor of 1.4 for sinusoidal vibration.

Table 54 suggests that people will just be able to feel floor vibration at levels of about 0.1 mm/s (RMS) and that the motion becomes "noticeable" at a level of approximately 0.7 mm/s.

The *Assessing Vibration: a technical guideline* (DEC 2006) notes that *"vibration in buildings can be caused by many different external sources, including industrial, construction and transportation activities. The vibration may be continuous (with magnitudes varying or remaining constant with time), impulsive (such as in shocks) or intermittent (with the magnitude of each event being either constant or varying with time)."*

Examples of intermittent vibration events include vibration generated by vibratory rollers, drilling and materials handling. Examples of impulsive vibration events include the vibration the dropping of heavy equipment.

Where vibration is intermittent or impulsive in character, the DEC vibration guideline (and other similar guidelines) recognises that higher vibration levels are tolerable to building occupants than for continuous vibration. As such, higher vibration goals are usually applicable for short term, intermittent and impulsive vibration activities than for continuous sources

13.4.2 Vibration Goals

For most construction activities that generate perceptible vibration in nearby buildings, the character of the vibration emissions is intermittent. The *Assessing Vibration: A Technical Guideline* nominates preferred and maximum vibration goals for critical areas, residences and other sensitive receivers as shown in **Table 55**. The guideline advises a low probability of adverse comment or disturbance to building occupants would be expected at or below the preferred values.

The applicable human comfort vibration goal for intermittent vibration source is defined in terms of Vibration Dose Values (VDVs) where the permissible vibration level corresponding to the VDV varies according to the duration of exposure.

Table 55 Preferred and maximum vibration dose values for intermittent vibration

Building Type	Vibration Dose Value ($m/s^{1.75}$)	
	Preferred	**Maximum**
Critical Working Areas (e.g. hospital operating theatres, precision laboratories)	0.10	0.20
Residential Daytime	0.20	0.40
Residential Night-time	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80
Workshops	0.80	1.60

Note: Daytime is 7:00 am to 10:00 pm and night-time is 10:00 pm to 7:00 am

In applying the preferred and maximum VDV the guidelines states that:

> *Situations exist where vibration above the preferred values can be acceptable, particularly for temporary disturbances and infrequent events of short term duration. An example is a construction or excavation project.*

The guideline also advises that:

> *Where all feasible and reasonable measures have been applied to control potential ground vibration levels the maximum values may be used. For values above the maximum value the proponent should negotiate directly with the affected community.*

13.5 Safe working distances for vibration intensive plant

Propagation of vibration emitted from a source would be site specific with the level of vibration potentially experienced at a receiver dependent upon the vibration energy generated by the source, the predominant frequencies of vibration, the localised geotechnical conditions and the interaction of structures and features which can dampen vibration.

While the ground damping characteristics may vary between the ground types likely to be found in study area (understood to be shale and sandstone), this is expected to have negligible effect on the vibration predicted at the relatively short distances to the nearest receivers. It should be noted that the source frequency can change with different ground types and local site conditions should be considered during the detailed design.

The recommended safe working distances for construction plant in **Table 56** are referenced from the *Construction Noise Strategy (*Transport for NSW, 2012)[xvi].

Consistent with the British Standard and the Assessing Vibration guideline, the recommendations are for the practical management of potential vibration to minimise the likelihood of cosmetic damage to buildings and disturbance or annoyance in humans. The human comfort safe working distances are conservative, developed with reference to the more stringent objectives for continuous vibration for typical residential building constructions.

Table 56 Recommended safe working distances for vibration intensive plant

Plant Item	Rating/ Description	Safe Working Distance			
		Cosmetic Damage			Human Response[3]
		Residential and Light Commercial[1]	Group 2 (Typical)[2]	Group 3 (Structurally unsound)[2]	
Vibratory Roller	< 50 kN (Typically 1-2t	5 m	7 m	11 m	15 m to 20 m
	< 100 kN (Typically 2-4t)	6 m	8 m	13 m	20 m
	< 200 kN (Typically 4-6t)	12 m	16 m	15 m	40 m
	< 300 kN (Typically 7-13)t	15 m	20 m	31 m	100 m
	> 300 kN (Typically 13-18t)	20 m	26 m	40 m	100 m
	> 300 kN (Typically > 18t)	25 m	33 m	50 m	100 m
Small Hydraulic Hammer	300 kg - 5 to 12t excavator	2 m	3 m	5 m	7 m
Medium Hydraulic Hammer	900 kg - 12 to 18t excavator	7 m	10 m	15 m	23 m
Large Hydraulic Hammer	1600 kg - 18 to 34t excavator	22 m	29 m	44 m	73 m
Vibratory Pile Driver	Sheet piles	2 m to 20 m	3 m	5 m	20 m
Pile Boring	≤ 800 mm	2 m (nominal)	3 m	5 m	N/A
Jackhammer	Hand held	1 m (nominal)	2 m	3 m	Avoid contact with structure
Roadheader[4]	Tunnelling	2 m	3 m	5 m	7 m

Note 1: Criteria referenced from British Standard BS 7385 Part 2-1993 *Evaluation and measurement for vibration in buildings Part 2*

Note 2: Criteria referenced from DIN 4150 Structural Damage - Safe Limits for Short-term Building Vibration

Note 3: Criteria referenced from EPA's *Assessing Vibration: a technical guideline (*DEC, 2006)

Note 4: Measurement from SLR Database

13.6 Estimated working distances and vibration intensive plant

The proposed works have been analysed to determine best estimate minimum safe working distances for the vibration intensive mechanical plant proposed for the construction activities. Proposed vibration intensive construction plant are listed in **Table 57** and compared to the safe working distances listed in **Table 56** in order to determine potential vibration impacts of the main construction scenarios.

Refer to **Section 10.5.2** for a discussion of indicative durations for the construction activities.

Table 57 Construction vibration assessment summary

Work Scenario	Vibration Intensive Equipment	NCA	Number of buildings within safe working distance for highest vibration plant item			
			Cosmetic Damage			Human Response
			Residential and Light Commercial	Group 2 (Typical)	Group 3 (Structurally unsound)[1]	
Road Works[2]	Bored piling Jackhammer Rock anchor drill Rockbreaker[3]	NCA01	4	8	-	12
		NCA02	9	13	-	48
		NCA03	2	7	-	33
		NCA04	7	8	-	28
		NCA05	-	1	-	8
		NCA06	22	24	5	47
		NCA07	30	31	2	41
		NCA08	4	4	-	10
		NCA09	1	3	-	17
		NCA10	-	-	-	-
		NCA11	3	3	-	9
		NCA12	-	-	-	-
		NCA13	1	1	1	4
		NCA14	20	22	-	45
		NCA15	24	25	-	48
		NCA16	9	11	-	17
		NCA17	11	13	-	37
		NCA18	20	20	2	27
		NCA19	1	2	2	4
		NCA20	7	10	-	14
		NCA21	28	32	1	44
		ALL	**203**	**238**	**13**	**493**
Tunnelling	Roadheader[3] Rock anchor drill	NCA01	-	-	-	-
		NCA02	-	-	-	3
		NCA03	-	-	-	-
		NCA04	-	-	-	-
		NCA05	-	-	-	-
		NCA06	-	-	-	-
		NCA07	-	-	-	-
		NCA08	-	-	-	-
		NCA09	-	-	-	-
		NCA10	-	-	-	-
		NCA11	-	-	-	-
		NCA12	-	-	-	-
		NCA13	-	-	-	-
		NCA14	-	-	-	-
		NCA15	-	-	-	-
		NCA16	-	-	-	-
		NCA17	-	-	-	-
		NCA18	-	-	-	-
		NCA19	-	-	-	-
		NCA20	-	-	-	-
		NCA21	-	-	-	-
		ALL	-	-	-	**3**

Note 1: Heritage buildings only and represents a screening test applicable where a historic building is deemed to be sensitive to damage from vibration (following inspection) to be confirmed during detailed design.

Note 2: Including the vertical shaft construction at Underwood Road tunnel site.

Note 3: Proposed highest vibration plant item for these works

Estimated safe working distances for the roadworks and tunnelling works are shown graphically in **Appendix T**. Heritage listed buildings identified within cosmetic damage safe working distances are listed in **Table 58**.

Table 58 Heritage and Conservation Listed Buildings within Cosmetic Damage Safe Working Distance

NCA	Address	Building Occupancy	Construction Type[1]
NCA06	33 Sydney Street, North Strathfield	House	Masonry
	35 Sydney Street, North Strathfield	House	Masonry
	2 Carrington Street, North Strathfield	House	Masonry
	4 Carrington Street, North Strathfield	House	Timber
	14 Carrington Street, North Strathfield	House	Masonry
NCA07	81 Concord Road, Concord	Place of Worship	Masonry
NCA13	476 Parramatta Road, Ashfield	Commercial (Bunnings)	Masonry
NCA18	146-148 Ramsay Street, Haberfield	House	Masonry
	150-152 Ramsay Street, Haberfield	House	Masonry
NCA19	185 Parramatta Road, Haberfield	Training Facility	Masonry
NCA21	86 Orpington Street, Ashfield	House	Masonry

Note 1: Estimated from photographic information only and should be confirmed on site.

Masonry constructions listed in **Table 58** are not likely to be structurally unsound; however, timber constructions in this table have the potential to be considered structurally unsound. The construction type classifications and structural integrity of all the listed heritage buildings should be confirmed at detailed design by a suitably qualified structural engineer. This information can then be used to verify the applicable vibration criteria and associated impacts.

13.6.1 Cosmetic damage assessment summary

The separation distance(s) between the proposed works and the nearest receivers would generally be sufficient so that nearby buildings are unlikely to suffer 'Cosmetic Damage' for most of the proposed construction equipment. However, based on the arrangement of the work zones, some items of construction equipment have the potential to be operated closer to sensitive receivers than the recommended safe working distances. Operation of large rockbreakers has the potential to generate some of the most significant construction vibration impacts due to the high vibration characteristics of the plant.

The information presented in **Table 57** indicates that up to 203 buildings may be within the BS 7385 safeworking distances for Residential and Light Commercial building types should a large rockbreaker be used at the outer extents of the M4 East construction footprint. In practice, it is unlikely that a rockbreaker would be required at all areas and therefore the vibration impacts presented in this assessment should be considered conservative and represents a worst-case. The required locations for vibration intensive equipment should be reviewed during detailed design when more specific information is available.

The assessment considers vibration from the main construction scenarios (roadworks and tunnelling) which extend across the extents of the study area. Should other isolated works require vibration intensive plant, the safe working distances presented in **Table 56** should be used to determine the indicative safeworking distance for any works.

Vibration trials and/or attended vibration monitoring or should be undertaken prior to and during any works proposed within the safe working distances to ensure that levels remain below the criteria. Building condition surveys should also be completed both before and after the works at any potentially affected properties to identify existing damage and any proposal related damage.

At locations where the predicted and/or measured vibration levels are greater than the nominated screening levels, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure would be required to determine the applicable safe vibration level.

13.6.2 Human comfort vibration assessment summary

The assessment presented in **Table 57** indicates a low risk of annoyance from the proposed tunnelling works using a roadheader with all receivers outside the nominated safe working distance except three receivers in NCA02 near the tunnel dives at the western end of the project.

Assessment of the proposed roadworks using a large rockbreaker may result in a significant number of receivers (around 500 residential receivers across the project) within the nominated safe working distance for human comfort vibration.

In relation to human comfort (response), the safe working distances in **Table 56** relate to continuous vibration and apply to residential receivers. For most construction activities, vibration emissions are intermittent in nature and for this reason, higher vibration levels, occurring over shorter periods are permitted, as discussed in BS 6472-1.

Receivers adjacent to construction areas have been identified as likely to perceive vibration impacts at times during construction works. This is expected to be primarily due to works associated with rockbreakers and other high vibration plant items such as heavy vibratory rollers. In practice vibration impacts from most construction activities would be intermittent within the duration of the project and generally tend to move along the alignment such that impacts at any given receiver are for a far shorter duration. The required locations for vibration intensive equipment should be reviewed during detailed design when more specific information is available.

13.7 Cumulative vibration impacts

Due to the intermittent nature of construction works, vibration impacts due to multiple works scenarios are considered unlikely to result in concurrent vibration peaks, but rather, may increase the effective duration of the exposure to vibration. Vibration impacts due to multiple simultaneous works would therefore be managed in the same manner as for single works scenarios (dependant on the operating equipment).

13.8 Blasting

The use of blasting has been proposed for consideration to assist in the excavation of tunnel benches and cross passages. Blasting is proposed as an excavation technique because the vibration impacts from blasting are of a much shorter duration for nearby sensitive receivers compared to the vibration impacts associated with mechanical excavation methods such as roadheaders or rockbreakers.

The suitability of blasting would be confirmed during the detailed design stage of the proposal on a location specific basis.

13.8.1 Project blasting criteria (human comfort)

Guidance in relation to acceptable overpressure and vibration from blasting is provided in the ICNG, which specifies that the assessment should be based on the levels in the *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration* (ANZEC 1990).

Airblast overpressure criteria for blasting

- Recommended maximum level of 115 dB (linear peak). This may be exceeded on up to 5% of the total number of blasts over a period of 12 months.
- A maximum level of 120 dB (linear peak) should not be exceeded at any time.

Ground vibration criteria for blasting

- Recommended maximum level of 5 mm/s (peak particle velocity). This may be exceeded on up to 5% of the total number of blasts over a period of 12 months.
- A maximum level of 10 mm/s (peak particle velocity) should not be exceeded at any time.

This criteria relates to sensitive sites (includes houses and low rise residential buildings, theatres, schools, and other similar buildings occupied by people).

The blast vibration criteria identified in ANZECC 1990 are considered conservative and were originally developed to protect communities exposed to long-term blasting operations such as communities adjacent to mining sites. For projects (such as this one) with a shorter duration of blasting of 12 months or less a higher vibration criteria may be reasonable as a short duration project should not be assessed to the same criteria as a long-term project. For this project the location of the blast moves along the alignment such that any one receiver is affected for only a short proportion of the project.

Table J4.5(A) in Appendix J of AS2187 presents vibration limits designed to safeguard human comfort in relation to blasting that have been used by some authorities as it defines clearer vibration limits which are dependent on the specific duration of the project. Based on the limitations of ANZECC 1990 and further guidance in AS2187 we recommend a human comfort vibration limit of **10 mm/s** (peak particle velocity) for blasting operations lasting less than 12 months be applied to this project.

13.8.2 Project blasting criteria (control of damage)

In terms of the most recent relevant vibration damage criteria, Australian Standard AS 2187: Part 2-2006 *Explosives - Storage and Use - Part 2: Use of Explosives* recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 as they "are applicable to Australian conditions". The AS 2187 criteria are presented in **Table 52**.

It should be noted that BS7385 states that "a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive". Nominating appropriate criteria for heritage buildings generally require site inspections and should be confirmed during detailed design.

In relation to damage from airblast, AS2187 notes that from Australian and overseas research, damage (even of a cosmetic nature) has not been found to occur at airblast levels below 133 dBL.

13.8.3 Recommended blasting hours

For blasting, the recommended standard hours of construction in NSW are applicable:

- 9:00 am to 5:00 pm Monday to Friday
- 9:00 am to 1:00 pm Saturday
- No blasting on Sundays and Public Holidays

Other hours may be worked if approved by the relevant authority.

13.8.4 Blasting assessment

Reference to the proposed tunnel depth presented in **Figure 14** indicates that the depth of cover is typically 30 metres or more for the majority of the tunnel alignment.

In order to estimate the level of ground vibration resulting from the subject tunnel blasting, the blast vibration "site law" developed from blasting the northern section of the Sydney Harbour Tunnel was employed. Geotechnical conditions for the Sydney Harbour tunnel project included sandstone rock which is considered comparable to the worst-case conditions anticipated for tunnelling works on this project.

The subject site law for ground vibration is:

PVS (mm/s) = 135(R/Q0.5)-1.08

where,

PVS= Peak Vector Sum ground vibration level (mm/s)

R = Distance between charge and receiver (m)

Q = Charge mass per delay detonator (MIC - kg)

Based on the above vibration site law and the typical 30 metre depth of cover, the predicted level of vibration for an MIC of 10 kg is 12 mm/s.

Measured blast emissions data indicates a dominant frequency of the vibration signal of around 20 Hz at an offset of 30 m.

Reference to **Table 52** in **Section 13.2.1** indicates a transient vibration guide value for the prevention of cosmetic building damage of 26 mm/s.

The corresponding guide value for human comfort is a maximum of 10 mm/s (refer **Section 13.8.1**). Compliance with a ground vibration level of 10 mm/s is predicted to be achieved by using an MIC of approximately 7.0 kg.

13.8.5 Blasting recommendations

Blasting has the potential to significantly reduce the noise and vibration impacts if managed appropriately by the contractor. Blasting is proposed as an excavation technique because the vibration impacts from blasting are of a much shorter duration for nearby sensitive receivers compared to the vibration impacts associated with mechanical excavation methods such as roadheaders or rockbreakers.

Noise and vibration impact predictions for blasting operations should be undertaken in the detailed design phase when more information is available on the blasting scope and methods. Blasting specific noise and vibration mitigation methods should be incorporated into the CNVMPs where required.

Blasting should be restricted to standard daytime hours only (except where approved by the relevant authority). Site investigations should be conducted prior to production blasting to define suitable blast sizes to comply with project blasting noise and vibration criteria. Dilapidation studies of nearby receiver buildings may be required where potential for exceedances of the blasting criteria are identified.

Should the predicted levels exceed the noise or vibration criteria, alternative construction methods would need to be considered such as penetrating cone fracture.

13.8.6 Other blasting methods

Electronic Detonation Blasting

In electronic detonation the delay is achieved electronically to control delay timing. An integrated circuit chip and a capacitor internal to each detonator control the initiation time of the detonation. Generally electronic detonation reduces the overall vibration level (peak particle velocity) and increases the frequency of the vibration event – both of which are desirable when considering the construction vibration criteria.

Specific details on the vibration events generated by this type of blasting are not available as the technique is proprietary and vibration information is not generally publically available. The use of this blasting technique is potentially feasible, however the manufacturer's data should be confirmed with independent testing / review before commencement on site.

It is understood that Electronic Detonation Blasting technique has been utilised on a number of construction projects in Australia such as the Brisbane Airport Link Project.

Penetrating Cone Fracture

This technique has successfully been utilised on a number of construction sites in Sydney, including at the Westfield site in Bondi Junction.

Rock can be fractured by the introduction of a pulse of high pressure gas at the base of a short drill-hole. The generated gas penetrates into small microfractures created from the percussive drilling process. These microfractures are forced to expand and propagate into tensile cracks causing the rock to fail.

A cartridge filled with a specially formulated propellant produces gas by deflagrating when the propellant is ignited. Because the gas is confined down the hole in a very small volume, very high gas pressure is generated when the propellant is ignited.

A direct comparison between similar weights of explosive and propellants has indicated that the energy released by a PCF cartridge is approximately 45% that of the energy of a similar size explosive charge (using traditional detonation). The difference in energy required to break the same amount of rock between PCF and conventional blasting is because PCF utilises tensile breakage rather than compressive breakage, which is generally more energy efficient.

Since PCF utilises pressurised gases from deflagrating propellant to break rock, the method does not produce a shock wave that is characteristic of high explosives. PCF cartridges are described as deflagrating products rather than detonating explosives.

Vibration levels induced by PCF are generally lower when compared to explosives of the same weight, using tradition detonation techniques. Manufacturer's data shows that at 6 m vibration levels of less than 3 mm / s peak particle velocity are observed in very hard rock (30 – 50 MPa). Importantly, the frequency of the vibration generated has been shown to be typically above 100 Hz and often over 500 Hz. Vibration of this frequency and level is unlikely to have any detrimental effect even on *sensitive* heritage buildings, so may be appropriate for use at this site. The manufacturer's data should be confirmed with independent testing / review before commencement on site.

13.9 Vibration mitigation

Depending on the specific construction equipment, and where vibration intensive construction activities are proposed in relation to nearby sensitive receivers, vibration intensive construction works should be confined to the less sensitive daytime period as far as reasonably practicable. The potential impacts from vibration are to be considered in the site-specific CNVMPs, to be developed during the detailed design phase when more information is available on the schedule for the works, the equipment to be used and the localised geotechnical conditions. In general, mitigation measures that should be considered are summarised as follows:

- Investigate the feasibility of rescheduling the hours of operation of major vibration generating plant and equipment to less sensitive times such as 9:00 am to 12:00 pm or 2:00 pm to 5:00 pm, if agreed by the community affected.
- Use lower vibration generating items of excavation plant and equipment eg smaller capacity rockbreaker hammers as far as reasonably practicable.
- Minimise consecutive nights works in the same locality (if applicable) – likely to only apply to the moving corridor works and not the civil and tunnel sites.
- Use dampened rockbreakers and/or 'city' rockbreakers to minimise the impacts associated with rockbreaking works where a larger breaker may result in adverse noise impacts.
- If vibration intensive works are required within the safe working distances, vibration monitoring or attended vibration trials would be undertaken at the outset of these works to ensure that levels are within relevant criterion.
- Building condition surveys of potentially affected structures would be completed both before and after the works to identify existing damage and any damage due to the works.

Measurements of existing ambient vibration levels would be undertaken at identified receivers with vibration sensitive equipment during the detailed design phase. This information would be used to inform the site-specific CNVMPs for works near these locations.

14 Overall Impact Summary

This section provides an overall summary of the environmental noise and vibration impact assessment from the preceding technical chapters.

14.1 NCA01

14.1.1 Operation

NCA01 is at the western end of the study area with existing noise levels dominated by the M4 Motorway and Parramatta Road. In the No Build situation, predicted noise levels at receivers near the M4 Motorway are greater than 65 dBA in the daytime and night-time. To the south of the NCA, Parramatta Road begins to dominate the noise levels away from the M4 Motorway, while the receivers to the north of the NCA away from the M4 Motorway have noise levels of 55 dBA and 50 dBA for the daytime and night-time respectively.

The project splits the current M4 alignment, making new lanes closer to the receivers and forms the new M4 East lanes in the middle which enter the tunnel portals to the east. An increase in traffic is forecast on Parramatta Road in this section which is predicted to increase noise levels at adjacent receivers by more than 2 dBA and therefore designates this part of Parramatta Road as a project road under Roads and Maritime policy.

Redeveloped road criteria (60 dBA in the daytime and 55 dBA in the night-time) have been applied in this catchment. Without mitigation, eight receivers (seven individual buildings) qualify for consideration of noise mitigation due to an increase in noise level and 1 receiver (1 individual building) qualify on the basis of a cumulative limit exceedance. A further 44 receivers (23 individual buildings) qualify on the basis of more than one trigger.

Installation of low noise pavement is proposed to reduce noise levels at triggered locations, with wider noise benefits across the NCA.

To the south of the M4, noise barriers are not considered reasonable adjacent to the M4 in this location due to noise wall performance being reduced by noise from Parramatta Road.

To the north, a 6.0 metre noise barrier (either as an extension to the existing barrier, or with partial relocation) is considered as the optimum height for benefit at the adjacent residential receivers however this is subject to further considerations during detailed design such as construction limitations, overshadowing, urban design and community preference.

The overall noise levels with the low noise pavement and noise barrier are predicted to be in the region of 65 dBA in the daytime and 60 dBA in the night-time at the closest receivers to the north of the M4. To the south of the M4, overall noise levels with the low noise pavement are predicted to be around 65 dBA in the daytime and 60 dBA in the night-time.

With the low noise pavement and noise barriers, 22 receivers (22 individual buildings) qualify for consideration of at-property treatment.

14.1.2 Construction

Construction activities associated with general corridor construction works and the Homebush Bay Drive construction civil site are required within this catchment. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is < 10 metres with the catchment extending approximately 400 metres away from the works area.

Noise impacts are predicted during the initial road corridor work area establishment works with high NML exceedances of over 20 dBA predicted at the nearest receivers. Similar worst-case exceedances are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers.

Noise impacts are typically seen to reduce to minor impacts (less than 10 dBA above NML) at locations which are past the second row of buildings from the works.

The potential noise impacts from the operation of the Homebush Bay Drive construction civil site are sufficient to require the use of temporary hoarding in order to reduce the noise impacts. Moderate daytime NML exceedances of up to around 15 dBA are however still predicted during the worst-case scenarios due to the proximity of the adjacent receivers to the construction site.

Management of the construction noise impacts in this catchment will likely include restricting operating times of noise intensive plant to less sensitive daytime and evening periods, as far as practicable.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.2 NCA02

14.2.1 Operation

NCA02 is north of the M4 with existing noise levels dominated by the M4 Motorway. In the No Build situation, predicted noise levels at receivers near the M4 Motorway are in the region of 70 dBA in the daytime and 60 dBA in the night-time. Further from the M4 Motorway, receivers have lower noise levels of around 55 dBA and 50 dBA for the daytime and night-time respectively.

This catchment is adjacent to the proposed tunnel portals and modified alignment of the M4 lanes closer to the receivers. West of the portals, noise levels along the M4 carriageway are predicted to reduce due to a reduction in traffic volume (vehicles use the M4 East tunnel instead).

Redeveloped road criteria (60 dBA in the daytime and 55 dBA in the night-time) have been applied in this catchment. Without mitigation, 13 receivers (10 individual buildings) qualify for consideration of noise mitigation due to an increase in noise level and all receivers are below the cumulative limit. A further eight receivers (eight individual buildings) qualify on the basis of more than one trigger.

Installation of low noise pavement is proposed to reduce noise levels, with wider noise benefits across the NCA.

Noise barriers of varying heights are proposed in this NCA. These comprise of relocated barriers (maintaining the same height or increasing in height), a new barrier at 4.0 metres and increasing the height of the existing 2.1 metre barrier section to 4.0 metres. Noise barriers are subject to further considerations during detailed design such as construction limitations, overshadowing, urban design and community preference.

The overall noise levels with the low noise pavement and noise barrier are predicted to be in the region of 65 dBA in the daytime and 55 dBA in the night-time at the closest receivers. Further from the M4 Motorway, receivers have lower noise levels of around 50 dBA and 45 dBA for the daytime and night-time respectively.

With the low noise pavement and noise barriers, five receivers (five individual buildings) qualify for consideration of at-property treatment.

14.2.2 Construction

Construction activities associated with general corridor construction works and the Pomeroy Street construction civil site are required within this catchment. Construction activities for the western ventilation facility and associated demolition of acquired properties are also required at the eastern end of this NCA. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is approximately 10 metres with the catchment extending approximately 400 metres away from the works area.

Noise impacts are predicted during the initial road corridor work area establishment works with predicted NML exceedances of over 25 dBA at nearby receivers. Similar worst-case exceedances are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers. High NML exceedances of more than 20 dBA are also predicted during the demolition of acquired properties in this NCA. Noise impacts reduce to minor impacts of less than 10 dBA generally past the second row of buildings from the works.

Minor NML exceedances (up to 10 dB) are predicted during the construction of the western ventilation facility during the daytime with moderate NML exceedances (up to 20 dB) for these activities during the night-time.

The potential noise impacts from the operation of the Pomeroy Street construction civil site are sufficient to require the use of temporary hoarding to reduce the noise impacts, however the performance of hoarding in this NCA is limited due to the elevated receiver height at upper storeys. Therefore management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Vibration intensive works at the outer extents of the roadworks area and tunnelling activities in this catchment may exceed the nominated safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.3 NCA03

14.3.1 Operation

NCA03 is south of the M4 with existing noise levels dominated by the M4 Motorway and Parramatta Road. In the No Build situation, predicted noise levels at receivers near the M4 Motorway are in the region 65 dBA in the daytime and 60 dBA in the night-time. Parramatta Road begins to dominate the noise levels away from the M4 Motorway.

This catchment is adjacent to the proposed tunnel portals and the modified alignment of the M4 lanes is closer to the adjacent receivers. An increase in traffic is forecast on Parramatta Road in this section which is predicted to increase noise levels at immediately adjacent receivers by more than 2 dBA and therefore designates this part of Parramatta Road as a project road under Roads and Maritime policy.

Redeveloped road criteria (60 dBA in the daytime and 55 dBA in the night-time) have been applied in this catchment. Without mitigation, 24 receivers (22 individual buildings) qualify for consideration of noise mitigation due to an increase in noise level and 4 receivers (3 individual buildings) qualify on the basis of a cumulative limit exceedance. A further seven receivers (seven individual buildings) qualify on the basis of more than one trigger.

Installation of low noise pavement is proposed to reduce noise levels, with wider noise benefits across the NCA.

Noise barrier modifications proposed in this NCA comprise of relocated barriers (maintaining the same height) and are subject to further considerations during detailed design such as construction limitations, overshadowing, urban design and community preference.

The overall noise levels with the low noise pavement and noise barriers are predicted to be in the region of 60 dBA in the daytime and 55 dBA in the night-time at the closest receivers to the M4 corridor. Adjacent to Parramatta Road, overall noise levels are predicted to be around 65 dBA in the daytime and 60 dBA in the night-time.

With the low noise pavement and noise barrier modifications, 30 receivers (28 individual buildings) qualify for consideration of at-property treatment.

14.3.2 Construction

Construction activities associated with general corridor construction works and the Pomeroy Street construction civil site (across the M4 from this catchment) are required in the vicinity of receivers located in NCA03. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is approximately 15 metres with the catchment extending > 500 metres away from the works area.

Noise impacts are predicted during worst-case general corridor works with predicted NML exceedances of over 25 dBA at nearby receivers. Moderate NML exceedances of up to 20 dBA are predicted for the operation of the Pomeroy Street civil site. Minor daytime exceedances (up to 10 dB) are predicted during the demolition of acquired properties on the northern side of the M4.

Reduction of these impacts by early installation of the operational noise barriers as far as practicable will be considered as a mitigation measure during detailed design along with restricting operating times of noise intensive plant to less sensitive periods as far as practicable.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits.

A construction noise and vibration management plan will be prepared during construction planning in order to manage noise and vibration impacts during construction.

14.4 NCA04

14.4.1 Operation

NCA04 is north of the M4 corridor with existing noise levels dominated by the M4 Motorway. In the No Build situation, predicted noise levels at receivers near the M4 Motorway are in the region of 60 dBA in the daytime and 55 dBA in the night-time.

This NCA is east of the proposed tunnel portals and adjacent to a section of the M4 Motorway which is forecast to see a significant reduction in traffic volumes once the project is operational (traffic uses the M4 East tunnel instead).

Redeveloped road criteria (60 dBA in the daytime and 55 dBA in the night-time) have been applied in this catchment. Without mitigation, no receivers qualify for consideration of noise mitigation due to an increase in noise level and five receivers (four individual buildings) qualify on the basis of a cumulative limit exceedance.

Installation of low noise pavement is proposed on the new section of road, with wider noise benefits across the NCA.

Noise barrier modifications proposed in this NCA comprise of relocated barriers (maintaining the same height) and are subject to further considerations during detailed design such as construction limitations, overshadowing, urban design and community preference.

The overall noise levels with the low noise pavement and noise barriers are predicted to be in the region of 55 dBA in the daytime and 50 dBA in the night-time at the closest receivers to the M4 corridor.

With the low noise pavement and noise barrier modifications, five receivers (four individual buildings) qualify for consideration of at-property treatment.

14.4.2 Construction

Construction activities associated with general corridor construction works and the Underwood Road construction civil and tunnel site are required within this catchment. Construction activities for the western ventilation facility and demolition of acquired properties are also required between the M4 and the southern receivers in this NCA. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 10 metres with the catchment extending approximately 500 metres away from the works area.

Noise impacts are predicted during the initial road corridor work area establishment works with predicted high NML exceedances of over 25 dBA at nearby receivers. Similar worst-case exceedances are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers.

High daytime NML exceedances of greater than 20 dBA are predicted during the demolition of acquisition properties, while the construction of the western ventilation facility may result in moderate NML exceedances (up to 20 dB) in the daytime and high NML exceedances (over 20 dB) in the night-time. These impacts are confined to the nearest receivers to the works. Noise impacts generally reduce to minor impacts of less than 10 dBA past the second row of buildings from the works.

The potential noise impacts from the operation of the construction civil site are sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the site operation. Moderate (up to 20 dB) and minor NML exceedances (up to 10 dB) are predicted at the majority of surrounding receivers with the exception of the immediately adjacent receivers which are predicted with high NML exceedances of over 20 dBA during the daytime worst-case operations.

Predicted noise impacts from the tunnel site are sufficient to require the use of an acoustic shed to reduce noise. With the acoustic shed, worst-case night-time NML exceedances are predicted to be below :

- Minor (less than 10dB) at seven receivers

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Vibration intensive works are unlikely to exceed the nominated safe working distances for cosmetic damage in this NCA.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.5 NCA05

14.5.1 Operation

NCA05 is south of the M4 with existing noise levels dominated by the M4 Motorway and Parramatta Road. In the No Build situation, predicted noise levels at receivers near the M4 Motorway are in the region of 65 dBA in the daytime and 60 dBA in the night-time. Parramatta Road begins to dominate the noise levels away from the M4 Motorway.

This NCA is east of the proposed tunnel portals and adjacent to a section of the M4 Motorway which is forecast to see a significant reduction in traffic volumes once the project is operational (traffic uses the M4 East tunnel instead). An increase in traffic is forecast on Parramatta Road in this section which is predicted to increase noise levels at immediately adjacent receivers by more than 2 dBA and therefore designates this part of Parramatta Road as a project road under the Roads and Maritime policy.

Redeveloped road criteria (60 dBA in the daytime and 55 dBA in the night-time) have been applied in this catchment. Without mitigation, no receivers qualify for consideration of noise mitigation due to an increase in noise level and one receiver (one individual building) qualify on the basis of a cumulative limit exceedance. A further 13 receivers (seven individual buildings) qualify on the basis of more than one trigger. All triggered receivers in this NCA are adjacent to Parramatta Road.

Low noise pavement or noise barriers on Parramatta Road is not considered reasonable as the traffic speeds are relatively low and interrupted (traffic lights) and access requirements reduce the effectiveness of noise barriers.

The overall noise levels are predicted to be in the region of 60 dBA in the daytime and 55 dBA in the night-time at the closest receivers to the M4 corridor. Adjacent to Parramatta Road, overall noise levels are predicted to be around 70 dBA in the daytime and 65 dBA in the night-time.

14 receivers (8 individual buildings) qualify for consideration of at-property treatment.

14.5.2 Construction

Construction activities associated with general corridor construction works, the Powells Creek civil site, and the Underwood Road construction civil site and tunnel site (opposite the M4) are required within this catchment. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 15 metres with the catchment extending approximately 500 metres away from the works area.

High worst-case daytime NML exceedances of over 20 dBA at nearby receivers are predicted during the initial work area establishment works. Moderate worst-case exceedances of up to 20 dBA are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located near adjacent to the receivers.

Minor (up to 10 dB) NML exceedances in the daytime are predicted during the demolition of acquisition properties (across M4 on the northern side), while the construction of the western ventilation facility may result in minor (up to 10 dB) NML exceedances in the daytime and moderate (up to 20 dB) in the night-time. These impacts are confined to the nearest receivers to the works which have elevated upper floor receivers.

Temporary hoarding is not proposed at the Powells Creek civil site as impacted receivers are multi-storey and the works are elevated with respect to suitable hoarding locations in this NCA, resulting in reduced hoarding noise reduction efficiency. Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.6 NCA06

14.6.1 Operation

NCA06 is located north of Sydney Street with existing noise levels dominated by the M4 Motorway Sydney Street and Concord Road. In the No Build situation, predicted noise levels at receivers near the M4 Motorway are greater than 65 dBA in the daytime and night-time.

This NCA is adjacent to the existing Sydney Street off ramp from the M4 and near to the new roads and tunnel portals at the proposed Concord Road interchange. The project acquires a number of front row properties and subsequent demolition would reduce screening at receivers to the rear.

Redeveloped road criteria (60 dBA in the daytime and 55 dBA in the night-time) have been applied in this catchment. Without mitigation, four receivers (four individual buildings) qualify for consideration of noise mitigation due to an increase in noise level and one receiver (one individual building) qualify on the basis of a cumulative limit exceedance. A further six receivers (six individual buildings) qualify on the basis of more than one trigger.

Noise barriers have been considered in this assessment, however, based on further feasible and reasonable considerations the barrier may potentially sterilise future use of the adjacent land by restricting visibility and/or access. Therefore, consideration of at-property treatments for the triggered receivers instead of a barrier have been recommended and are to be further considered during detailed design.

The overall noise levels are predicted to greater than 65 dBA in the daytime and night-time at the closest receivers to Sydney Street. Receivers further back in this catchment are dominated by noise from Concord Road with overall noise levels are predicted to be around 55 dBA in the daytime and 50 dBA in the night-time.

11 receivers (11 individual buildings) qualify for consideration of at-property treatment.

14.6.2 Construction

Construction activities associated with general corridor construction works and the Concord Road tunnel and civil site are required within this NCA. Construction activities associated with the demolition of acquisition properties as well as temporary road modifications are also required near receivers in NCA06. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 10 metres with the catchment extending approximately 500 metres away from the works area.

High daytime NML exceedances of over 20 dBA are predicted at nearby receivers during the initial work area establishment works. Similar worst-case exceedances are predicted during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers. NML exceedances reduce to minor impacts of less than 10 dBA generally within 200 meters of the works.

High NML exceedances of over 20dBA are predicted during the demolition of acquisition properties at receivers directly adjacent rockbreaking activities. Noise impacts are typically seen to reduce to moderate impacts (less than 20 dB) or minor impacts (less than 10 dBA above NML) at locations which are past the first row of buildings from the works.

The potential noise impacts from the operation of the Concord Road construction civil site are sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the compound operation. The temporary hoarding is predicted to significantly reduce noise impacts from the construction site. However, even with temporary hoarding, high residual worst-case NML exceedances of over 20 dBA are predicted during site operation due to the close vicinity of some receivers to the site.

Predicted noise impacts from the tunnel site are sufficient to require the use of an acoustic shed to reduce noise impacts, in addition to the temporary hoarding erected on the nearby Concord Road construction site boundary.

With the acoustic shed and acoustic hoarding, worst-case night-time NML exceedances are predicted to be reduced to below NML.

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

In the vicinity of Concord Road, where the access ramps to/from the main M4E tunnels climb to meet with Concord Road at ground elevation, receivers above the tunnels are predicted to be subject to ground-borne noise levels up to around 45 dBA $L_{Aeq(15minute)}$, which exceeds both the evening and night-time criteria. Based on a progress rate of 30 metres per week, the most affected receivers are likely to experience noise levels above the night-time criterion for up to around ten days.

The concurrent operation of tunnelling and construction site plant is not anticipated to increase NML exceedances significantly.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage at some buildings close to the vibration intensive activities in this NCA and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits. Five heritage listed buildings are located within the screening safe working distance for structurally unsound buildings and will be investigated further during detailed design.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.7 NCA07

14.7.1 Operation

NCA07 extends along Concord road with existing noise levels dominated by Concord Road. In the No Build situation, predicted noise levels at receivers near the M4 Motorway are greater than 65 dBA in the daytime and night-time.

The south end of this catchment is adjacent to new roads and tunnel portals at the proposed Concord Road interchange. The project acquires a number of front row properties and subsequent demolition would reduce screening at receivers to the rear. Forecast traffic volume increase and potential for improved traffic flow results in an increase of more than 2 dBA on Concord Road in this section therefore designates this part of Concord Road as a project road under the guidelines.

Redeveloped road criteria (60 dBA in the daytime and 55 dBA in the night-time) have been applied in this catchment with the exception of the residential receiver immediately adjacent to Concord interchange which is in a new and redeveloped transition zone with a criteria of 59 dBA daytime and 54 dBA night-time. Without mitigation, five receivers (four individual building) qualify for consideration of noise mitigation due to an increase in noise level and all receivers are below the cumulative limit. A further 65 receivers (52 individual buildings) qualify on the basis of more than one trigger.

Noise barriers have been considered to the east of Concord Road in this assessment, however, based on further feasible and reasonable considerations the barrier may potentially sterilise future use of the adjacent land by restricting visibility and/or access. Therefore, consideration of at-property treatments for the triggered receivers instead of a barrier have been recommended and are to be further considered during detailed design.

The overall noise levels are predicted to be greater than 65 dBA in the daytime and night-time at the closest receivers to Concord Road.

70 receivers (56 individual buildings) qualify for consideration of at-property treatment.

14.7.2 Construction

Construction activities associated with general corridor construction works and the Concord Road tunnel and civil site are required within NCA07. Construction activities associated with the demolition of acquisition properties as well as temporary road modifications are also required adjacent to receivers in NCA07. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 10 metres with the catchment extending approximately 500 metres away from the works area.

High daytime NML exceedances of over 20 dBA are predicted at nearby receivers during the initial work area establishment works. Similar worst-case exceedances are predicted during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent receivers. NML exceedances reduce to minor impacts of less than 10 dBA generally within 200 meters of the works.

High NML exceedances of over 20dBA are predicted during the demolition of acquisition properties. Temporary road modifications works may result in moderate NML exceedances (less than 20 dB) in the night-time only. Temporary road modifications impacts are confined to the nearest receivers to the works, typically within the first row of receivers.

The potential noise impacts from the operation of the Concord Road construction site are sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the site operation. The temporary hoarding is predicted to significantly reduce noise impacts from the construction site. However, even with temporary hoarding, high residual worst-case NML exceedances of over 20 dBA are predicted during daytime site operation due to the close vicinity of some receivers to the site.

Predicted noise impacts from the tunnel site are sufficient to require the use of an acoustic shed to reduce noise impacts, in addition to the temporary hoarding erected on the nearby Concord Road construction site boundary.

With the acoustic shed and acoustic hoarding, worst-case night-time NML exceedances are predicted to be:

- Minor (less than 10dB) at three receivers

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

In the vicinity of Concord Road receivers near the tunnels are predicted to be subject to ground-borne noise levels of up to around 45 dBA $L_{Aeq(15minute)}$, which exceeds both the evening and night-time criteria. Based on a progress rate of 30 metres per week, the most affected receivers are likely to experience noise levels above the night-time criterion for up to around ten days.

The concurrent operation of tunnelling and construction site plant is not anticipated to increase NML exceedances significantly.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage at some buildings close to the vibration intensive activities in this NCA and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits. Two heritage listed buildings are located within the screening safe working distance for structurally unsound buildings and will be investigated further during detailed design.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.8 NCA08 and NCA09

14.8.1 Operation

NCA08 and NCA09 are located to the east of the Concord Road interchange with existing noise levels dominated by Concord Road and the M4 Motorway. In the No Build situation, predicted noise levels at receivers near the M4 Motorway are up to 55 dBA in the daytime and 50 dBA in the night-time.

NCA08 properties are mostly acquired by the project for which the subsequent demolition results in reduced screening to the rear. These NCAs are adjacent to new roads and tunnel portals at the proposed Concord Road interchange.

Criteria for these NCAs are transitioned from slightly greater than the new road criteria (56 dBA daytime and 51 dBA night-time) at the front to redeveloped criteria (60 dBA daytime and 55 dBA night-time) approximately two rows back. Without mitigation, one receiver (one individual building) qualifies for consideration of noise mitigation due to an increase in noise level and all receives are below the cumulative limit. A further one receiver (one individual building) qualifies on the basis of more than one trigger.

A noise barrier of 3.0 metres high has been recommended to the east of Concord Road interchange however this is subject to further considerations during detailed design such as construction limitations, overshadowing, urban design and community preference.

The overall noise levels with the noise barrier are predicted to be in the region of 60 dBA in the daytime and 55 dBA in the night-time at the closest receivers reducing to around 50 dBA in the daytime and 45 dBA in the night-time towards the far extent of NCA09.

With the noise barriers, one receiver (one individual building) qualifies for consideration of at-property treatment.

14.8.2 Construction

Construction activities associated with general corridor construction works for the interchange and the Concord Road tunnel and civil site and are required close to these NCAs. Demolition of acquired properties is also required in NCA08. There is only one row of receivers in this NCA due to the property acquisitions in this area. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 10 metres with the catchment extending approximately 500 metres away from the works area.

General construction works within the Concord interchange are predicted to result in high NML exceedances (greater than 20 dB) at the receivers fronting the interchange.

Hoarding on the north and east sides of the Concord Road tunnel and civil site are proposed to reduce noise impacts during operation of the site. With hoarding, the predicted daytime NML exceedances due to site operation are moderate (up to 20 dB) during the daytime.

Predicted noise impacts from the tunnel site are sufficient to require the use of an acoustic shed to reduce noise. With the acoustic shed, worst-case night-time NML exceedances are predicted to be:

- Moderate up to 12 dB at two receivers
- Minor (less than 10dB) at approximately 30 receivers

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage at the front row buildings and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits.

Receivers above the tunnels are predicted to be subject to ground-borne noise levels of up to around 45 dBA $L_{Aeq(15minute)}$, which exceeds both the evening and night-time criteria. Based on a progress rate of 30 metres per week, the most affected receivers are likely to experience noise levels above the night-time criterion for up to around ten days.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.9 NCA10

14.9.1 Operation

NCA10 is located adjacent to Ada Street with existing noise levels dominated by Parramatta Road and Ada Street. In the No Build situation, predicted noise levels are around 65 dBA in the daytime and 60 dBA in the night-time.

No physical works are proposed immediately adjacent to this NCA, however, the western end of NCA10 is near to the new roads and tunnel portals at the proposed Concord Road interchange. Generally, this NCA sees a reduction in noise due to a decrease in traffic on Parramatta Road.

No receivers have been identified for consideration of at-property treatment in this NCA.

14.9.2 Construction

Construction activities associated with general corridor construction works for the Concord Road interchange and the Concord Road tunnel and civil site are required near the western extent of this NCA. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 55 metres with the catchment extending > 500 metres away from the works area.

Minor NML exceedances (up to 10 dB) are generally predicted during the proposed construction activities with the exception of the small number of receivers to the west of NCA10, near the Concord interchange. At these receivers, high NML exceedances (greater than 20 dB) are predicted during the most noise intensive work area establishment works. NML exceedances during the site operations and tunnel site activities are typically minor (up to 10 dB) at all but the westernmost receivers which may experience worst-case moderate (up to 20 dB) NML exceedances during the operation of the site during the daytime and high (over 20 dB) NML exceedance at a single receiver on the edge of this NCA.

Vibration from the proposed construction activities is considered unlikely exceed the nominated residential safe working distances for cosmetic damage in this catchment.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.10 NCA11

14.10.1 Operation

NCA11 is located adjacent to Parramatta Road with existing noise levels dominated by Parramatta Road. In the No Build situation, predicted noise levels are greater than 65 dBA in the daytime and night-time.

NCA11 is just south of the new roads and tunnel portals at the proposed Concord Road interchange. Generally, this NCA sees a reduction in noise due to decrease in traffic on Parramatta Road to the east of Concord Road, but an increase in traffic on Parramatta Road to the west of Concord Road and therefore designates Parramatta Road west of Concord Road as a project road under the guidelines.

Redeveloped road criteria (60 dBA in the daytime and 55 dBA in the night-time) have been applied in this catchment. Without mitigation 14 receivers (eight individual buildings) qualify on the basis of more than one trigger.

Low noise pavement or noise barriers on Parramatta Road are not considered reasonable as the traffic speeds are relatively low and interrupted (traffic lights) and access requirements reduce the effectiveness of noise barriers.

The overall noise levels are predicted to be in the greater than 65 dBA in the daytime and night-time at the closest receivers to the M4 corridor.

14 receivers (eight individual buildings) qualify for consideration of at-property treatment.

14.10.2 Construction

Construction activities associated with general corridor construction works for the Concord Road interchange and the Concord Road tunnel and civil site are required near the northern extent of this NCA. Demolition of acquired properties is required on the opposite side of the M4. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 10 metres with the catchment extending > 500 metres away from the works area.

Minor (up to 10 dB) NML exceedances are generally predicted in this NCA with the exception of the two multi-story receivers just south of the Concord Road interchange. At these receivers (one commercial and one residential), high (greater than 20 dB) NML exceedances are predicted during the most noise intensive work area establishment works during the daytime. High NML exceedances are also predicted for the residential multi-storey receiver during the night-time.

Moderate daytime NML exceedances (up to 20 dB) are predicted during the demolition of acquisition properties at the multi-storey residential receivers. These impacts are confined to the nearest receivers overlooking the works.

Night-time NML exceedances during the site operations are high (greater than 20 dB) at the multi-storey residential receiver which overlooks the interchange area. Predicted noise from the tunnel site results in negligible daytime impacts.

Predicted noise impacts from the tunnel site are sufficient to require the use of an acoustic shed to reduce noise. With the acoustic shed, worst-case night-time NML exceedances are predicted to be:

- Minor (less than 10dB) at 17 receivers

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage at the nearest buildings and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.11 NCA12

14.11.1 Operation

No physical works are proposed immediately adjacent to this NCA. Generally, this NCA sees a reduction in noise due to decrease in traffic on Parramatta Road.

No receivers have been identified consideration of at-property treatment in this NCA.

14.11.2 Construction

Construction activities associated with construction of the fresh air supply facility at Cintra Park as well as the Cintra park tunnel site are required within this catchment. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 25 metres with the catchment extending > 500 metres away from the works area.

Noise impacts are predicted during the initial work area establishment works with high predicted NML exceedances of greater than 20 dBA at nearest receivers during the daytime and night-time.

Minor (up to 10 dB) NML exceedances in the daytime and moderate NML exceedances (up to 20 dB) are predicted during the night-time for construction of the fresh air supply facility at Cintra park. These impacts are confined to the nearest receivers to the works on the front row of receivers overlooking Contra Park.

Predicted noise impacts from the tunnel site are sufficient to require the use of an acoustic shed and temporary hoarding to reduce noise. With the acoustic shed and hoarding, worst-case night-time NML exceedances are predicted to be:

- Minor (less than 10dB) at two receivers

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Management of the construction noise impacts in this catchment will likely include restricting operating times of noise intensive plant to less sensitive daytime and evening periods, as far as practicable.

At receivers east of Burwood Road, marginal exceedances of the night-time ground-borne noise criterion are predicted, with ground-borne noise levels of up to 37 dBA $L_{Aeq(15minute)}$ being predicted.

Vibration from the proposed construction activities is considered unlikely exceed the nominated residential safe working distances for cosmetic damage in this catchment.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.12 NCA13

14.12.1 Operation

NCA13 is located south of Parramatta Road west of Bland Street with existing noise levels dominated by Parramatta Road. In the No Build situation, predicted noise levels are around 59 to 65 dBA in the daytime and 56 to 60 dBA in the night-time at the receivers fronting Parramatta Road.

To the east of this NCA, the project splits Parramatta Road and forms the new dives to/from the portals on the inside. The portals and associated ramps to Parramatta Road are also located east of the NCA and face east, away from this catchment.

Redeveloped road criteria (60 dBA in the daytime and 55 dBA in the night-time) have been applied in this catchment. Without mitigation, no receivers qualify for consideration of noise mitigation due to an increase in noise level and four receivers (two individual buildings) qualify on the basis of a cumulative limit exceedance.

Noise barriers are not considered in this catchment as there are too few triggered receivers.

The overall noise levels with mitigation are predicted to be in the region of 55 to 65 dBA in the daytime and 52 to 60 dBA in the night-time at the closest receivers on Parramatta Road.

Four receivers (two individual buildings) qualify for consideration of at-property treatment in this NCA.

14.12.2 Construction

Construction activities associated with general corridor construction works, the Northcote Street tunnel site, Eastern ventilation facility site, and Parramatta Road civil site are required within the vicinity of this catchment. Construction activities for the eastern ventilation facility and demolition of acquired properties are also required across Parramatta Road from this NCA and in neighbouring NCA21. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 10 metres with the catchment extending > 500 metres away from the works area.

Noise impacts are predicted during the initial road corridor work area establishment works with high NML exceedances (greater than 20 dB) predicted at receivers in the southern extents of the NCA. Similar worst-case exceedances are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers.

High NML exceedances (greater than 20 dB) in the daytime are predicted during the demolition of acquisition properties, while the construction of the Eastern ventilation facility may result in minor NML exceedances (less than 10 dB) in the daytime and moderate NML exceedances (less than 20 dB) during the night-time. These impacts are confined to receivers nearest the works.

Noise impacts generally reduce to minor NML exceedances of less than 10 dBA past the second row of buildings from the works.

The potential noise impacts from the operation of the Northcote Street tunnel Site, Eastern ventilation facility site, and Parramatta Road civil site are sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the site operation in the direction of NCA13. The temporary hoarding is predicted to significantly reduce noise impacts from the construction sites. However, even with temporary hoarding, high residual daytime worst-case NML exceedances of over 20 dBA are predicted due to the close vicinity of some receivers to the site.

Predicted noise impacts from the tunnel site are sufficient to require the use of an acoustic shed in addition to temporary hoarding on the site boundary to reduce noise impacts. With the acoustic shed and hoarding, worst-case night-time NML exceedances are predicted to be:

- Minor (less than 10dB) at approximately 15 receivers

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Receivers to the south of Parramatta Road are predicted to be subject to ground-borne noise levels up to around 43 dBA $L_{Aeq(15minute)}$, which exceeds both the evening and night-time criteria. This area of receivers is above the location where the mainline tunnels rise in elevation and become shallower. Based on a progress rate of 30 metres per week, the most affected receivers are likely to experience noise levels above the night-time criterion for up to around six days.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits. One heritage listed building is located within the screening safe working distance for structurally unsound buildings and will be investigated further during detailed design.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.13 NCA14

14.13.1 Operation

NCA14 is located at the intersection of Parramatta Road and Wattle Street with existing noise levels dominated by road traffic on Parramatta Road and Wattle Street. In the No Build situation, predicted noise levels are around 60 dBA in the daytime and 55 dBA in the night-time.

In this NCA, Wattle Street is realigned to the outside of the proposed tunnel dives to/from City Westlink which moves traffic closer to the receivers to the southeast of Wattle Street where the project also acquires a number of front row properties and subsequent demolition would reduce screening.

Criteria in NCA14 are new road criteria (55 dBA daytime and 50 dBA night-time) at receivers adjacent to the new roads at Wattle Street transitioning to redeveloped criteria (60 dBA daytime and 55 dBA night-time) on the edge of the NCA where Parramatta Road contributes significantly to the overall noise. Without mitigation, four receivers (four individual building) qualify for consideration of noise mitigation due to an increase in noise level and all receivers are below the cumulative limit excedance. A further 13 receivers (11 individual buildings) qualify on the basis of more than one trigger.

Low noise pavement is not considered reasonable in this area as the traffic speeds are relatively low and interrupted (traffic lights).

A 5.0 metre noise barrier on the southeast of Wattle Street has been identified as the optimum height to reduce noise impacts at receivers to the southeast however access requirements mean that a barrier on the northwest side of Wattle Street is not feasible.

The overall noise levels are predicted to be in the region of 60 dBA in the daytime and 50 dBA in the night-time at the closest receivers on the south east of Wattle Street. On the opposite side of Wattle, overall noise levels are predicted to be greater than 65 dBA in the daytime and night-time.

10 receivers (nine individual buildings) qualify for consideration of at-property treatment in this NCA.

14.13.2 Construction

Construction activities associated with general corridor construction works, the Northcote Street tunnel site, and Eastern ventilation facility site are required within the vicinity of this catchment. Construction activities for the demolition of acquired properties are also required within this NCA.

Noise impacts are predicted during the initial road corridor work area establishment works with predicted high (greater than 20 dB) NML exceedances at nearby receivers. Similar worst-case exceedances are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 15 metres with the catchment extending approximately 150 metres away from the works area.

High daytime NML exceedances (greater than 20 dB) are predicted during the demolition of acquisition properties. The construction of the Eastern ventilation facility may result in minor NML exceedances (less than 10 dB) in the daytime and night-time periods. These impacts are confined to the receivers nearest the works. The potential noise impacts from the operation of the Northcote Street tunnel site, and Eastern ventilation facility site are sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the site operations. Moderate NML exceedances (less than 20 dB) are predicted at the immediately adjacent receivers during the daytime periods.

Noise impacts reduce to minor impacts of less than 10 dBA generally past the second row of buildings from the works.

Predicted noise impacts from the Northcote Street tunnel site are sufficient to require the use of an acoustic shed in addition to boundary hoarding to reduce noise impacts. With the acoustic shed and hoarding, worst-case night-time NML exceedances are predicted to be reduced to below NML.

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.14 NCA15

14.14.1 Operation

NCA15 is located at the intersection of Parramatta Road and Wattle Street with existing noise levels dominated by road traffic on Wattle Street. In the No Build situation, predicted noise levels are greater than 65 dBA in the daytime and night-time.

In this NCA, Wattle Street is realigned to the outside of the proposed tunnel dives to/from City Westlink and portals. The alignment change moves traffic closer to the receivers to the southeast of Wattle Street where the project also acquires a number of front row properties and subsequent demolition would reduce screening. Receivers to the north of Wattle Street see a reduction in noise due to a decrease in traffic on Wattle Street due to traffic using the new tunnels.

Criteria in NCA14 are new road criteria (55 dBA daytime and 50 dBA night-time) at receivers adjacent to the new roads at Wattle Street transitioning to redeveloped criteria (60 dBA daytime and 55 dBA night-time) at the far northwest of this NCA where Parramatta Road traffic begins to contribute to the overall noise. Without mitigation, one receiver (one individual building) qualifies for consideration of noise mitigation due to an increase in noise level and all are below the cumulative limit. A further 27 receivers (25 individual buildings) qualify on the basis of more than one trigger.

Low noise pavement is not considered reasonable on Wattle Street as the traffic speeds are relatively low and interrupted (traffic lights).

A 5.0 metre noise barrier on the southeast of Wattle Street has been identified as the optimum height to reduce noise impacts at receivers to the southeast however access requirements mean that a barrier on the northwest side of Wattle Street is not feasible.

The overall noise levels are predicted to be in the region of 55 dBA in the daytime and 50 dBA in the night-time at the closest receivers on the south east of Wattle Street. On the opposite side of Wattle, overall noise levels are predicted to be greater than 65 dBA in the daytime and night-time.

18 receivers (16 individual buildings) qualify for consideration of at-property treatment in this NCA.

14.14.2 Construction

Construction activities associated with general corridor construction works and the Wattle Street and Walker Avenue civil site are required within the vicinity of this catchment. Construction activities associated with the demolition of acquisition properties are also required near receivers in NCA06. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 15 metres with the catchment extending approximately 250 metres away from the works area.

Noise impacts are predicted during the initial road corridor work area establishment works with predicted high (greater than 20 dB) NML exceedances at nearby receivers. Similar worst-case exceedances are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers.

Moderate daytime NML exceedances (less than 20 dB) are predicted during the demolition of acquisition properties. These impacts are confined to the receivers nearest the works.

Temporary road modifications works may result in moderate NML exceedances (less than 20 dB) in the night-time only. Temporary road modifications impacts are confined to the nearest receivers to the works, typically within the first row of receivers.

Noise impacts reduce to minor impacts of less than 10 dBA generally past the second row of buildings from the works.

The potential noise impacts from the operation of the Wattle Street and Walker Avenue civil site are sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the site operations. Moderate NML exceedances (less than 20 dB) are predicted at the immediately adjacent receivers during the daytime period.

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.15 NCA16

14.15.1 Operation

NCA16 is located to the northwest of Wattle Street extending to the edge of the study area along Wattle Street. Existing noise levels are dominated by road traffic on Wattle Street and Ramsay Street. In the No Build situation, predicted noise levels are greater than 65 dBA in the daytime and night-time at the receivers fronting Wattle Street, while at the back of the NCA to the northwest noise levels are in the region of 60 dBA in the daytime and 55 dBA in the night-time.

In this NCA, Wattle Street is realigned to the outside of the proposed tunnel dives to/from the portals near Ramsay Street. The realignment moves traffic slightly closer to the receivers on the edge of Reg Coady Reserve.

Criteria in NCA16 are new road criteria (55 dBA daytime and 50 dBA night-time) at receivers adjacent to the new roads at Wattle Street transitioning to redeveloped criteria (60 dBA daytime and 55 dBA night-time) at the far northwest of this NCA where traffic on the unmodified section of Wattle Street begins to contribute to the overall noise. Without mitigation, no receivers qualify for consideration of noise mitigation due to an increase in noise level and seven receivers (six individual buildings) qualify on the basis of a cumulative limit exceedance. A further 10 receivers (nine individual buildings) qualify on the basis of more than one trigger.

Low noise pavement is not considered reasonable on Wattle Street as the traffic speeds are relatively low and interrupted (traffic lights).

Access requirements to Wattle Street in this NCA mean that a barrier on the northwest side of Wattle Street is not feasible.

The overall noise levels are predicted to be greater than 65 dBA in the daytime and night-time at the receivers fronting Wattle Street. Noise levels would be lower at the back of the NCA beyond Timbrell Park dropping to around 55 dBA during the daytime and 50 dBA during the night-time.

17 receivers (15 individual buildings) qualify for consideration of at-property treatment in this NCA.

14.15.2 Construction

Construction activities associated with general corridor construction works and the Wattle Street and Walker Avenue civil site are required within the vicinity of this catchment. Construction activities associated with the demolition of acquisition properties as well as temporary road modifications are also required near receivers in NCA16. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 15 metres with the catchment extending approximately 300 metres away from the works area.

Temporary road modifications works may result in moderate NML exceedances (less than 20 dB) in the daytime period and high NML exceedances during the night-time. Temporary road modifications impacts are confined to the nearest receivers to the works.

Noise impacts are predicted during the initial road corridor work area establishment works with predicted high NML exceedances (greater than 20 dB) at nearby receivers. Similar worst-case exceedances are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers.

High daytime NML exceedances (more than 20 dB) are predicted during the demolition of acquisition properties. These impacts are confined to the receivers nearest the works.

The potential noise impacts from the operation of the Wattle Street and Walker Avenue civil site are sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the site operations. Moderate NML exceedances (less than 20 dB) are predicted at the immediately adjacent receivers during the daytime period.

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.16 NCA17

14.16.1 Operation

NCA17 is located to the southeast of Wattle Street extending to the edge of the study area along Wattle Street. Existing noise levels are dominated by road traffic on Wattle Street. In the No Build situation, predicted noise levels are greater than 65 dBA in the daytime and night-time at the receivers fronting Wattle Street.

In this NCA, Wattle Street is realigned to the outside of the proposed tunnel dives to/from Wattle Street near Ramsay Street which moves traffic slightly closer to the receivers.

Criteria in NCA17 are new road criteria (55 dBA daytime and 50 dBA night-time) at receivers adjacent to the new roads at Wattle Street transitioning to redeveloped criteria (60 dBA daytime and 55 dBA night-time) away from the new roads section. Without mitigation, one receiver (one individual building) qualifies for consideration of noise mitigation due to an increase in noise level and one receiver (one individual building) qualify on the basis of a cumulative limit exceedance. A further 30 receivers (25 individual buildings) qualify on the basis of more than one trigger.

Low noise pavement is not considered reasonable on Wattle Street as the traffic speeds are relatively low and interrupted (traffic lights).

A 5.0 metre noise barrier along Wattle Street has been identified as the optimum height to reduce noise impacts at receivers northwest of Waratah Street. A number of short barrier sections (broken by driveway access) between Waratah Street and Martin Street were assessed but are unlikely to be built due to overshadowing and visual impacts and would be further considered during detailed design.

The overall noise levels are predicted to be greater than 65 dBA in the daytime and night-time at the closest receivers on the south east of Wattle Street.

25 receivers (20 individual buildings) qualify for consideration of at-property treatment in this NCA.

14.16.2 Construction

Construction activities associated with general corridor construction works and the Wattle Street and Walker Avenue civil site are required within the vicinity of this catchment. Construction activities associated with the demolition of acquisition properties as well as temporary road modifications are also required near receivers in NCA17. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 10 metres with the catchment extending > 500 metres away from the works area.

Temporary road modifications works may result in minor NML exceedances (less than 10 dB) in the daytime period and high NML exceedances (greater than 20 dB) during the night-time.

Noise impacts are predicted during the initial road corridor work area establishment works with predicted high NML exceedances (greater than 20 dB) at nearby receivers. High worst-case exceedances are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers.

High daytime NML exceedances (more than 20 dB) are predicted during the demolition of acquisition properties. These impacts are confined to the receivers nearest the works.

The potential noise impacts from the operation of the Wattle Street and Walker Avenue civil site are sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the site operations. Moderate NML exceedances (less than 20 dB) are predicted at the immediately adjacent receivers during the daytime period.

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Receivers in the vicinity of Wattle Street are predicted to be subject to ground-borne noise levels up to around 53 dBA $L_{Aeq(15minute)}$, which exceeds both the evening and night-time criteria. This area is above where the underground access ramps to/from the main M4E tunnels climb to meet with Wattle Street and Parramatta Road at ground elevation. Based on a progress rate of 30 metres per week, the most affected receivers are likely to experience noise levels above the night-time criterion for up to around two weeks

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.17 NCA18

14.17.1 Operation

NCA18 extends from the Ramsay Street and Wattle Street intersection to Parramatta Road including receivers from the second row on Wattle Street. Existing noise levels are dominated by road traffic on Wattle Street at the northern end and Parramatta Road on the southern edge of the NCA. In the No Build situation, predicted noise levels are around 65 dBA in the daytime and 60 dBA in the night-time at the receivers near the Wattle Street and Ramsay Street intersection. Noise levels at receivers on Parramatta Road are around 60 dBA in the daytime and 55 dBA in the night-time.

No physical works are proposed on Parramatta Road in this NCA. This NCA sees a reduction in noise due to decrease in traffic on Parramatta Road. At the Wattle Street end, Wattle Street is realigned to the outside of the proposed tunnel dives to/from the portals near Ramsay Street. The alignment change moves traffic closer to the receivers to the southeast of Wattle Street where the project also acquires a number of front row properties and subsequent demolition would reduce screening.

Criteria in NCA18 are new road criteria (55 dBA daytime and 50 dBA night-time) at receivers adjacent to the new roads at Wattle Street transitioning to redeveloped criteria (60 dBA daytime and 55 dBA night-time) at the far southeast of this NCA where Parramatta Road traffic contributes to the overall noise. Without mitigation, four receivers (three individual building) qualify for consideration of noise mitigation due to an increase in noise level and one receiver (one individual building) qualify on the basis of a cumulative limit exceedance. A further eight receivers (six individual buildings) qualify on the basis of more than one trigger.

Low noise pavement is not considered reasonable on Wattle Street as the traffic speeds are relatively low and interrupted (traffic lights).

A 5.0 metre noise barrier on the southeast of Wattle Street has been recommended to reduce noise impacts at adjacent receivers.

The overall noise levels are predicted to be in the region of greater than 65 dBA in the daytime and night-time at the closest receivers on Wattle Street. Overall noise levels on Parramatta Road are predicted to be around 60 dBA in the daytime and 55 dBA in the night-time.

Eight receivers (six individual buildings) qualify for consideration of at-property treatment in this NCA.

14.17.2 Construction

Construction activities associated with general corridor construction works as well as the Wattle Street and Walker Avenue civil site and Eastern ventilation site are required within the vicinity of this catchment. Construction activities associated with the demolition of acquisition properties as well as temporary road modifications are also required near receivers in NCA18. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 10 metres with the catchment extending approximately 150 metres away from the works area.

Temporary road modifications works may result in moderate NML exceedances (less than 20 dB) in the daytime period and high NML exceedances (greater than 20 dB) during the night-time.

Noise impacts are predicted during the initial road corridor work area establishment works with predicted high NML exceedances (greater than 20 dB) at nearby receivers. High worst-case exceedances are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers.

High daytime NML exceedances (more than 20 dB) are predicted during the demolition of acquisition properties. These impacts are confined to the receivers nearest the works.

The potential noise impacts from the operation of the Wattle Street and Walker Avenue civil site and Eastern ventilation facility site are sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the site operations. Generally, moderate NML exceedances (less than 20 dB) are predicted at the immediately adjacent receivers during the daytime period.

Management will include restricting operating times of noise intensive plant to less sensitive periods as far as practicable to minimise impacts.

Receivers in the vicinity of Wattle Street are predicted to be subject to ground-borne noise levels up to around 53 dBA $L_{Aeq(15minute)}$, which exceeds both the evening and night-time criteria. This area is above where the underground access ramps to/from the main M4E tunnels climb to meet with Wattle Street and Parramatta Road at ground elevation. Based on a progress rate of 30 metres per week, the most affected receivers are likely to experience noise levels above the night-time criterion for up to around two weeks

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits. Two heritage listed buildings are located within the screening safe working distance for structurally unsound buildings and will be investigated further during detailed design.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.18 NCA19

14.18.1 Operation

NCA19 is located north east of Parramatta Road near Bland Street with existing noise levels dominated by Parramatta Road. In the No Build situation, predicted noise levels are around 65 dBA in the daytime and 60 dBA in the night-time at the receivers fronting Parramatta Road.

The project splits Parramatta Road and forms the new dives to/from the portals on the inside. This generally moves traffic away from these receivers to the opposite side of Parramatta Road and does not significantly change the location of the nearest lane to the receivers in this NCA. The portals and associated ramps to Parramatta Road are located at the southeast end of the NCA and face east, away from this catchment.

Criteria in NCA19 are new road criteria (55 dBA daytime and 50 dBA night-time) at receivers adjacent to the new roads on Parramatta Road transitioning to redeveloped criteria (60 dBA daytime and 55 dBA night-time) where the unmodified section of Parramatta Road traffic contributes to the overall noise. Without mitigation, no receivers qualify for consideration of noise mitigation due to an increase in noise level and two receivers (two individual building) qualify on the basis of a cumulative limit exceedance. These receivers are generally predicted to have a reduction in noise due to decrease in traffic on Parramatta Road.

Low noise pavement is not considered reasonable on Parramatta Road as the traffic speeds are relatively low and interrupted (traffic lights).

Noise barriers are not considered in this catchment as there are too few triggered receivers.

The overall noise levels are predicted to be in the region of 65 dBA in the daytime and 60 dBA in the night-time at the closest receivers on Parramatta Road.

Two receivers (two individual buildings) qualify for consideration of at-property treatment in this NCA.

14.18.2 Construction

Construction activities associated with general corridor construction works, the Parramatta Road civil site, and the Wattle Street and Walker Avenue civil site are required within the vicinity of this catchment. Construction activities associated with the demolition of acquisition properties as well as temporary road modifications are also required near receivers in NCA19. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 25 metres with the catchment extending > 500 metres away from the works area.

Noise impacts are predicted during the initial road corridor work area establishment works with predicted high NML exceedances of over 25 dBA at nearby receivers. High worst-case NML exceedances are predicted at the nearest educational receivers during the daytime, and high exceedances are predicted at the nearest residential receivers during the night-time for noise intensive roadworks using equipment such as rockbreakers.

High daytime NML exceedances of greater than 20 dBA are predicted during the demolition of acquisition properties. NML exceedances generally reduce to moderate impacts of less than 20 dBA past the second row of buildings from the works.

The potential noise impacts from the operation of the construction sites are sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the site operation. Moderate daytime NML exceedances (less than 20 dB) are predicted surrounding educational and residential receivers during worst-case daytime operations.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits. Two heritage listed buildings are located within the screening safe working distance for structurally unsound buildings and will be investigated further during detailed design.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.19 NCA20

14.19.1 Operation

NCA20 is located northeast of Parramatta Road at the eastern extent of the study area with existing noise levels dominated by Parramatta Road. In the No Build situation, predicted noise levels are greater than 65 dBA in the daytime and night-time at the receivers fronting Parramatta Road. Noise levels on Dalhousie Street are around 65 dBA in the daytime and 60 dBA in the night-time.

The project splits Parramatta Road and forms the new dives to/from the portals on the inside. This generally moves traffic away from these receivers to the opposite side of Parramatta Road and does not significantly change the location of the nearest lane to the receivers in this NCA. The portals and associated ramps to Parramatta Road are located at the southeast end of the NCA and face southeast, along this catchment.

Criteria in NCA20 are new road criteria (55 dBA daytime and 50 dBA night-time) at receivers adjacent to the new roads on Parramatta Road transitioning to redeveloped criteria (60 dBA daytime and 55 dBA night-time) where the unmodified section of Parramatta Road traffic contributes to the overall noise. Without mitigation, five receivers (five individual building) qualify for consideration of noise mitigation due to an increase in noise level and three receivers (three individual buildings) qualify on the basis of a cumulative limit exceedance. A further nine receivers (five individual buildings) qualify on the basis of more than one trigger.

Low noise pavement or noise barriers on this section of Parramatta Road are not considered reasonable as the traffic speeds are relatively low and interrupted (traffic lights), and access requirements reduce the effectiveness of noise barriers.

The overall noise levels are predicted to be greater than 65 dBA in the daytime and night-time at the receivers fronting Parramatta Road. Noise levels on Dalhousie Street are around 65 dBA in the daytime and 60 dBA in the night-time.

17 receivers (13 individual buildings) qualify for consideration of at-property treatment in this NCA.

14.19.2 Construction

Construction activities associated with general corridor construction works and the Parramatta Road civil site are required within this catchment. Construction activities associated with the demolition of acquisition properties on the opposite side of Parramatta Road as well as temporary road modifications are also required near receivers in NCA20. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 20 metres with the catchment extending > 500 metres away from the works area.

Temporary road modifications works may result in moderate NML exceedances (less than 20 dB) in the daytime and night-time periods.

Noise impacts are predicted during the initial road corridor work area establishment works with predicted high NML exceedances (greater than 20 dB) at nearby receivers. High worst-case exceedances are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers.

High daytime NML exceedances of greater than 20 dBA are predicted during the demolition of acquisition properties.

The potential noise impacts from the operation of the Parramatta Road civil site site is sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the site operation. Moderate (up to 20 dB) residual daytime NML exceedances are predicted at the upper floors of the nearest receivers.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

14.20 NCA21

14.20.1 Operation

NCA21 is located south west of Parramatta Road at the eastern extent of the study area with existing noise levels dominated by Parramatta Road. In the No Build situation, predicted noise levels are up to 65 dBA in the daytime and 60 dBA in the night-time at the receivers fronting Parramatta Road.

The project splits Parramatta Road and forms the new dives to/from the portals on the inside. This generally moves traffic closer to these receivers on Parramatta Road. The portals and associated ramps to Parramatta Road are located adjacent to this NCA and face southeast. The project acquires a number of front row properties and subsequent demolition would reduce screening between receivers and Parramatta Road.

Criteria in NCA21 are new road criteria (55 dBA daytime and 50 dBA night-time) at receivers adjacent to the new roads on Parramatta Road transitioning to redeveloped criteria (60 dBA daytime and 55 dBA night-time) where the unmodified section of Parramatta Road traffic contributes to the overall noise. Without mitigation, six receivers (four individual building) qualify for consideration of noise mitigation due to an increase in noise level and three receivers (two individual building) qualify on the basis of a cumulative limit exceedance. A further 28 receivers (16 individual buildings) qualify on the basis of more than one trigger.

Low noise pavement on this section of Parramatta Road is not considered reasonable as the traffic speeds are relatively low and interrupted (traffic lights).

Noise barriers have been considered in this assessment, however, based on further feasible and reasonable considerations the barrier may potentially sterilise future use of the adjacent land by restricting visibility and/or access. Therefore, consideration of at-property treatments for the triggered receivers instead of a barrier have been recommended and are to be further considered during detailed design.

The overall noise levels are predicted to be greater than 65 dBA in the daytime and night-time at the closest receivers on Parramatta Road while the receivers behind Orpington Street are predicted to have noise levels at around 50 dBA in the daytime and 45 dBA in the night-time.

37 receivers (21 individual buildings) qualify for consideration of at-property treatment in this NCA.

14.20.2 Construction

Construction activities associated with general corridor construction works and the Parramatta Road civil site are required within this catchment. Construction activities associated with the demolition of acquisition properties as well as temporary road modifications are also required near receivers in NCA21. The typical offset distance to the nearest sensitive receivers (or land uses) from the nearest works is 10 metres with the catchment extending > 500 metres away from the works area.

Temporary road modifications works may result in minor NML exceedances (less than 10 dB) in the daytime and high NML exceedances (more than 20 dB) during night-time periods.

Noise impacts are predicted during the initial road corridor work area establishment works with predicted high NML exceedances (greater than 20 dB) at nearby receivers. High worst-case exceedances are predicted at the nearest receivers during noise intensive roadworks using equipment such as rockbreakers when works are located immediately adjacent to the receivers.

High daytime NML exceedances of greater than 20 dBA are predicted during the demolition of acquisition properties.

The potential noise impacts from the operation of the Parramatta Road civil site is sufficient to require the use of temporary hoarding around the site to reduce noise impacts from the site operation. High residual daytime NML exceedances (more than 20 dB) are predicted at the upper floors of the nearest surrounding multi-storey residential receivers.

Vibration intensive works at the outer extents of the roadworks area in this catchment may exceed the nominated residential safe working distances for cosmetic damage and would require vibration monitoring at the outset of these works to ensure vibration levels are within acceptable limits. One heritage listed building is located within the screening safe working distance for structurally unsound buildings and will be investigated further during detailed design.

A construction noise and vibration management plan will be prepared during construction planning in order to manage the potential noise and vibration impacts during construction.

15 Recommendations for further analysis at detailed design

15.1 Operational road traffic noise

- **Case by case external criteria for other sensitive receivers**. Refer to **Section 4.4**. External criteria for Other sensitive receivers have been derived using a 10 dBA factor to convert internal to external noise levels. For some non-residential receivers this assumption may be overly conservative as the facade area to window ratios are often larger when compared to residential receivers, or windows may not be openable.
- **Confirm noise barriers adjacent to acquired land**. Refer to **Section 8.3**. Based on potential sterilisation (due to access, and visual impacts) of future use of acquired land, noise barriers in some locations were considered not feasible. Once the future use of this land is confirmed, consideration should be given to the suitability of noise barriers in these locations.
- **Consideration of feasible and reasonable mitigation for maximum noise levels**. Refer to **Section 8.7**. Consideration of noise mitigation on the basis of maximum noise levels should take account of additional factors including engineering feasibility considerations, discussions with the community and community preference.
- **Confirm congestion in the Build scenarios**. Refer to **Section 5.7**. The assessment has conservatively assumed that no congestion in the Build case would be apparent. Where congestion remains when the project is operational, levels would be expected to be lower than for non-congested flow and predicted increases would be reduced. Consequently, should detailed design considerations indicate that congestion may remain with the project, the assessment should be revisited incorporating corresponding congestion factors in the Build scenarios.

15.2 Operational ventilation facilities

- **INP modifying factors**. Refer **Section 9.8**.
  No INP modifying factors were found to be applicable in this assessment. However, given the indicative nature of the assessment possible during this EIS for ventilation facilities it should be noted that all finalised plant items should be assessed during detailed design with consideration of the INP modifying factors. Where modifying factors are found to be applicable they should be added to the assessment and compliance with the INP criteria checked at all receivers.

15.3 Construction noise and vibration

- **Confirm heritage building vibration sensitivity**. Refer to **Section 13.3**. Where a historic building is deemed to be particularly sensitive to damage from vibration (following inspection), the more conservative DIN 4150 superficial cosmetic damage criteria of 2.5 mm/s should be considered as a screening criterion. Where heritage buildings of a typical residential-type construction are not found to be structurally unsound, DIN 4150 superficial cosmetic damage criteria of 5 mm/s may be more suitable as a screening criterion.
- **Confirm existing maximum noise levels on finalised local road haul routes**. Refer to **Section 11**. Where the finalised haul routes are required to use local roads, additional assessment of potential maximum noise events is recommended, including establishing existing maximum noise levels at adjacent receivers.

- **Additional noise monitoring adjacent to tunnel sites and ventilation facilities**. Refer to **Section 10**. Where night-time noise impacts adjacent to the tunnel sites are predicted, at-property treatments or alternative accommodation may be considered subject to feasible and reasonable considerations during detailed design and construction planning. It is therefore recommended to supplement the noise monitoring undertaken for this assessment during detailed design in order to confirm the variation of existing background noise levels surrounding the sites and therefore refine the extent of additional mitigation measures to be considered.

16 References

[i] Road Noise Policy, NSW EPA, 2011

[ii] Noise Criteria Guideline, Roads and Maritime, December 2014, RMS 14.583

[iii] Noise Mitigation Guideline, Roads and Maritime, December 2014, RMS 14.584

[iv] Environmental Noise Management Manual, Roads and Maritime, 2001

[v] Industrial Noise Policy (INP), NSW EPA, 1999

[vi] Interim Construction Noise Guideline, DECC, 2009

[vii] Assessing Vibration: a technical guideline, DEC, 2006

[viii] Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration (ANZEC), 1990.

[ix] AS 2187: Part 2-2006 Explosives - Storage and Use - Part 2: Use of Explosives, Standards Australia, 2006

[x] AS IEC 61672.1—2004 - Electroacoustics—Sound level meters, Part 1: Specifications, Standards Australia, 2004

[xi] Calculation of Road Traffic Noise, UK Department of Transport, 1988

[xii] Brown R, The Effect of Signalisation on Road Traffic Noise Levels - A Case Study, AAS, 1996

[xiii] *Internoise 96 "Noise from Tunnel Openings – An Engineering Approach", Olafsen, 1996*

[xiv] BS 7385 Part 2-1993 Evaluation and measurement for vibration in buildings Part 2, BSI, 1993

[xv] DIN 4150:Part 3-1999 Structural vibration - Effects of vibration on structures, Deutsches Institute fur Normung, 1999

[xvi] Construction Noise Strategy, TfNSW, 2012

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Acoustic Terminology

1 Sound Level or Noise Level

The terms 'sound' and 'noise' are almost interchangeable, except that in common usage 'noise' is often used to refer to unwanted sound.

Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very wide range. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (abbreviated as dB) scale reduces this ratio to a more manageable size by the use of logarithms.

The symbols SPL, L or L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2×10^{-5} Pa.

2 'A' Weighted Sound Pressure Level

The overall level of a sound is usually expressed in terms of dBA, which is measured using a sound level meter with an 'A-weighting' filter. This is an electronic filter having a frequency response corresponding approximately to that of human hearing.

People's hearing is most sensitive to sounds at mid frequencies (500 Hz to 4000 Hz), and less sensitive at lower and higher frequencies. Thus, the level of a sound in dBA is a good measure of the loudness of that sound. Different sources having the same dBA level generally sound about equally loud.

A change of 1 dBA or 2 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness. The table below lists examples of typical noise levels

Sound Pressure Level (dBA)	Typical Source	Subjective Evaluation
130	Threshold of pain	Intolerable
120	Heavy rock concert	Extremely noisy
110	Grinding on steel	
100	Loud car horn at 3 m	Very noisy
90	Construction site with pneumatic hammering	
80	Kerbside of busy street	Loud
70	Loud radio or television	
60	Department store	Moderate to quiet
50	General Office	
40	Inside private office	Quiet to very quiet
30	Inside bedroom	
20	Recording studio	Almost silent

Other weightings (eg B, C and D) are less commonly used than A-weighting. Sound Levels measured without any weighting are referred to as 'linear', and the units are expressed as dB(lin) or dB.

3 Sound Power Level

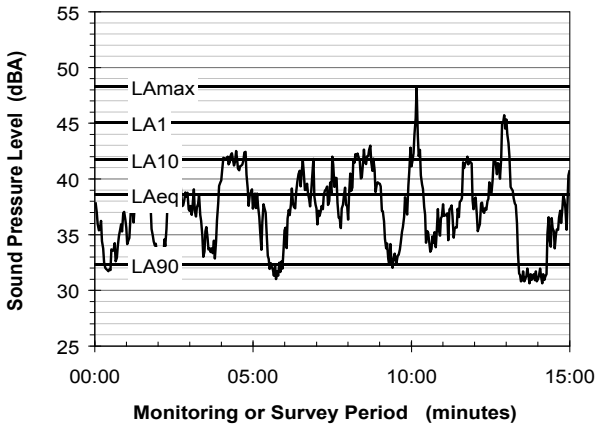
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 10^{-12} W.

The relationship between Sound Power and Sound Pressure may be likened to an electric radiator, which is characterised by a power rating, but has an effect on the surrounding environment that can be measured in terms of a different parameter, temperature.

4 Statistical Noise Levels

Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels L_{AN}, where L_{AN} is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the L_{A1} is the noise level exceeded for 1% of the time, L_{A10} the noise exceeded for 10% of the time, and so on.

The following figure presents a hypothetical 15 minute noise survey, illustrating various common statistical indices of interest.



Of particular relevance, are:

L_{A1} The noise level exceeded for 1% of the 15 minute interval.

L_{A10} The noise level exceed for 10% of the 15 minute interval. This is commonly referred to as the average maximum noise level.

L_{A90} The noise level exceeded for 90% of the sample period. This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.

L_{Aeq} The A-weighted equivalent noise level (basically the average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

When dealing with numerous days of statistical noise data, it is sometimes necessary to define the typical noise levels at a given monitoring location for a particular time of day. A standardised method is available for determining these representative levels.

This method produces a level representing the 'repeatable minimum' L_{A90} noise level over the daytime and night-time measurement periods, as required by the EPA. In addition the method produces mean or 'average' levels representative of the other descriptors (L_{Aeq}, L_{A10}, etc).

5 Tonality

Tonal noise contains one or more prominent tones (ie distinct frequency components), and is normally regarded as more offensive than 'broad band' noise.

6 Impulsiveness

An impulsive noise is characterised by one or more short sharp peaks in the time domain, such as occurs during hammering.

7 Frequency Analysis

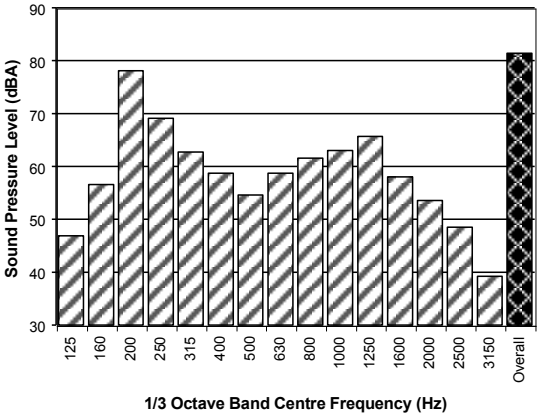
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

The units for frequency are Hertz (Hz), which represent the number of cycles per second.

Frequency analysis can be in:

- Octave bands (where the centre frequency and width of each band is double the previous band)
- 1/3 octave bands (3 bands in each octave band)
- Narrow band (where the spectrum is divided into 400 or more bands of equal width)

The following figure shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.



8 Vibration

Vibration may be defined as cyclic or transient motion. This motion can be measured in terms of its displacement, velocity or acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of 'peak' velocity or 'rms' velocity.

The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as 'peak particle velocity', or PPV. The latter incorporates 'root mean squared' averaging over some defined time period.

Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse.

The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated. A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/V_o), where V_o is the reference level (10^{-9} m/s). Care is required in this regard, as other reference levels may be used by some organizations.

9 Human Perception of Vibration

People are able to 'feel' vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building (even though they may not be disturbed by the motion). An individual's perception of motion or response to vibration depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as 'normal' in a car, bus or train is considerably higher than what is perceived as 'normal' in a shop, office or dwelling.

10 Over-Pressure

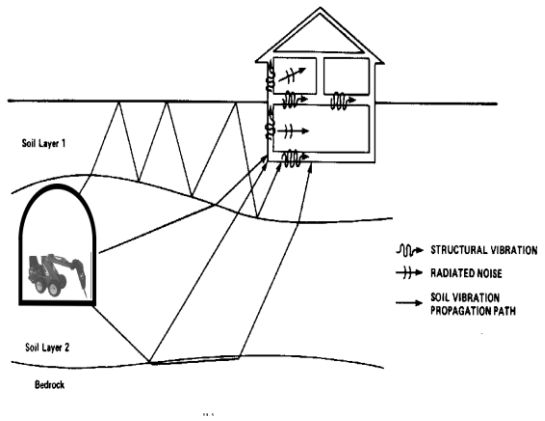
The term 'over-pressure' is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

11 Ground-borne Noise, Structure-borne Noise and Regenerated Noise

Noise that propagates through a structure as vibration and is radiated by vibrating wall and floor surfaces is termed 'structure-borne noise', 'ground-borne noise' or 'regenerated noise'. This noise originates as vibration and propagates between the source and receiver through the ground and/or building structural elements, rather than through the air.

Typical sources of ground-borne or structure-borne noise include tunnelling works, underground railways, excavation plant (eg rockbreakers), and building services plant (eg fans, compressors and generators).

The following figure presents the various paths by which vibration and ground-borne noise may be transmitted between a source and receiver for construction activities occurring within a tunnel.

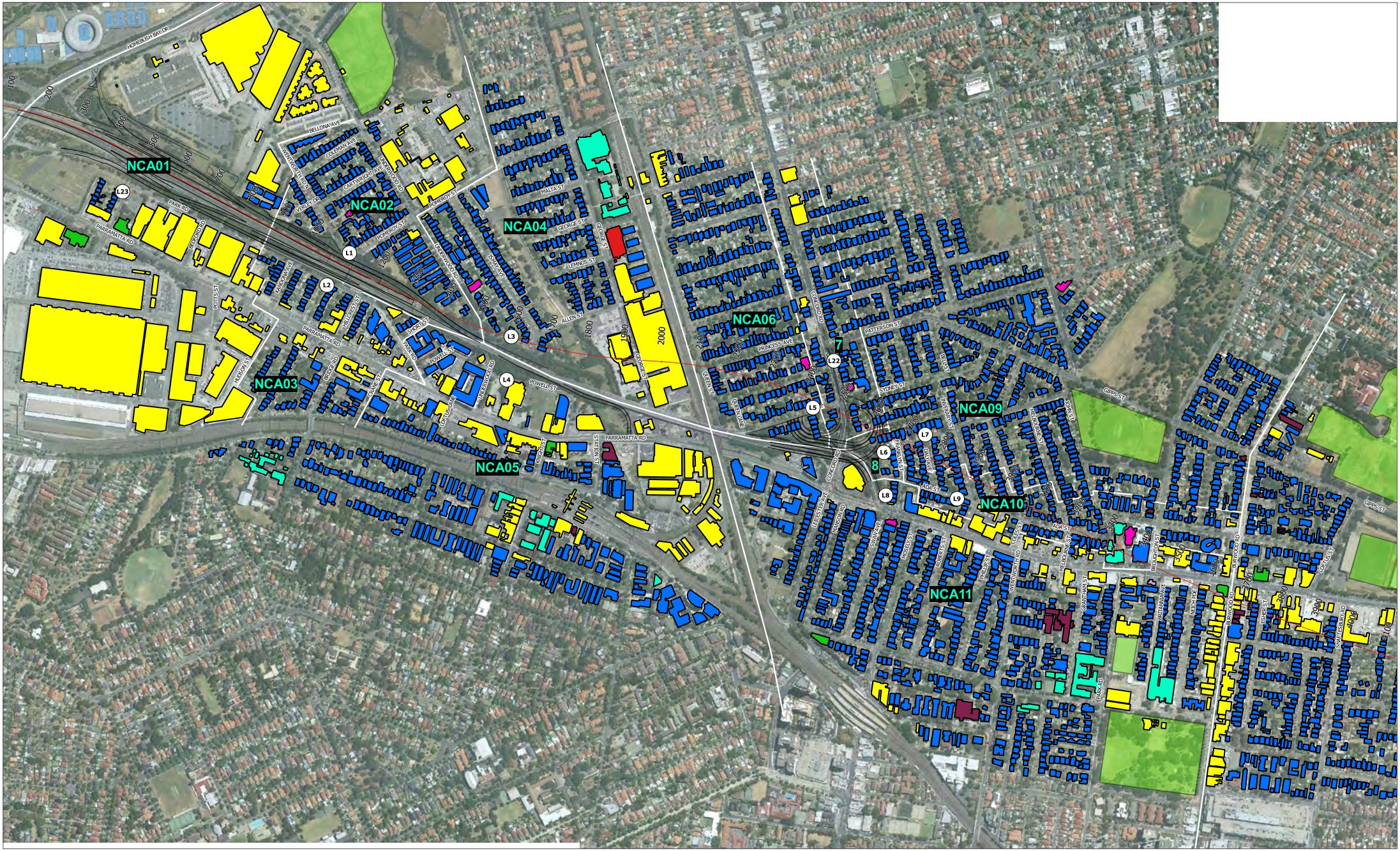


The term 'regenerated noise' is also used in other instances where energy is converted to noise away from the primary source. One example would be a fan blowing air through a discharge grill. The fan is the energy source and primary noise source. Additional noise may be created by the aerodynamic effect of the discharge grill in the airstream. This secondary noise is referred to as regenerated noise

Appendix B

Report 610.13569-R2

Site plan and Sensitive Receivers



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Project No.:	610.13569
Date:	31/08/2015
Drawn by:	ALW
Scale:	1:13,000
Sheet Size:	@ A4
Projection:	GDA 1994 MGA Zone 56

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0 100 200 300 400 m

Receiver Types

- Residential
- Commercial
- Other (Educational)
- Other (Medicall)
- Other (Place of Worship)
- Other (Public Building)
- Other (Hotel)
- Other (Cafe Bar)
- Other (Child Care)
- Outdoor Space (Active)
- Outdoor Space (Passive)
- Design
- Noise Logging Location

WestConnex Delivery Authority

WestConnex - M4 East

Site Plan and Sensitive Receivers