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Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Appendix G

Noise and vibration

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Prepared by

Renzo Tonin and Associates Pty Ltd

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Executive summary

Introduction (Section 1)

Renzo Tonin & Associates has been engaged by Transport for NSW to assess potential noise and vibration impacts from the construction and operation of the Beaches Link and Gore Hill Freeway Connection (the project), which would comprise two main components:

- Twin tolled motorway tunnels connecting the Warringah Freeway at Cammeray and the Gore Hill Freeway at Artarmon to the Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights (the Beaches Link). This would also include surface road works along Wakehurst Parkway and the road network around the Burnt Bridge Creek Deviation
- Connection and integration works along the existing Gore Hill Freeway at Artarmon (the Gore Hill Freeway Connection).

Existing noise environment (Section 2)

The project extends from Cammeray at the southern extent, through to Frenchs Forest at the northern most extent. Areas adjacent to the project alignment have been separated into 82 noise catchment areas, which represent areas with similar acoustic environments.

The existing acoustic environment varies throughout the project alignment. Residents located along existing major road corridors, such as Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation, experience high levels of road traffic noise. Further away from these major road corridors, other roads and noise sources influence the existing noise environment.

Long-term noise monitoring was carried out at 45 locations throughout the project extent, and supplemented by data from the Northern Beaches Hospital road upgrade project, where required. The monitoring data was used to quantify the existing noise environment in areas where receivers may potentially be impacted by construction noise, and to determine the existing levels of road traffic noise along the project. Noise logging occurred for between seven days and 25 days at each location.

Criteria and noise management levels (NMLs) for the assessment of operational and construction noise were derived with reference to this long-term noise monitoring. In addition, the operational road traffic noise models have been calibrated using the monitoring of existing road traffic noise levels.

Relevant guidelines and noise and vibration objectives (Section 3)

Noise and vibration guidelines listed in the project Secretary's environmental assessment requirements have been considered in this assessment. Transport for NSW's *Construction Noise and Vibration Guideline* (2016) (CNVG) provides guidance for the assessment and mitigation of construction noise and vibration. The CNVG refers to the policies, guidelines and standards presented in Table 3-1, which have been adopted in the construction noise and vibration assessment for the project.

The operational noise guidelines and policies adopted for the operational noise assessment for the project are presented in Table 3-18.

Noise and vibration assessment methodology (Section 4)

Construction

The construction scenarios described and considered in this assessment are indicative. All construction works and predicted noise outcomes reported here would be reviewed during the design development and construction planning phase to re-evaluate all mitigation and management measures as required.

Across the Beaches Link and Gore Hill Freeway Connection project, the construction works with the potential for noise and vibration impacts have been separated into two major categories:

- **Construction support sites** are fixed construction support sites located along the project length and would be established for a large proportion of the project duration. Within these support sites the louder construction activities would occur predominantly during standard construction hours, with support for 24 hour tunnelling taking place within acoustic sheds with some associated but limited out of hours access to the support site for light and heavy vehicles. Tunnel access decline, shaft or ventilation tunnel construction is also assessed as part of construction support sites
- **Surface road works** where construction locations vary along the corridor and where works occur at each location for shorter periods of time. For surface road works, portions of the construction works that need to occupy trafficable parts of the road surface would require partial road closures. As partial road closures for major arterial roads must occur outside the peak traffic period, a large amount of out of hours construction works (OOHW) would be needed during the evenings and nights.

Construction noise and vibration impacts have been assessed using three dimensional models which include all proposed noise sources, receiver locations, topographical and manmade features, and feasible and reasonable noise mitigation measures developed for this project. Models were developed for each of the major stages of construction across the project based on preliminary site layouts and reasonable worst case construction plant and equipment. Feasible and reasonable noise treatment measures and management methods have been identified and incorporated into the models to assist in attenuating and managing noise from construction activities as discussed in Section 4.1.

For surface road works, additional assessment took place to look at both typical and reasonable worst case construction activities, both when works are in close proximity to receivers and further away within the construction works area. Predicted impacts for both these cases represent the highest noise levels that occur over an entire stage/works area and not an individual activity/night. The number of potential noise affected receivers on an individual night would be less than presented, and receivers potentially impacted would also vary between nights as the location and type of activity change.

Both assessment approaches are conservative. Actual noise levels would vary greatly depending on a range of factors including the location of the construction works within each construction works area, the distance between noise sources and nearby receivers, the noise intensity of works taking place and the time of day specific activities take place.

The potential ground-borne noise and vibration impacts from the construction of the mainline and ramp tunnels is assessed as a separate section.

Operation

Operational road traffic noise impacts were assessed for surface roads associated with the project. Noise modelling predictions were carried out for all noise sensitive receiver locations. For multi-storey buildings, all floor levels which accommodate noise sensitive receivers have been included in the road traffic noise assessment.

Various operational traffic noise scenarios were modelled. However, the identification of additional traffic noise mitigation (eg noise barriers, at property treatment) was based on the assessment between the 'without the project' ('Do minimum 2037') and the 'with the project cumulative' ('Do something cumulative 2037') scenarios, where these scenarios represent the following:

- 'without the project' – **WITH** the WestConnex, **WITHOUT** the project, Western Harbour Tunnel and Warringah Freeway Upgrade, Sydney Gateway and the M6 Motorway
- 'with the project cumulative' - **WITH** the project, WestConnex, Western Harbour Tunnel and Warringah Freeway Upgrade, Sydney Gateway and the M6 Motorway.

Operational noise impacts from the proposed fixed facilities associated with the project in addition to the new and improved open space and recreation facilities at Balgowlah have been modelled to assess potential noise impacts at nearby sensitive receivers. The noise predictions have incorporated indicative plant and equipment typically for similar major road infrastructure projects, or from similar recreational activities to determine the predicted noise levels at the nearby sensitive receivers.

Construction noise and vibration assessment (Section 5)

This section summaries the potential noise and vibration impacts, with the mitigation and management measures to control these impacts outlined in the following section.

Warringah Freeway surface road works (Section 5.2)

The Warringah Freeway surface road works would be carried out within the Warringah Freeway corridor near Cammeray Golf Course. Project works would be likely timed to occur in conjunction with staged

surface works in the area for the Warringah Freeway Upgrade project so as to limit disruption to traffic and duration of noise impacts for the adjacent community.

During standard hours no receiver buildings are predicted to be noise affected (ie >NML) by typical construction works along the Warringah Freeway. However, during worst case works up to 18 residential receiver buildings are predicted to be noise affected. Six receiver buildings are predicted to be highly noise affected (ie >75 dB(A)) during periods of worst case works.

Outside standard construction hours during the northbound portal construction (WFU2H_10), typical construction works are predicted to result in up to 148 residential receiver buildings being noise affected (ie >NML). During worst case northbound portal construction works that could involve concrete saws, noise impacts are predicted to result in up to about 1900 receiver buildings being noise affected, with noise impacts at seven receivers predicted to be above the NML by more than 25 dB(A). Maximum noise levels during typical construction works are predicted to exceed the sleep disturbance screening level at up to 65 receiver buildings, and awakening reaction levels at eight of those receiver buildings. These are predicted to increase to 692 and 46 receiver buildings respectively during worst case works.

The project timeline overlaps nearby construction sites associated with the project, specifically the ventilation outlet and motorway facilities building construction at Warringah Freeway as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project. Cumulative noise impacts are unlikely to occur during standard hours or with other nearby major projects but could occur from work outside standard hours from other project construction sites. As there are a number of the project's construction sites close together, there is potential for increased overall duration and frequency of construction noise impacts. These will be managed, coordinated and mitigated during detailed construction planning in the site specific construction noise and vibration impact statements (CNVIS).

Construction road traffic management and vehicle movements associated with building the Warringah Freeway surface road works are not likely to increase overall road traffic noise levels by more than 2 dB(A). This change represents a minor impact.

If large rock hammers are used, two heritage listed items would be within the vibration minimum working distance for cosmetic damage to an unsound heritage structure. Due to the limited duration that rock hammering activities would take place at this site, there is a low risk of adverse human response to vibration. However, occupants of up to 14 receiver buildings have the potential to be within the minimum working distance for adverse human response and may therefore be able to feel vibration from construction activities.

Cammeray Golf Course construction support site (BL1) (Section 5.3)

The Cammeray Golf Course construction support site (BL1) would operate at Ernest Street in Cammeray, adjacent to the Warringah Freeway. It would occupy part of a site established by the Western Harbour Tunnel and Warringah Freeway Upgrade project.

Up to 10 receivers are predicted to be noise affected during standard hours work, except for during the short term piling stage of the site, when up to 157 residential receiver buildings are predicted to be noise affected. Two receiver buildings would be highly noise affected during the decline piling stage.

Outside standard hours, up to eight residential receiver buildings are predicted to be noise affected by support work for the Warringah Freeway surface road works, tunnelling and tunnel fitout. Maximum noise levels are predicted to be above sleep disturbance screening levels at up to 69 receiver buildings, but below the awakening reaction level at all receiver buildings. These impacts are predominately from heavy vehicle movements along internal construction support site roads. The configuration of the internal layout would be reviewed during further design development and construction planning to mitigate and manage these potential impacts.

Cumulative construction noise, road traffic noise and ground-borne noise from the activities proposed at the site are not expected to be substantial.

If large rock hammers are used, two heritage listed items would be within the vibration minimum working distance for cosmetic damage for unsound heritage structures. Due to the limited duration that the rock hammering activities would take place at this site, there is a low risk of adverse human response to vibration.

Gore Hill Freeway Connection surface road works (Section 5.4)

The project would connect to the Gore Hill Freeway at Artarmon between the existing Lane Cove Tunnel and railway overbridge. The noise assessment has assessed six subzones, which is then broken down further into ten major works areas. These construction works would be supported by three minor construction support sites. In addition to those areas, some ancillary local area road works or utility adjustment works would be required for relatively short term periods (less than one month) within the construction footprint at locations to be determined during further design development and construction planning.

During standard construction hours, up to 31 residential receiver buildings are predicted to be noise affected (ie >NML) during worst case works across the work subzones, excluding subzone 7, as part of the Gore Hill Freeway Connection surface road works, as well as up to nine highly noise affected (ie >75 dB(A)) residential receiver buildings. In subzone 7 at the intersection of Pacific Highway and Dickson Avenue, Artarmon, up to 100 receiver buildings are predicted to exceed the NMLs during the worst case works due to the proximity of the nearby receivers. A range of childcare, educational facilities, a place of worship, a recreational area and commercial receiver buildings that are located around the Gore Hill Freeway works area are also predicted to be noise affected by the work.

Outside standard construction hours and across the major works areas typical works for any one subzone is predicted to result in up to 112 residential receiver buildings being noise affected over the entire stage. This is predicted to increase to 1453 noise affected receiver buildings across the duration of a subzone stage during periods of worst case construction activities. During works in anyone subzone, maximum noise levels during typical construction works are predicted to be above the sleep disturbance screening level at up to 63 receiver buildings for any works subzone, and above the

awakening reaction level at up to 19 receiver buildings. During periods of worst case works, this may increase to 454 above the sleep disturbance screening level, and up to 46 receiver buildings above the awakening reaction level.

The project timeline overlaps nearby construction sites associated with the project, specifically the Punch Street and Flat Rock Drive construction support sites, (BL3 and BL2 respectively), as well as the Warringah Freeway surface road works for the Western Harbour Tunnel and Warringah Freeway Upgrade project. Construction program planning and coordination where feasible and reasonable would be implemented to manage cumulative impacts from the various construction activities and between projects. Where required, additional mitigation measures would be adopted with consideration of cumulative and long-term noise impacts on the impacted receivers, specifically noting the works areas that would be operating concurrently or consecutively and affecting the same receiver locations.

Construction road traffic management and vehicle movements associated with building the Gore Hill Freeway Connection are not likely to increase overall road traffic noise levels by more than 2 dB(A).

If large rock hammers are used during early works, a potential archaeological deposit and up to 16 receiver buildings would be within the minimum working distance for cosmetic damage from rock hammering across the construction subzones. Due to the limited duration that rock hammers would be operating at this site during early construction stages, the risk of annoyance is low. However, up to 84 receiver buildings are predicted to be exposed to vibration above the human response screening level (ie building occupants may feel vibration from construction).

Flat Rock Drive construction support site (BL2) (Section 5.5)

The Flat Rock Drive construction support site (BL2) in Northbridge would be used to support tunnelling works between Cammeray and the Middle Harbour crossing (BL7 and BL8).

During standard construction hours, up to 174 residential receiver buildings are predicted to be noise affected by short term early works. Up to two receivers are predicted to be highly noise affected (ie >75 dB(A)) during the early works, site establishment and road widening stages.

The highest number of noise affected receivers during standard hours is from site establishment vegetation clearing and onsite intersection modification works. Commercial, childcare and active recreation receivers are also predicted to be noise affected (ie >NML) by work at the site.

Outside standard construction hours, during short term road widening works at night, up to 698 residential receiver buildings are predicted to be noise affected. During tunnel support and tunnel fitout works outside standard hours, there are no predicted noise affected residential receivers. Maximum noise levels from concrete or delivery trucks during tunnel support and fitout works are predicted to be above sleep disturbance screening levels at up to 143 receiver buildings. Nonetheless, sleep disturbance impacts are unlikely due to the infrequent nature of the works and through management of maximum noise level event noise sources.

Cumulative noise impacts from other construction activities are expected to be negligible, except for during utilities relocation for the Gore Hill Freeway Connection and Warringah Freeway Upgrade as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project, where those works would dominate any noise from the site.

Overall road traffic noise levels at receivers directly exposed to traffic noise on construction haulage and traffic routes (Flat Rock Drive) are predicted to increase by less than 2 dB(A) during both day and night, as a result of the addition of construction traffic from the project. This change represents a minor impact. Since the number of night truck movements generated by the site is not substantial compared to existing heavy vehicle numbers on Flat Rock Drive, the number of maximum noise events that could disturb sleep are not likely to substantially increase.

During the construction of the tunnel access decline between the Flat Rock Drive construction support site (BL2) and the ramp and mainline tunnels, no residential receiver buildings are predicted to experience ground-borne noise above the night time NML of 35 dB(A) due to the depth of the tunnel access decline and the resulting slant distance to nearby occupied receivers.

If large rock hammers are used, one heritage item being an area of potential aboriginal archaeological deposits located near Flat Rock Creek, and two buildings would be within the minimum working distance for cosmetic damage from vibration.

Due to the limited duration that rock hammering activities would take place at this site, there is a low risk of adverse human response to vibration. However, occupants of up to eleven receiver buildings have the potential to be exposed to vibration above the human response screening level caused by vibration intensive activities and may therefore feel vibration from construction activity.

Punch Street construction support site (BL3) (Section 5.6)

The Punch Street construction support site (BL3) in Artarmon would be used to support tunnelling works between Artarmon and Willoughby.

No residential receivers would be noise affected by tunnel support or fitout works during standard hours. Up to 97 residential buildings are predicted to be noise affected by shorter term site establishment, decline construction and shed construction works during standard hours. As the site is in an industrial area, up to 16 non-residential noise sensitive receiver buildings are predicted to be noise affected during earlier stages. Up to five commercial receiver buildings are predicted to be noise affected during the late stages during the construction of the operational motorway facilities and restoration of the site.

Outside standard construction hours, there are no predicted noise affected residential receivers. Maximum noise levels from truck arrivals or departures during these stages are predicted to be above the sleep disturbance screening level at up to 107 receiver buildings, three of which may be above the awakening reaction level. Since the number of truck movements generated by the site is not substantial

compared to existing heavy vehicle numbers on the Gore Hill Freeway, the number of maximum noise events that could disturb sleep are not likely to substantially increase.

The project timeline overlaps nearby construction sites associated with the project, specifically the Gore Hill Freeway Connection surface road works and the Flat Rock Drive construction support site (BL2), in addition to the Warringah Freeway surface road works for the Western Harbour Tunnel and Warringah Freeway Upgrade project, and the construction site at Artarmon Substation for the Sydney Metro Chatswood to Sydenham project. If works across these projects occur simultaneously, the greatest increase in noise level due to combined construction noise would be 3 dB(A) during OOHW. Even though cumulative increases are not expected to be substantial, as there are a number of major projects and multiple works areas from the project close together, there is potential for increased overall duration and frequency of construction noise impacts. These would be managed, coordinated and mitigated during detailed construction planning in the CNVIS.

As the construction traffic route passes through an existing industrial area and then onto the Gore Hill Freeway which has high existing traffic movements, overall road traffic noise levels are expected to increase by less than 2 dB(A) during both day and night. This change represents a minor impact. Since the number of truck movements generated by the site is not substantial compared to existing heavy vehicle numbers on Gore Hill Freeway the number of maximum noise events that could disturb sleep are not likely to substantially increase.

Seven residential receiver buildings are predicted to experience ground-borne noise above the NMLs during the construction of the tunnel access decline between Punch Street construction support site (BL3) and the mainline and ramp tunnel alignment.

Six buildings would be within the cosmetic damage minimum working distance for rock hammering at the site. Due to the limited duration that rock hammering activities would take place at this site, there is a low risk of adverse human response to vibration. However, occupants of 25 buildings have the potential to be exposed to vibration levels above the human response screening level (ie building occupants may feel vibration from construction).

Middle Harbour crossing (BL7 and BL8) (Section 5.7)

The Middle Harbour crossing would be an immersed tube tunnel crossing Middle Harbour, between Northbridge and Seaforth, which includes the Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8).

During standard construction hours, up to 1075 receiver buildings may be noise affected by cofferdam impact piling activity. Ten of these receiver buildings are predicted to be highly noise affected (ie >75 dB(A)) by piling of the Middle Harbour north cofferdam (BL8) only. The high noise levels are due to impact piling with large (23 tonne) hammers. These hammers are difficult to physically mitigate.

To manage noise impacts, the vibratory and impact piling works would be restricted to standard construction hours and would have longer respite periods provided to receivers than normally required for high noise work. This is because the high noise generating activities from impact piling would likely

occur for no more than two hours a day. The associated setup and piling preparation works would occur during the rest of the day. Vibratory piling would occur throughout the day and noise impacts would be managed in a similar manner, with respite.

During excavation within the cofferdams to provide space for the interface structures, up to 222 receiver buildings are predicted to be noise affected including one highly noise affected building. Excavation would only occur during standard construction hours and respite would be provided. During other standard hours works at the crossing, up to 57 receiver buildings are predicted to be noise affected.

One commercial receiver (Northbridge Sailing Club) is predicted to be noise affected (ie >NML) during construction of the Middle Harbour south cofferdam and piling for the foundations for immersed tube tunnel. Due to the distance from the construction works, other non-residential receivers are predicted to be noise affected from the construction works.

Tunnel unit immersion activities would be required outside standard construction hours. Up to 295 receiver buildings are predicted to be noise affected during night tunnel unit immersion. Tunnel unit immersion would only take 24 to 48 hours to immerse each of the six tunnel tubes. Maximum noise levels associated with tunnel unit immersion activities at night are predicted to be above the sleep disturbance screening level, while events related to crane/equipment/plant operation during tunnel unit immersion are predicted to also be above the awakening reaction level at seven receiver buildings.

The project timeline overlaps the nearby Spit West Reserve construction support site (BL9) as this supports the Middle Harbour crossing work. However, cumulative noise impacts are not expected to be substantial as impact piling works would be short in duration and intermittent, immersion of each tunnel unit would take place continuously over 48 hours and increases in construction noise would not occur at the most affected receivers. There are potential increases in overall duration and frequency of construction noise impacts from the nearby construction site, which would be managed, coordinated and mitigated during detailed construction planning in the CNVIS.

During cofferdam construction activities eight buildings would be within the vibration cosmetic damage minimum working distance for sound structures and seven heritage structures would be within the unsound structure minimum working distance. Due to the proximity of vibration sensitive structures, including heritage items, to the cofferdams a specific review of the vibration intensive works methodologies will be required during the design development and construction planning phase to manage vibration impacts. Occupants of up to 148 buildings have the potential to be exposed to vibration above the human response screening level.

Spit West Reserve construction support site (BL9) (Section 5.8)

The Spit West Reserve construction support site (BL9) would support work at the Middle Harbour crossing, including casting and fitting out of tunnel units.

No receivers are predicted to be highly noise affected (ie >75 dB(A)) at any stage, or noise affected (ie >NML) while the site is supporting the Middle Harbour crossing, casting or fitting out tunnel units during standard construction hours. Up to 131 residential receiver buildings are predicted to be noise

affected during works. Five commercial receiver buildings on the east of Spit Road and two recreational receivers are predicted to be noise affected during early works.

The only work that would occur outside standard hours is support for the tunnel unit immersion at Middle Harbour crossing and extended concrete pours for the casting of tunnel units. During tunnel unit immersion (SMH_06), up to 79 receiver buildings are predicted to be noise affected and 132 receiver buildings are predicted to potentially be exposed to maximum noise levels above the sleep disturbance screening level. All receivers are predicted to be below the awakening reaction level. Sleep disturbance noise sources (ie metal on metal bangs) would be managed however, it should also be noted that any impacts would be over a small periods of time as the tunnel unit immersion would occur for only six periods each of 24 to 48 hours as each tunnel unit is sunk, and so impacts can likely be managed. In the case that concrete pours for casting of the tunnel units (SMH_05) extend into the evening period, up to 219 receiver buildings are predicted to be noise affected.

The project timeline overlaps the nearby project construction sites at the Middle Harbour crossing as this site supports those construction works. However, cumulative noise impacts are not expected to be substantial between these two sites due to the distances between them. There are potential increases in overall duration and frequency of construction noise impacts from the nearby construction site, which would be managed, coordinated and mitigated during further design development and construction planning phase in the CNVIS.

Overall road traffic noise levels at receivers directly exposed to traffic noise on construction haulage and traffic routes (Military Road/Spit Road) are predicted to increase by less than 0.5 dB(A) during both day and night as a result of the addition of construction traffic from the project. No night time heavy vehicle movements would occur to or from this site, so road traffic related sleep disturbance impacts are not expected to occur.

Ground-borne noise from the activities proposed at the site are expected to be negligible due to the distance to the closest building and the minimal proposed vibration intensive works.

Due to the limited duration vibration intensive activities would take place at this site, there is a low risk of adverse human response to vibration. However, occupants of up to 2 buildings have the potential to be exposed to vibration levels above the human response screening level.

Balgowlah Golf Course construction support site (BL10) (Section 5.9)

During standard construction hours, no residential receiver buildings are predicted to be above the NML during the surface road works support, tunnel support or tunnel fitout stages. However, during site establishment up to 1004 receiver buildings are predicted to be noise affected, including two which are predicted to be highly noise affected (ie >75 dB(A)). Respite would be provided during the noisiest works (rock hammering). Up to 32 non-residential receiver buildings are predicted to be noise affected during site establishment works. The mitigation measures installed as part of the Balgowlah Golf Course

construction support site (BL10) would assist with mitigating noise impacts to nearby receivers, especially to the receiver buildings to the east of the works in NCA 50.1.

Outside standard construction hours, no receivers are predicted to be noise affected, except for during short term intersection works at Sydney Road. During short term intersection works, which need to occur at night under a road occupancy licence, up to 548 receiver buildings are predicted to be noise affected.

During night time road and intersection modification work, maximum noise levels are predicted to be above the sleep disturbance screening level at up to 256 receiver buildings, including eleven receivers where noise levels are above the awakening reaction level.

During tunnel support, occasional night time concrete trucks may cause high maximum noise levels on arrival or departure. Maximum noise levels at up to 136 receiver buildings are predicted to be above the sleep disturbance screening level. All receivers are predicted to be below the awakening reaction level. Since typically only up to three to four concrete trucks are expected during a night, the number of truck movements generated by the site is not substantial compared to existing traffic numbers on Sydney Road and Burnt Bridge Creek Deviation. Consequently, the number of maximum noise events that could disturb sleep are not likely to substantially increase

The project timeline overlaps the adjacent Balgowlah surface road works as this site also supports those works. If works across these areas occur simultaneously, there is potential for cumulative increases in the construction noise levels at nearby receivers. In addition, as there are multiple works areas from the project located close together, there is potential for increased overall duration and frequency of construction noise impacts. These would be managed, coordinated and mitigated during detailed construction planning as part of the CNVIS.

Overall road traffic noise levels at receivers directly exposed to traffic noise on construction haulage and traffic routes (Sydney Road and Burnt Bridge Creek Deviation) are predicted to increase by less than 2 dB(A) during both day and night, as a result of the addition of construction traffic from the project, which is considered a minor impact. Since the number of night period truck movements generated by the site is not substantial compared to existing heavy vehicle numbers on Sydney Road and Burnt Bridge Creek Deviation, the number of maximum noise events that could disturb sleep are not likely to substantially increase.

Five residential receiver buildings are predicted to experience ground-borne noise above the night time NML of 35 dB(A) during the construction of the tunnel access decline between the site at Balgowlah Golf Course (BL10) and the mainline tunnel alignment. Potential impacts would be managed by restricting construction hours for the tunnel access decline excavation.

If large rock hammers are used during site establishment stages, 33 buildings and one heritage item would be within the minimum working distance for cosmetic damage. Due to the limited duration that rock hammering activities would take place at this site, there is a low risk of adverse human response to vibration. However, occupants of up to 167 receiver buildings have the potential to be exposed to

vibration levels above the human response screening level (ie building occupants may feel vibration from construction).

No receivers are expected to perceive vibration during the construction of the tunnel access decline.

Balgowlah surface road works (Section 5.10)

The Balgowlah surface road works would link the project with the southern areas of the Northern Beaches including Seaforth, North Balgowlah, Manly and Brookvale at Burnt Bridge Creek Deviation and Sydney Road at Balgowlah.

During standard construction hours receivers in in Seaforth, Clontarf, Balgowlah, North Balgowlah and Manly Vale (NCAs 46.1, 46.2, 47.1, 48.1, 49.1, 50.1 and 51.1) are predicted to be noise affected at times during the surface road works. Up to 127 receiver buildings for any one of the major works areas are predicted to be noise affected (ie >NML) during typical construction activities, with no receiver buildings predicted to be highly noise affected (ie >75 dB(A)). However, this is predicted to increase to 912 noise affected receiver buildings during periods of worst case activities, including up to 25 highly noise affected. Up to eight non-residential receiver buildings are predicted to be noise affected during the work for any one of the major works area.

Outside standard hours, for the major works area with the highest number of potentially noise affected receiver buildings, typical works are predicted to result in up to 2318 noise affected receiver buildings. This could increase to 4059 noise affected receiver buildings during periods of worst case noise intensive construction activities. These numbers of receiver buildings are over the entire works stage, and only a subset would be noise affected on an individual night. Maximum noise levels during typical construction works are predicted to be above the L_{Amax} sleep disturbance screening level at up to 718 receiver buildings for any one works area, and above the awakening reaction level at up to 97 receiver buildings. During periods of worst case works, this may increase up to 1097 receiver buildings above the sleep disturbance screening level and up to 148 receiver buildings above the awakening reaction level.

The project timeline overlaps the adjacent Balgowlah Golf Course construction support site (BL10) which also supports these works. If works across these construction work areas occur simultaneously, there is potential for cumulative increases in construction noise levels at nearby receivers. As there are multiple work areas from the project close together, there is also potential increase in overall duration and frequency of construction noise impacts. Construction program planning and coordination would be implemented where feasible and reasonable to manage cumulative and consecutive impacts from the multiple work areas. The site specific CNVIS would detail feasible and reasonable programming, coordination and management of concurrent and consecutive construction work areas and activities to minimise noise impacts and provide respite to noise affected receivers.

A relatively small number of construction vehicles are proposed to travel between the Balgowlah surface road works major works areas, with most vehicles travelling directly to each area at the start of a shift. Construction road traffic management such as traffic switches combined with construction traffic movements are not expected to increase overall road noise levels by more than 2 dB(A), but traffic noise

impacts would be reviewed as part of further design development considering that an existing noise wall would be removed as part of the construction works.

If large rock hammers are used during the construction works, up to 44 receiver buildings would be within minimum working distances for cosmetic damage. Due to the limited duration that rock hammering activities would take place at this site, there is a low risk of adverse human response to vibration. However, occupants of up to 197 receiver buildings have the potential to be exposed to vibration levels above the human response screening level from vibration intensive activities (ie building occupants may feel vibration from construction).

Wakehurst Parkway south construction support site (BL12) (Section 5.11)

The Wakehurst Parkway south construction support site (BL12), located at the corner of Wakehurst Parkway and Judith Street at Seaforth, would support surface road works including the cut and cover portal works and the ventilation outlet and motorway facility construction at Wakehurst Parkway.

During standard construction hours, while the construction support site is in operation, no receivers are expected to be noise affected (ie >NML). During early works, site establishment and site restoration, up to 54 residential receiver buildings are predicted to be noise affected, including 18 highly noise affected receivers (ie >75 dB(A)). Up to two non-residential buildings are predicted to be noise affected.

The project timeline overlaps the nearby Wakehurst Parkway surface road works and the Wakehurst Parkway east construction support site (BL13). If work across these construction work areas occurs simultaneously, there is potential for cumulative increases in the construction noise levels at nearby receivers. In addition, as there are multiple works areas from the project close together, there is potential increases in overall duration and frequency of construction noise impacts. These would be managed, coordinated and mitigated during detailed construction planning in the CNVIS.

Construction traffic movements for this site are low. As for the Wakehurst Parkway east construction support site (BL13) the overall traffic noise increases from combined project construction traffic (Wakehurst Parkway) is predicted to be less than 2 dB(A) during both day and night. The number of maximum noise events that could disturb sleep are also not likely to substantially increase.

Large rock hammers would be used during early works. Two heritage items (Bantry Bay Water Pumping Station (WPS 122) and Bantry Bay Reservoir (WS 0008)) and 21 receiver buildings would be within the cosmetic damage minimum working distance. Due to the limited duration that rock hammering activities would take place at this site, there is a low risk of adverse human response to vibration. However, occupants of up to 27 receiver buildings have the potential to be exposed to vibration levels above the human response screening level during early works and site establishment.

Wakehurst Parkway east construction support site (BL13) (Section 5.12)

The Wakehurst Parkway east construction support site (BL13) would be a tunnel support site on Wakehurst Parkway at Seaforth.

During standard construction hours, for site establishment works and early works up to two receiver buildings are predicted to be noise affected (ie >NML). For the remaining stages construction noise levels are predicted to be below the NML. No non-residential buildings are predicted to be noise affected.

Outside standard construction hours work would be mitigated and managed to achieve the NMLs, except during night time tunnel support activities where two residential receiver buildings are predicted to be marginally noise affected by up to 2 dB(A) as a result of external laydown and delivery activities. During the short term intersection works up to 63 residential receiver buildings are predicted to be noise affected during work outside standard construction hours.

The project timeline overlaps the nearby Wakehurst Parkway surface road works and the Wakehurst Parkway south construction support site (BL12). If work across these construction work areas occur simultaneously, there is potential for cumulative increases in the construction noise levels at nearby receivers. In addition, as there are multiple work areas from the project located close together, there is potential for increases in overall duration and frequency of construction noise impacts. These would be managed, coordinated and mitigated during the detailed construction planning as part of the CNVIS.

Overall road traffic noise levels at receivers directly exposed to traffic noise on construction haulage and traffic routes (Wakehurst Parkway), including other nearby project sites, are predicted to increase by less than 2 dB(A) during both day and night as a result of construction traffic. Since the number of night truck movements generated by the site is not substantial compared to existing heavy vehicle numbers on Wakehurst Parkway, the number of maximum noise events that could disturb sleep are not likely to substantially increase.

During the construction of the tunnel access decline between the site and the ramp tunnel, no receivers (occupied buildings) are predicted to be affected by ground-borne noise above the strictest NML of 35 dB(A) or be exposed to vibration levels above the human response screening level.

If large rock hammers are used, two heritage items (Bantry Bay Water Pumping Station (WPS 122) and Bantry Bay Reservoir (WS 0008)) would be within the minimum working distance for cosmetic damage. Due to the limited duration that rock hammering activities that would take place at this site and the distance to nearby residential buildings, there is a low risk of adverse human response to vibration.

Wakehurst Parkway north construction support site (BL14) (Section 5.13)

The Wakehurst Parkway north construction support site (BL14), located at the corner of Wakehurst Parkway and Warringah Road, would mainly be used to support the Wakehurst Parkway surface road works, before being converted into a tunnel support facility.

During standard construction hours, no residential receivers are expected to be noise affected (ie >NML) from the works, except for during early works, when up to 31 receiver buildings are predicted to be noise affected. Up to 11 non-residential receivers are predicted to be noise affected from works at the site. Outside standard hours, construction noise would be mitigated and managed to achieve the NMLs, so that no receivers are expected to be noise affected. No residential receivers are predicted to experience maximum noise levels above the sleep disturbance screening level, except for during surface work support. During surface work support predicted noise levels are above the sleep disturbance screening level at 161 receiver buildings. All receivers are below the awakening reaction level.

The project timeline overlaps the nearby Wakehurst Parkway surface road works as this site is supporting those works. If work in these construction work areas occur simultaneously, there is potential for cumulative increases in the construction noise levels of up to 2 dB(A) at nearby receivers. As there are multiple work areas from the project close together, there is also potential for increases in overall duration and frequency of construction noise impacts. These would be managed, coordinated and mitigated during detailed construction planning as part of the CNVIS.

Construction traffic movements for this site are low. For the Wakehurst Parkway north construction support site (BL14) the traffic noise increase from combined project construction traffic (Wakehurst Parkway/Warringah Road) is predicted to be less than 2 dB(A) during both day and night. Sleep disturbance impacts are not likely to occur.

Ground-borne noise impacts from the activities proposed at the site are expected to be negligible. Due to the limited duration of vibration intensive activities would take place at this site, there is a low risk of adverse human response to vibration. However, occupants of up to two nearby properties are predicted to be exposed to vibration levels above the human response screening level during early works. No receiver buildings fall within the minimum working distances for cosmetic damage.

Wakehurst Parkway surface road works (Section 5.14)

The project would connect to the Wakehurst Parkway at Seaforth. During standard construction hours up to 77 residential buildings are predicted to be noise affected (ie >NML), including five residential buildings that would be highly noise affected (ie >75 dB(A)) from any one construction works area. Up to seven non-residential receiver buildings are predicted to be noise affected from any one construction works area.

Limited work is proposed outside standard hours, supported mainly by the Wakehurst Parkway north construction support site (BL14). However, when this is required during periods such as partial road closure, as part of road intersection works near Warringah Road, noise levels from typical works are

predicted to result in up to 431 noise affected residential buildings (depending on stage). This may increase to 886 noise affected receiver buildings during periods of worst case construction activities. However, for other works areas, less than 250 receiver buildings are predicted to be noise affected from any one work area for construction works outside of standard construction hours. Maximum noise levels during typical construction works are predicted to be above the sleep disturbance screening level at up to 86 receiver buildings, and above the awakening reaction level at up to seven receiver buildings. However, these could increase to 115 receiver buildings being above the sleep disturbance screening level. Up to13 receiver buildings are predicted to be above the awakening reaction level, during periods of worst case works for any one works area.

No other major project overlaps the construction timeline, however, the Northern Beaches Hospital, road upgrade project would have only been complete one year prior to the start of construction for this site. The project timeline overlaps the nearby project construction sites at Wakehurst Parkway north (BL14), Wakehurst Parkway south (BL12) as these sites support the surface road works, and the Wakehurst Parkway east construction support site (BL13). As such, there is potential for cumulative increases and overall duration and frequency increases in the construction noise levels at nearby receivers. These would be managed, coordinated and mitigated during detailed construction planning as part of the CNVIS.

A relatively small number of construction vehicles are proposed to travel between the Wakehurst Parkway surface road works areas, with most vehicles travelling directly to each area at the start of a shift. Construction road traffic management such as traffic switches along with construction traffic movements are not expected to increase overall road noise levels by more than 2 dB(A). Sleep disturbance impacts are not likely to occur from night truck movements.

If large rock hammers are used, five heritage items would be within the vibration minimum working distances. Due to the limited duration that the piling or rock hammering activities would take place at this site, there is a low risk of adverse human response to vibration. However, occupants of up to 27 receiver buildings have the potential to be exposed to vibration levels above the human response screening level from vibration intensive activities. No receiver buildings fall within the minimum working distances for cosmetic damage for structurally sound structures. Controlled blasting has been identified as an opportunity to be further investigated during further design development and construction planning for deep cut excavation areas to reduce excavation time and assist with community commitments.

Impacts from mainline and ramp tunnelling works (Section 5.16)

Tunnelling activities associated with the construction of the project would include:

- Roadheader tunnelling
- Rock drilling for tunnel support
- Excavation using rock hammers
- Blasting (Section 5.17)

- Cross passage and ventilation shaft excavation
- Excavation of niches for tunnel operation equipment.

Buildings potentially affected by ground-borne noise from roadheader tunnelling are located across Cammeray, Naremburn, Willoughby, Seaforth and North Balgowlah, and include:

- 107 residential receiver buildings could be ground-borne noise affected during the night period (above 35 dB(A))
- No residential receiver buildings are predicted to be exposed to ground-borne noise levels above 40 dB(A)
- Other noise sensitive receivers and commercial/industrial premises and other noise sensitive receivers are not expected to be ground-borne noise affected during roadheader tunnelling.

Ground-borne noise affected properties would require, as a minimum, letterbox notification to advise that tunnelling would be occurring and that noise has the potential to be audible during tunnelling works. Other mitigation and management measures are to be implemented based upon the level of ground-borne noise.

Typically, excavators with large rock hammer attachments would follow behind the roadheaders to remove the rock along the tunnel floor (the bench) for the length of the mainline and ramp tunnel and undertake more detailed excavation such as for installation of stormwater pits. There is potential for substantially more receiver buildings to be affected by ground-borne noise from rock hammer tunnelling than from roadheader operations. Where ground-borne noise levels are predicted to exceed NMLs outside standard construction hours, impacts would be managed by restricting rock hammer excavation to standard construction hours.

No buildings are identified within the cosmetic damage minimum working distance for roadheader or rock hammer tunnelling. Two heritage items would be within the minimum working distance for rock hammer tunnelling. Vibration impacts from roadheader tunnelling are predicted to be below the vibration limit for human disturbance at all receivers. However, during rock hammer tunnelling it is likely that occupants of up to 440 receiver buildings would perceive vibration generated by these works. Additional mitigation measures would be provided for some noise affected receivers.

Construction noise and vibration mitigation and management (Section 6)

Site specific feasible and reasonable noise management, mitigation and treatment measures have been included in the assessment of the project's construction noise and vibration impacts. These include specifically designed measures such as construction noise barriers, acoustic sheds, acoustic enclosures, and limiting construction hours and activities.

A construction noise and vibration management plan (CNVMP) should be prepared during detailed construction planning to document the overall approach proposed to manage potential noise and vibration impacts associated with the project's construction. The plan should be prepared in accordance

with the CNVG and detail how all mitigation measures should be implemented for the project. The CNVMP should include:

- Management and mitigation at the source of noise or vibration
- Community consultation, engagement and notification protocols
- Detailed scheduling and respite protocols
- OOHW protocols
- Limiting timing of noise intensive work
- Construction traffic management
- Maintaining minimum vibration buffer distances
- Vibration and blasting trials and/or monitoring along with building condition surveys
- Weekend road closures to accelerate works and reduce impact durations
- A process for preparing site specific CNVIS to identify the mitigation and management measures to be implemented in specific situations.

The CNVMP, OOHW protocol and the site specific CNVIS should include detailed scheduling, coordination and management, where feasible and reasonable, of cumulative construction noise and vibration impacts to minimise and provide respite to affected receivers considering all construction noise and vibration impacts, not just individual projects or works.

Following these, additional mitigation measures should be provided to manage residual impacts in line with the CNVG, where receivers remain noise affected even after the incorporation of feasible and reasonable mitigation measures.

If early installation of operational noise mitigation is determined to be both feasible and reasonable at controlling construction noise impacts to receivers and likely to form part of the final design, then operational noise mitigation should be installed at an early stage in the project with the aim of assisting with the mitigation and management of construction noise impacts.

Operational road traffic noise assessment (Section 7)

The project is predicted to typically decrease road traffic noise levels at most receiver locations, with additional noise mitigation requirements a result of the high existing road traffic noise levels resulting in exceedances of the cumulative limit criterion or traffic noise levels being acute.

In total, 679 receiver buildings have been identified as eligible for consideration for additional noise mitigation, where 407 receiver buildings were identified in the Warringah Freeway and surrounds, 47 in the Gore Hill Freeway Connection area, 135 in the area around the connections to and from Burnt Bridge Creek Deviation and 90 receiver buildings in the area around the connections to and from the Wakehurst Parkway. Typically, high existing road traffic noise levels, rather than increases due to the project, are the reason that a large proportion of the properties are eligible for consideration for

additional mitigation. Options for quieter pavements, local traffic calming measures, noise barriers and at property treatment as forms of noise mitigation have been assessed.

Noise barriers have been considered for suitability at various locations in the areas of the Warringah Freeway, connections to and from Burnt Bridge Creek Deviation and connections to and from the Wakehurst Parkway. The feasibility and reasonableness of each barrier at the identified design height was then evaluated in accordance with the process in Transport for NSW *Noise Mitigation Guideline* (NMG) by considering engineering constraints, constructability constraints, land and property impacts, potential over shadowing and visual amenity and other environmental consideration as appropriate. For a number of barriers, the identified design height was not feasible and reasonable based on these considerations. In these cases, an alternative barrier height is proposed. The alternative barrier heights were assessed to confirm that they provide appropriate noise attenuation benefits and to identify properties that would be eligible for consideration for at-property treatment.

With the implementation of the reasonable and feasible noise barriers, residual receivers still exceeding the Transport for NSW *Noise Criteria Guideline* (NCG) project criteria and, therefore, eligible for consideration for at-property treatment were identified.

The operational traffic noise mitigation measures (ie quieter pavements, noise barriers and at-property treatment) recommended are indicative and confirmation of final mitigation measures would be subject to further design development. Accordingly, the receivers that are eligible for consideration for at-property treatment would be confirmed during further design development the proposed suite of noise mitigation measures and the resultant road traffic noise predictions would be reviewed.

The project is predicted to increase maximum noise levels and the number of maximum noise events in the following areas:

- Receivers to the east of the Warringah Freeway may experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the widening of the Warringah Freeway resulting in the southbound carriageway moving closer to those receivers
- Receivers to the west and east of the Burnt Bridge Creek Deviation may experience an increase in maximum noise levels and the number of events compared to the existing situation, due to the new surface connection at Balgowlah with the Burnt Bridge Creek Deviation and Sydney Road
- Receivers to the west of the Wakehurst Parkway may experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the realignment and upgrade of Wakehurst Parkway resulting in the northbound carriageways moving closer to those receivers.

Given there are no major realignments or widening of the roads in the other areas besides those discussed above, maximum noise levels are not expected to increase as a result of the project in other areas.

Operational noise impacts from the proposed fixed facilities associated with the project have been assessed for receivers surrounding the facilities. Predicted noise levels from the proposed fixed facilities are predicted to comply with the relevant project noise levels.

Assessment of final noise predictions from the proposed fixed facilities and any required noise mitigation measures would occur during further design development, when actual types, makes and models of the plant and equipment are known.

1 Introduction

This section provides an overview of the Beaches Link and Gore Hill Freeway Connection (the project), including its key features and location. It also outlines the Secretary's environmental assessment requirements addressed in this technical working paper.

1.1 Overview

The Greater Sydney Commission's Greater Sydney Region Plan – A Metropolis of Three Cities (Greater Sydney Commission, 2018) proposes a vision of three cities where most residents have convenient and easy access to jobs, education and health facilities and services. In addition to this plan, and to accommodate for Sydney's future growth the NSW Government is implementing the Future Transport Strategy 2056 (Transport for NSW, 2018), that sets the 40 year vision, directions and outcomes framework for customer mobility in NSW. The Western Harbour Tunnel and Beaches Link program of works is proposed to provide additional road network capacity across Sydney Harbour and Middle Harbour and to improve transport connectivity with Sydney's Northern Beaches. The Western Harbour Tunnel and Beaches Link program of works include:

- The Western Harbour Tunnel and Warringah Freeway Upgrade project which comprises a new tolled motorway tunnel connection across Sydney Harbour, and an upgrade of the Warringah Freeway to integrate the new motorway infrastructure with the existing road network and to connect to the Beaches Link and Gore Hill Freeway Connection project
- The Beaches Link and Gore Hill Freeway Connection project which comprises a new tolled motorway tunnel connection across Middle Harbour from the Warringah Freeway and the Gore Hill Freeway to Balgowlah and Killarney Heights and including the surface upgrade of the Wakehurst Parkway from Seaforth to Frenchs Forest and upgrade and integration works to connect to the Gore Hill Freeway at Artarmon.

A combined delivery of the Western Harbour Tunnel and Beaches Link program of works would unlock a range of benefits for freight, public transport and private vehicle users. It would support faster travel times for journeys between the Northern Beaches and areas south, west and north-west of Sydney Harbour. Delivering the program of works would also improve the resilience of the motorway network, given that each project provides an alternative to heavily congested existing harbour crossings.

1.2 The project

Transport for NSW is seeking approval under Part 5, Division 5.2 of the Environmental Planning and Assessment Act 1979 to construct and operate the Beaches Link and Gore Hill Freeway Connection project, which would comprise two components:

- Twin tolled motorway tunnels connecting the Warringah Freeway at Cammeray and the Gore Hill Freeway at Artarmon to the Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights, and an upgrade of the Wakehurst Parkway (the Beaches Link)

- Connection and integration works along the existing Gore Hill Freeway and surrounding roads at Artarmon (the Gore Hill Freeway Connection).

A detailed description of these two components is provided in Section 1.4.

1.3 Project location

The project would be located within the North Sydney, Willoughby, Mosman and Northern Beaches local government areas, connecting Cammeray in the south with Killarney Heights, Frenchs Forest and Balgowlah in the north. The project would also connect to both the Gore Hill Freeway and Reserve Road in Artarmon in the west.

Commencing at the Warringah Freeway at Cammeray, the mainline tunnels would pass under Naremburn and Northbridge, then cross Middle Harbour between Northbridge and Seaforth. The mainline tunnels would then split under Seaforth into two ramp tunnels and continue north to the Wakehurst Parkway at Killarney Heights and north-east to Balgowlah, linking directly to the Burnt Bridge Creek Deviation to the south of the existing Kitchener Street bridge.

The mainline tunnels would also have on and off ramps from under Northbridge connecting to the Gore Hill Freeway and Reserve Road east of the existing Lane Cove Tunnel. Surface works would also be carried out at the Gore Hill Freeway in Artarmon, Burnt Bridge Creek Deviation at Balgowlah and along the Wakehurst Parkway between Seaforth and Frenchs Forest to connect the project to the existing arterial and local road networks.

1.4 Key features of the project

Key features of the Beaches Link component of the project are shown in Figure 1-1 and would include:

- Twin mainline tunnels about 5.6 kilometres long and each accommodating three lanes of traffic in each direction, together with entry and exit ramp tunnels to connections at the surface. The crossing of Middle Harbour between Northbridge and Seaforth would involve three lane, twin immersed tube tunnels
- Connection to the stub tunnels constructed at Cammeray as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project
- Twin two lane ramp tunnels:
  - Eastbound and westbound connections between the mainline tunnel under Seaforth and the surface at the Burnt Bridge Creek Deviation, Balgowlah (about 1.2 kilometres in length)
  - Northbound and southbound connections between the mainline tunnel under Seaforth and the surface at the Wakehurst Parkway, Killarney Heights (about 2.8 kilometres in length)
  - Eastbound and westbound connections between the mainline tunnel under Northbridge and the surface at the Gore Hill Freeway and Reserve Road, Artarmon (about 2.1 kilometres in length).

- An access road connection at Balgowlah between the Burnt Bridge Creek Deviation and Sydney Road including the modification of the intersection at Maretimo Street and Sydney Road, Balgowlah
- Upgrade and integration works along the Wakehurst Parkway, at Seaforth, Killarney Heights and Frenchs Forest, through to Frenchs Forest Road East
- New and improved open space and recreation facilities at Balgowlah
- New and upgraded pedestrian and cyclist infrastructure
- Ventilation outlets and motorway facilities at the Warringah Freeway in Cammeray, the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights
- Operational facilities, including a motorway control centre at the Gore Hill Freeway in Artarmon, and tunnel support facilities at the Gore Hill Freeway in Artarmon and the Wakehurst Parkway in Frenchs Forest
- Other operational infrastructure including groundwater and tunnel drainage management and treatment systems, surface drainage, signage, tolling infrastructure, fire and life safety systems, roadside furniture, lighting, emergency evacuation and emergency smoke extraction infrastructure, Closed Circuit Television (CCTV) and other traffic management systems.

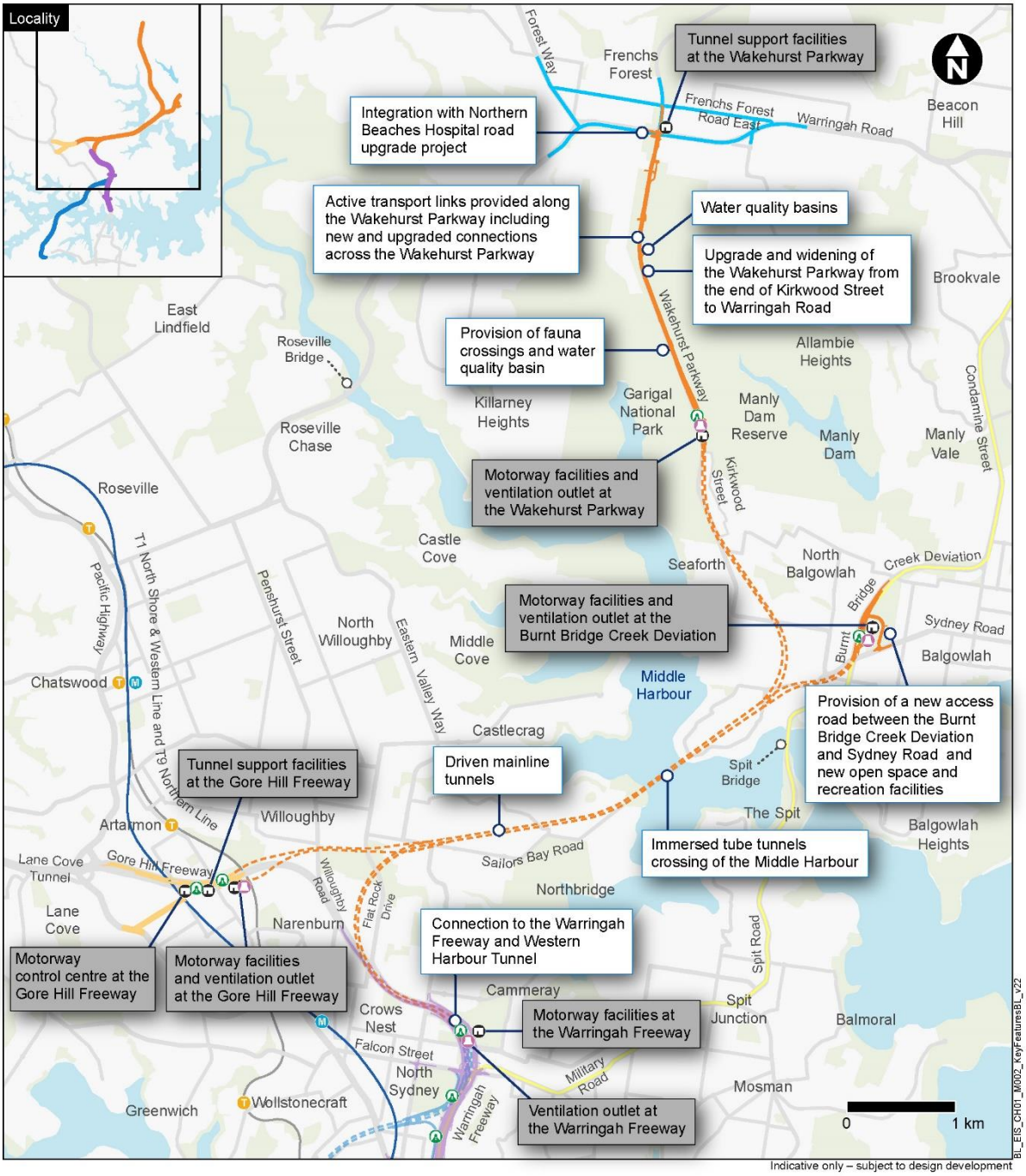
Key features of the Gore Hill Freeway Connection component of the project are shown in Figure 1-2 and would include:

- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore & Western Line and T9 Northern Line and the Pacific Highway
- Modifications to the Reserve Road and Hampden Road bridges
- Widening of Reserve Road between the Gore Hill Freeway and Dickson Avenue
- Modification of the Dickson Avenue and Reserve Road intersection to allow for the Beaches Link off ramp
- Upgrades to existing roads around the Gore Hill Freeway to integrate the project with the surrounding road network
- Upgrade of the Dickson Avenue and Pacific Highway intersection
- New and upgraded pedestrian and cyclist infrastructure
- Other operational infrastructure, including surface drainage and utility infrastructure, signage and lighting, CCTV and other traffic management systems.

A detailed description of the project is provided in Chapter 5 (Project description) of the environmental impact statement.

Subject to obtaining planning approval, construction of the project is anticipated to commence in 2023 and is expected to take around five to six years to complete.

Figure 1-1 – Key features of the Beaches Link component of the project



Legend

Operational features
- Beaches Link
- Gore Hill Freeway Connection
- Surface connection
- Permanent operational facility
- Ventilation outlet

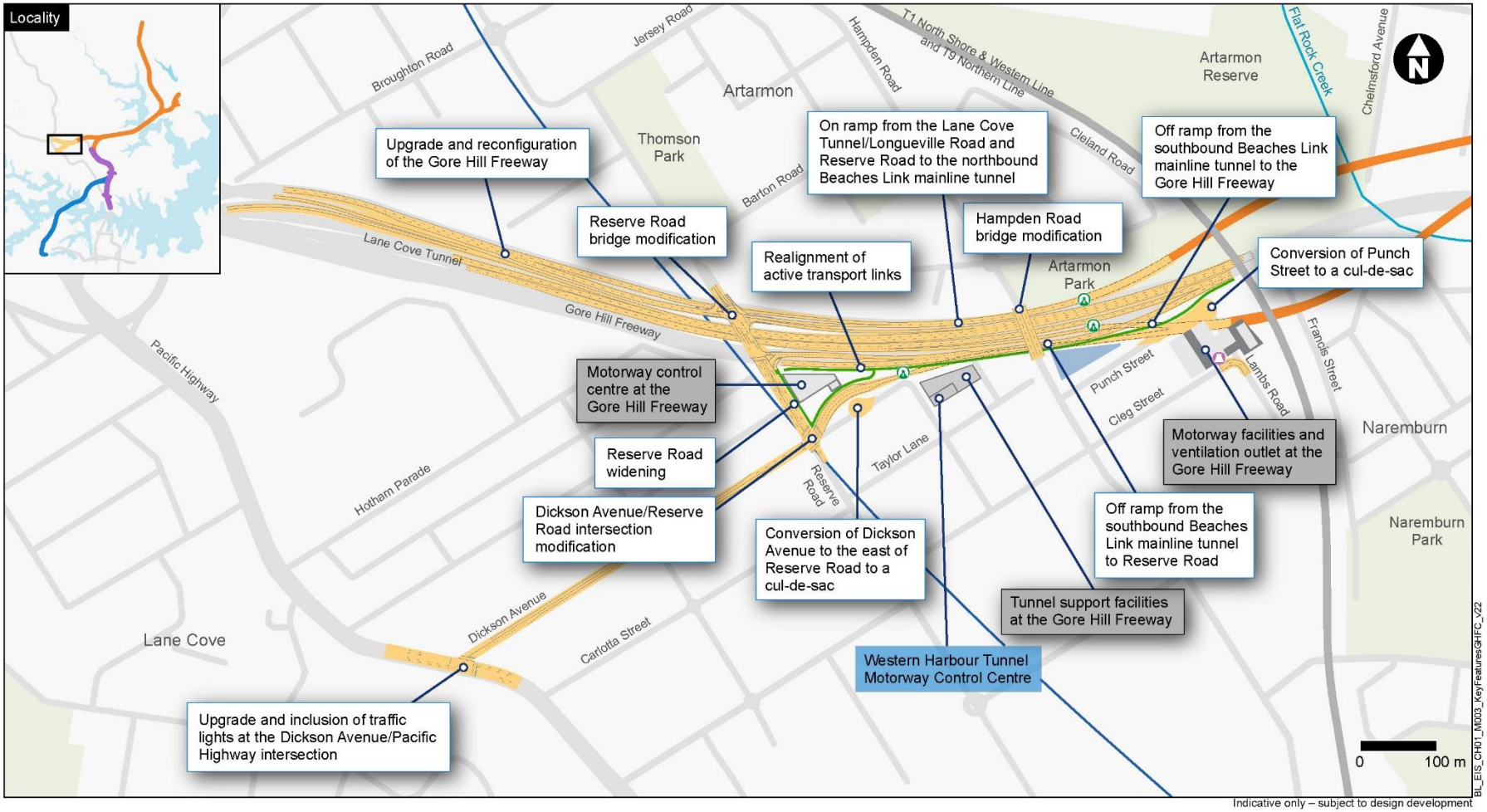
Connecting projects
- Western Harbour Tunnel
- Warringah Freeway Upgrade
- Northern Beaches Hospital road upgrade project (Completed 2020)

Other projects
- Sydney Metro City & Southwest – Chatswood to Sydenham (under construction)

Existing transport network
- Northern Beaches B-Line
- Suburban/Metro rail
- Train station

Design features
- Surface
- Tunnel

Figure 1-2 – Key features of the Gore Hill Freeway Connection component of the project



Legend

Operational features
- Gore Hill Freeway Connection
- Beaches Link
- Permanent operational facility
- Surface connection
- Ventilation outlet
- Pedestrian / active transport links
- Permanent water quality basin

Existing rail network
- Suburban/Metro rail

Other projects
- Sydney Metro City & Southwest – Chatswood to Sydenham (under construction)

1.5 Key construction activities

The area required to construct the project is referred to as the construction footprint. The majority of the construction footprint would be located underground within the mainline and ramp tunnels. However, surface areas would also be required to support tunnelling activities and to construct the tunnel connections, tunnel portals, surface road upgrades and operational facilities.

Key construction activities would include:

- Early works and site establishment, with typical activities being property acquisition and condition surveys, utilities installation, protection, adjustments and relocations, installation of site fencing, environmental controls (including noise attenuation and erosion and sediment control), traffic management controls, vegetation clearing, earthworks, demolition of structures, building construction support sites including acoustic sheds and associated access decline acoustic enclosures (where required), construction of minor access roads and the provision of property access, temporary relocation of pedestrian and cycle paths and bus stops, temporary relocation of swing moorings and/or provision of alternative facilities (mooring or marina berth) within Middle Harbour
- Construction of the Beaches Link, with typical activities being excavation of tunnel construction access declines, construction of driven tunnels, cut and cover and trough structures, construction of surface upgrade works, construction of cofferdams, dredging and immersed tube tunnel piled support activities in preparation for the installation of immersed tube tunnels, casting and installation of immersed tube tunnels and civil finishing and tunnel fitout
- Construction of operational facilities comprising:
  - A motorway control centre at the Gore Hill Freeway in Artarmon
  - Tunnel support facilities at the Gore Hill Freeway in Artarmon and at the Wakehurst Parkway in Frenchs Forest
  - Motorway facilities and ventilation outlets at the Warringah Freeway in Cammeray (fitout only of the Beaches Link ventilation outlet at the Warringah Freeway (being constructed by the Western Harbour Tunnel and Warringah Freeway Upgrade project), the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights
  - A wastewater treatment plant at the Gore Hill Freeway in Artarmon
  - Installation of motorway tolling infrastructure
- Staged construction of the Gore Hill Freeway Connection at Artarmon and upgrade and integration works at Balgowlah and along the Wakehurst Parkway with typical activities being earthworks, bridgeworks, construction of retaining walls, stormwater drainage, pavement works and linemarking and the installation of roadside furniture, lighting, signage and noise barriers

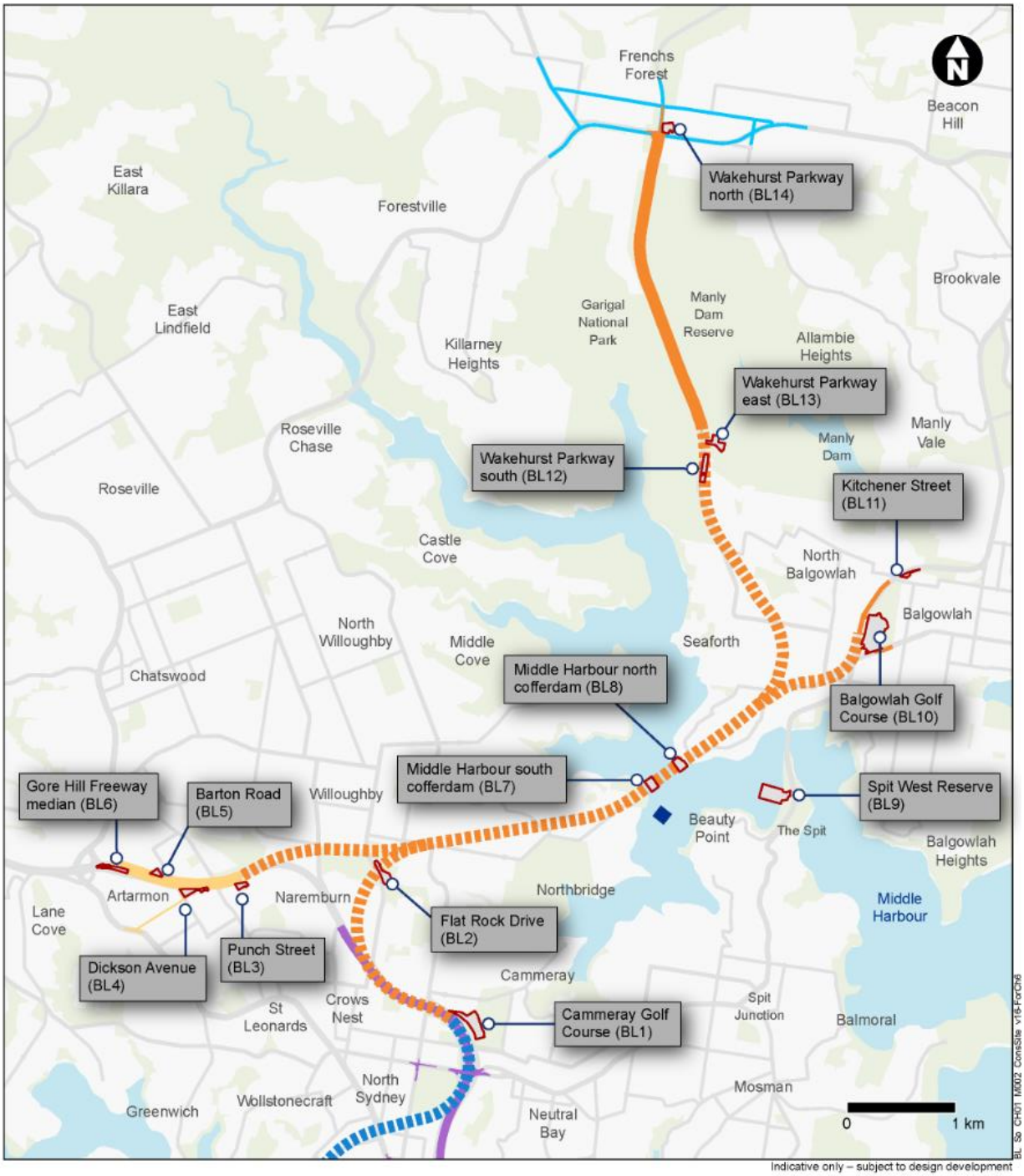
- Testing of plant and equipment and commissioning of the project, backfill of access declines, removal of construction support sites, landscaping and rehabilitation of disturbed areas and removal of environmental and traffic controls.

Temporary construction support sites would be required as part of the project (refer to Figure 1-3), and would include tunnelling and tunnel support sites, civil surface sites, cofferdams, mooring sites, wharf and berthing facilities, laydown areas, parking and workforce amenities. Construction support sites would include:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Dickson Avenue (BL4)
- Barton Road (BL5)
- Gore Hill Freeway median (BL6)
- Middle Harbour south cofferdam (BL7)
- Middle Harbour north cofferdam (BL8)
- Spit West Reserve (BL9)
- Balgowlah Golf Course (BL10)
- Kitchener Street (BL11)
- Wakehurst Parkway south (BL12)
- Wakehurst Parkway east (BL13)
- Wakehurst Parkway north (BL14).

A detailed description of construction works for the project is provided in Chapter 6 (Construction work) of the environmental impact statement.

Figure 1-3 – Overview of the construction support sites



1.6 Purpose of this report

This report has been prepared to support the environmental impact statement for the project and to address the environmental assessment requirements of the Secretary of the NSW Department of Planning, Industry and Environment.

The purpose of this report is to assess noise and vibration impacts during the construction and operational stages of the project and propose mitigation measures to reduce the nature of particular impacts in construction and operation. The noise and vibration assessment has been carried out in accordance with the policies, guidelines and standards presented in sections 3.1 and 3.5.1 of this report for construction noise and vibration and operational noise, respectively.

1.7 Secretary's environmental assessment requirements

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

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

Secretary's environmental assessment requirements	Where addressed
4. Noise and vibration - Amenity	
1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must take into consideration and address the redistribution of traffic (including on local feeder roads) and operational plant and equipment and must include consideration of impacts to sensitive receivers and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	**Section 5** assesses construction noise and vibration impacts associated with the project **Section 7** assesses operational noise and vibration impacts from the project
2. An assessment of construction noise and vibration impacts which must address:	**Section 5** assesses construction noise and vibration impacts addressing the requirements (a),(b),(d) to (j)
(a) the nature of construction activities (including transport, tonal or impulsive noise generating works and the removal of operational noise barriers, as relevant);	
(b) the intensity and duration of noise and vibration impacts (both air and ground borne). This must include consideration of extended construction impacts associated with ancillary facilities (and the like) and construction fatigue;	**Section 6 and 8** address construction noise and vibration mitigation and management measures for the project addressing the requirements (e),(f),(i) and (j)
(c) the identification of receivers, existing and likely, during the construction period;	
(d) the nature, sensitivity and impact to receivers;	**Section 2.2** and **Annexure B** identify the noise and vibration the sensitive receivers during the construction period in the project study area as required by (c)
(e) the need to balance timely conclusion of noise and vibration generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic management);	
(f) the potential for works outside standard construction hours, including predicted levels, exceedances, number of potentially affected receivers, and justification for the activity in terms of the Interim Construction Noise Guideline (DECCW, 2009);	Chapter 7 (Consultation) and Chapter 4 (Project development and alternatives) of the environmental impact statement provide further details of the
(g) a cumulative noise and vibration assessment inclusive of impacts from the project (including concurrent project construction activities);	

Secretary's environmental assessment requirements	Where addressed
(h) a cumulative noise and vibration assessment of the impacts from the project and the construction of other relevant development in the vicinity of the proposal;	community consultation that has been undertaken for the project and the design development as a result of this, which includes design changes with consideration of operational and construction noise and vibration.
(i) details and analysis of the effectiveness of mitigation measures to adequately manage identified impacts, including cumulative impacts as identified in (g) and (h) and a clear identification of residual noise and vibration following application of mitigation measures; and	
(j) a description of how community preferences have been taken into account in the design of mitigation measures and consider tailored mitigation, management and communication strategies for vulnerable community members.	
3. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	**Section 5.17**
5. Noise and Vibration - Structural	
1. The Proponent must assess construction and operation noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage).	**Section 5** assesses construction noise and vibration impacts **Sections 5.2 to 5.15** assess noise and vibration impacts from key construction sites and activities **Section 5.16** assesses potential noise and vibration impacts due to tunnelling **Section 7.6** assesses operational ground-borne noise and tactile vibration impacts
2. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	**Section 5.17**

1.8 Structure of this report

This noise and vibration technical working paper has been broken into the following structure:

Table 1-2 – Noise and vibration technical working paper report structure

Description	Report section
Overview of the project key features, and construction activities, Secretary's environmental assessment requirements and structure of the report	Section 1
Overview of the existing noise environment and the results from the ambient noise monitoring surveys	Section 2
Assessment guidelines and objectives - Construction	Section 3.1 to 3.4.6
Assessment guidelines and objectives - Operational	Section 3.5
Assessment methodology - Construction	Section 4.1 to 4.4
Assessment methodology and mitigation options - Operational	Section 4.6 to 4.8
Assessment of potential noise and vibration impacts, along with mitigation and management measures during the construction stages of the project	Section 5
Overview of construction noise and vibration mitigation and management measures	Section 6
Assessment of potential noise and vibration impacts and the mitigation measures during the operational stages of the project	Section 7

This report has been structured so that it can be navigated by multiple methods in addition to following the above report structure:

- In order to navigate the report via geographic locations, refer to Figure 1-4 to Figure 1-6
- In order to navigate the report via assessment types
  - Construction airborne noise, refer to the flow chart in Figure 4-2
  - Construction related road traffic noise, refer to Table 4-5
  - Construction ground-borne noise, refer to Table 4-10
  - Construction vibration, refer to Table 4-12
  - Mainline and ramp tunnelling construction noise and vibration, refer to Section 5.16
  - Operational road traffic airborne noise, refer to Section 7.1 to 7.3
  - Operational fixed facility noise, refer to Section 7.4.

For the purposes of this report, in order to assist with referring to each site within this noise and vibration assessment, each construction site or construction works area is referenced with a unique acronym. These site reference acronyms are as presented in Table 1-3.

Table 1-3 – Site specific construction noise and vibration assessment acronym reference

Location	Construction noise and vibration assessment acronym	Report section
Warringah Freeway surface road works	WFU2H	Section 5.2
Cammeray Golf Course construction support site (BL1)	CGC	Section 5.3
Gore Hill Freeway Connection surface road works[1]	GHC	Section 5.4
Flat Rock Drive construction support site (BL2)	FRD	Section 5.5
Punch Street construction support site (BL3)	PUN	Section 5.6
Middle Harbour crossing	MHC	Section 5.7
Spit West Reserve construction support site (BL9)	SMH	Section 5.8
Balgowlah Golf Course construction support site (BL10)	BAL	Section 5.9
Balgowlah surface road works[2]	BGC	Section 5.10
Wakehurst Parkway south construction support site (BL12)	WPS	Section 5.11
Wakehurst Parkway east construction support site (BL13)	WPE	Section 5.12
Wakehurst Parkway north construction support site (BL14)	WPN	Section 5.13
Wakehurst Parkway surface road works	WKP	Section 5.14

Notes: 1. The assessment of the Gore Hill Freeway Connection surface road works also covers a number construction sites. These construction sites include the Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6).

2. The assessment of the Balgowlah surface road works also covers the construction site at Kitchener Street (BL11).

Satellite imagery in this report was provided by Jacobs (Group) Australia Pty Ltd.

Figure 1-4 – Report navigation maps – Southern section

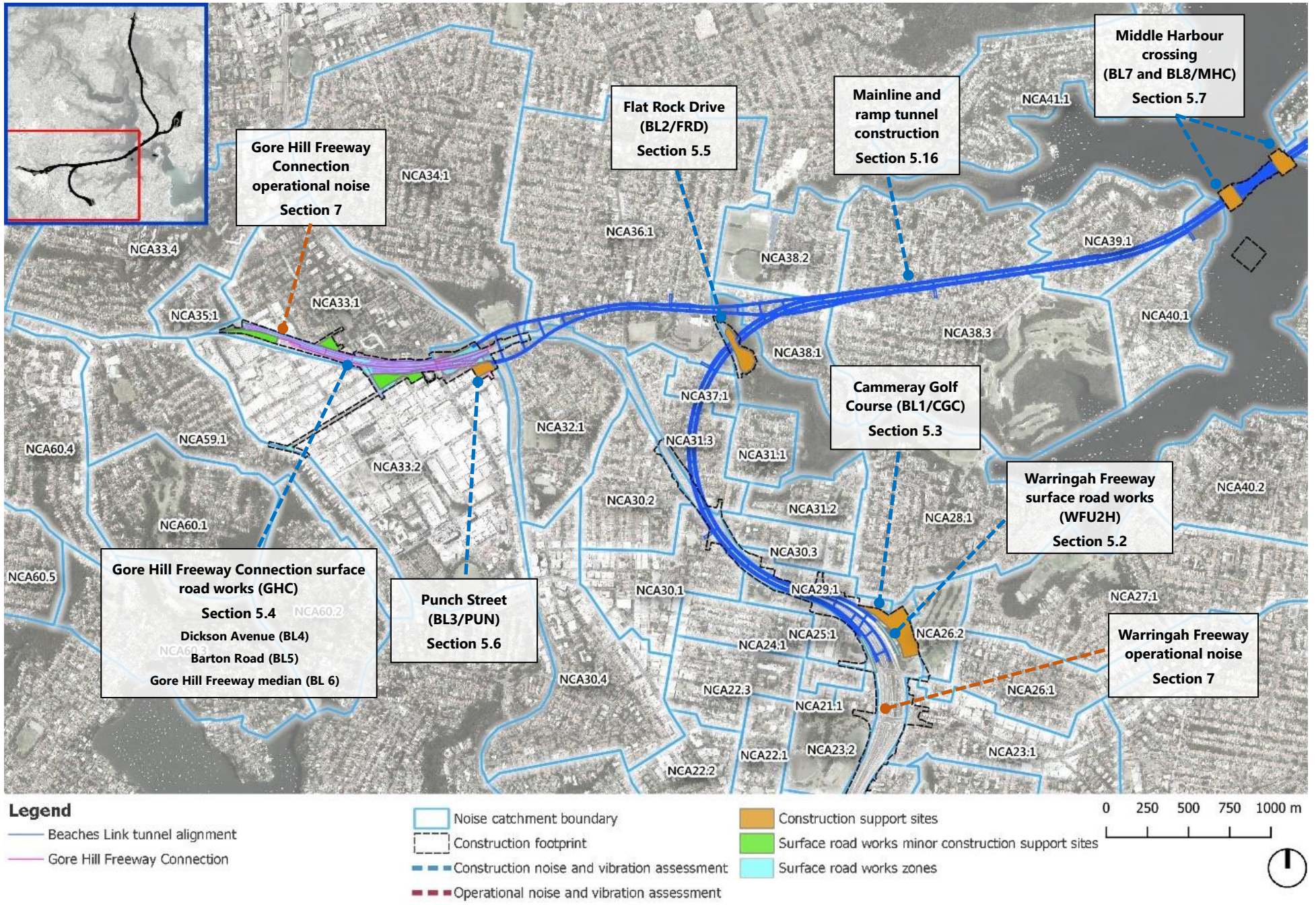


Figure 1-5 – Report navigation maps – Mid section

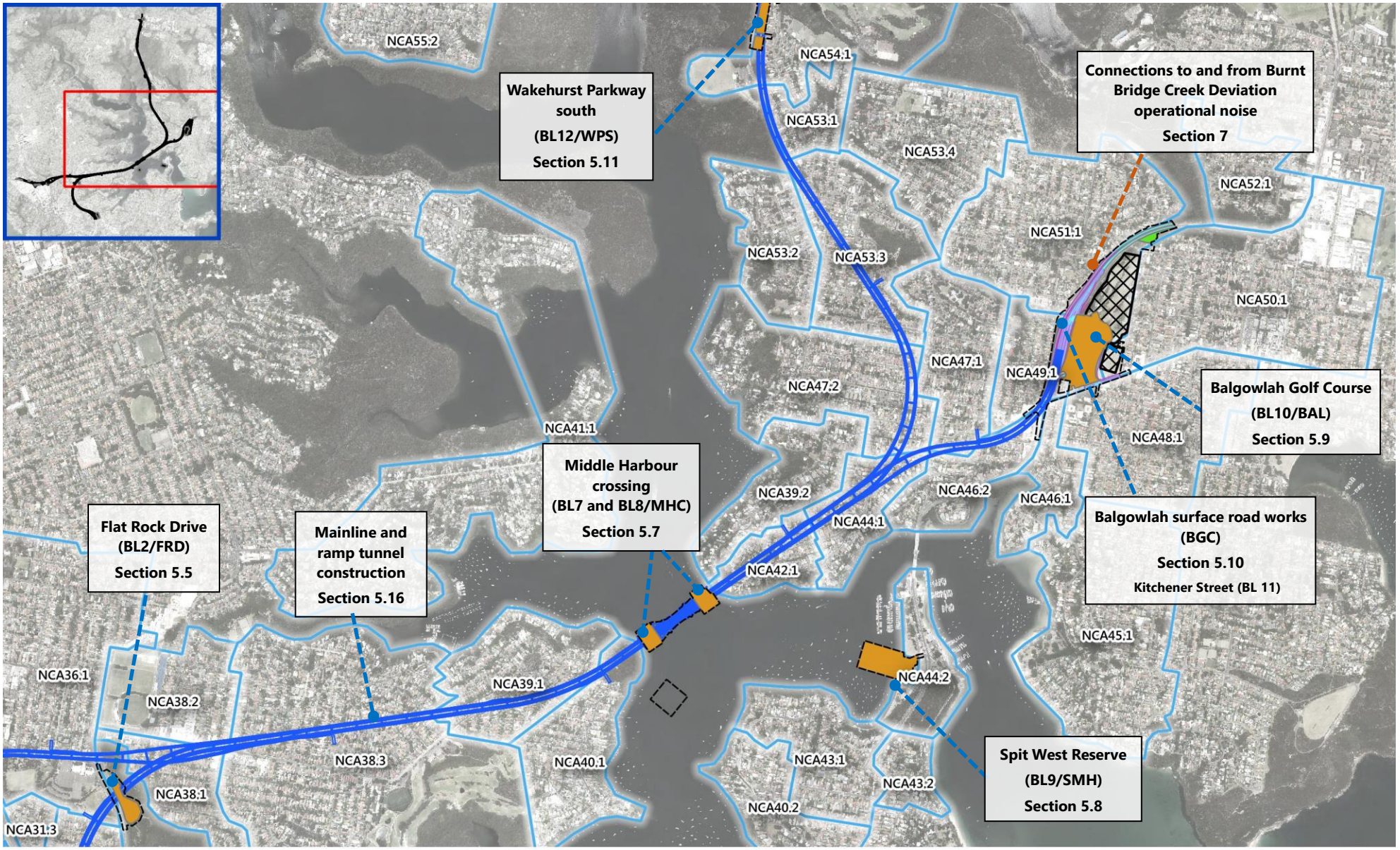
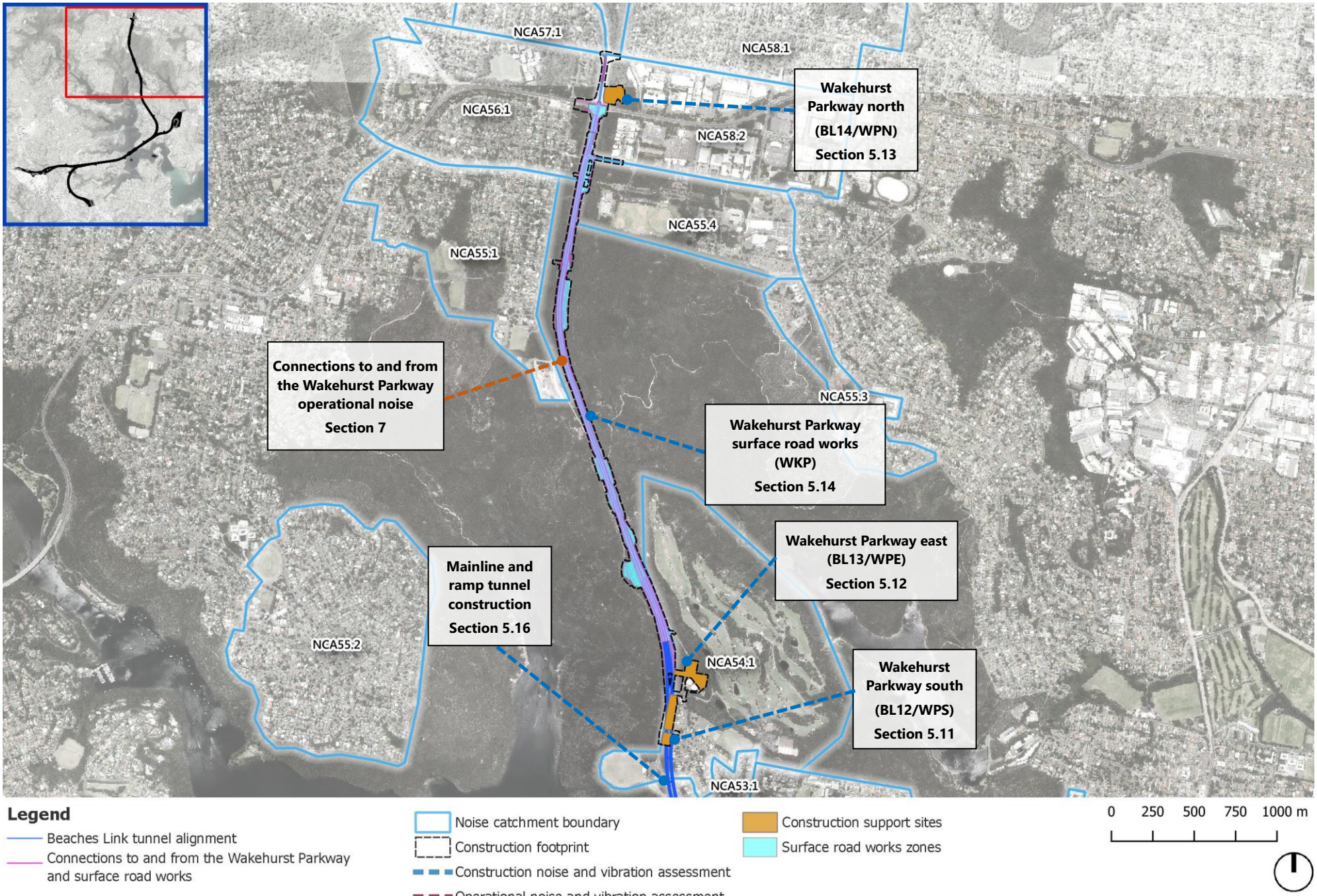


Figure 1-6 – Report navigation maps – Northern section



1.9 Terminology and acoustic concepts

This report is technical in nature and uses acoustic terminology throughout. A summary and explanation of the common acoustic terms that has been used in this report is presented in Annexure A, Section A.1.

Some of the key acoustic concepts used in this report are outlined in Annexure A, Section A.2.

2 Existing noise environment

2.1 Overview

The existing acoustic environment varies throughout the project extent. The areas surrounding the project alignment and construction support sites are mostly residential, except for clusters of commercial and industrial receivers around Artarmon and Frenchs Forest.

The acoustic environment in these residential areas is mostly influenced by noise from major arterial roads such as the Warringah Freeway, Gore Hill Freeway, Spit Road, Burnt Bridge Creek Deviation and Wakehurst Parkway, as well as local transport activities.

Traffic volumes on these main roads, and resulting noise levels, are generally highest in the morning between 7.00am and 9.00am, and lowest between 2.00am and 3.00am. Traffic noise on major arterial roads is generally more continuous, rather than intermittent.

Noise generated by shops, restaurants, employment and entertainment areas, and noise from local fauna, can influence the surrounding acoustic environment and may contribute to higher ambient noise levels which locally mask road traffic noise.

2.2 Noise and vibration-sensitive receivers

A land use survey was carried out to identify the receiver types and uses of buildings around the project that could potentially be impacted by noise or vibration from the project. The survey was carried out to assist with defining appropriate management objectives for the sensitive receivers.

Where future receivers were identified as likely to be in place during the construction period, these have been assessed as the likely future use. During further design development and construction planning a land use survey of current noise sensitive receivers at the time of construction should be carried out to confirm all potentially affected receivers.

The noise and vibration sensitive receivers are generally separated into the following major categories, with further details of the breakdown of categories and noise and vibration objectives presented in Section 3:

- Residential receivers (including mixed use buildings and aged care facilities)
- Other noise and vibration sensitive receivers, including:
  - Classrooms at schools and other educational institutions
  - Hospital wards and operating theatres
  - Places of worship
  - Childcare centres
  - Active recreation areas (eg sports fields / activities which generate their own noise and are generally less sensitive to external noise)

  - Passive recreation areas (eg areas used for low intensity and low noise producing activities such as reading or meditation that have the potential to be impacted by external noise)
  - Community centres
  - Special noise and/or vibration sensitive receivers (eg laboratories, recording studios)
- Commercial premises (including offices and retail outlets)
- Industrial premises.

All assessed noise and vibration sensitive receiver types for the project are shown in Annexure B.

2.3 Noise catchment areas

As the existing acoustic environment along the length of the project varies, noise sensitive receivers have been grouped into Noise Catchment Areas (NCAs) based on areas with similar acoustic characteristics. The project has been divided into 87 NCAs.

The NCAs also help to logically group all noise and vibration sensitive receivers to assist with the assessment of noise and vibration impacts from the project. Each NCA consists of a range of receiver types and land uses.

The noise monitoring, detailed in sections 2.4 and 2.5, along with the relative location of the NCAs to key environmental noise sources was used to define the NCA extents.

The locations of NCAs relative to the project are shown in Figure 2-1 to Figure 2-4. All NCAs and the key noise and vibration sensitive receiver types are described further in Annexure B.

2.4 Noise monitoring locations

Noise monitoring was carried out along the project extent to quantify the existing noise environment in areas where receivers may potentially be affected by construction noise and to determine the existing levels of road traffic noise along the project. Criteria and noise management levels (NMLs) for the assessment of operational and construction noise are usually derived from measurements of existing noise levels in an area, excluding noise from the subject development.

The rating background level (RBL) (see Section 2.5 for a description) is used to determine the following noise management and trigger levels at residential receiver locations:

- The NMLs described in *Interim Construction Noise Guideline* (Department of Environment and Conservation 2009) (the ICNG), for construction noise
- The project noise trigger levels in *Noise Policy for Industry* (Environment Protection Authority 2017) (the NPfI), for operational facility noise.

Fact Sheet A and Fact Sheet B of the NPfI outline the method for determining the RBL using long term noise measurements. As stated in the NPfI, typically one week of valid data covering the days and times of operation of the project is required to meaningfully determine the existing noise environment. Noise

measurements are ideally carried out at the nearest or most potentially affected locations for either construction or traffic noise impacts along the extent of the project. The long term noise monitoring locations are presented in Figure 2-1 to Figure 2-4 and details of the noise logging locations are outlined in Table 2-1.

In addition, existing traffic noise levels were measured at specific monitoring locations along the project extent to facilitate calibration of the road traffic noise models.

The NCAs are established both as a logical grouping of receivers within similar acoustic environments and as a grouping for the purposes of assessing and reporting noise and vibration impacts. As such, some areas which have similar acoustic environments (eg controlled by similar noise levels from a nearby major road), have been broken down into smaller NCAs to assist with reporting specific areas of noise or vibration impacts, while continuing to share the same noise monitoring location. For this reason, noise monitoring was not carried out within all NCAs across the project.

Figure 2-1 – Long term noise monitoring locations (southwest)

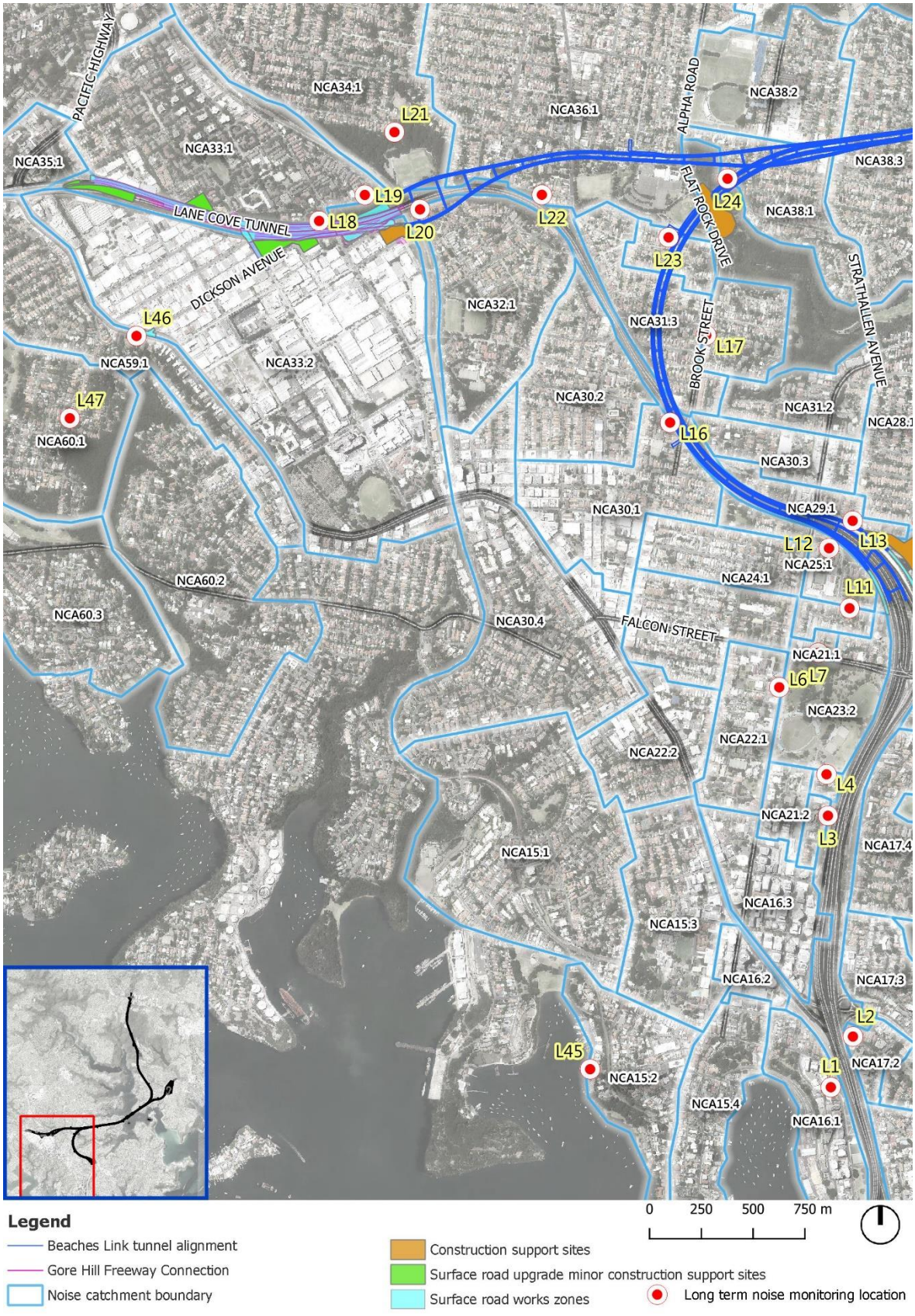


Figure 2-2 – Long term noise monitoring locations (southeast)

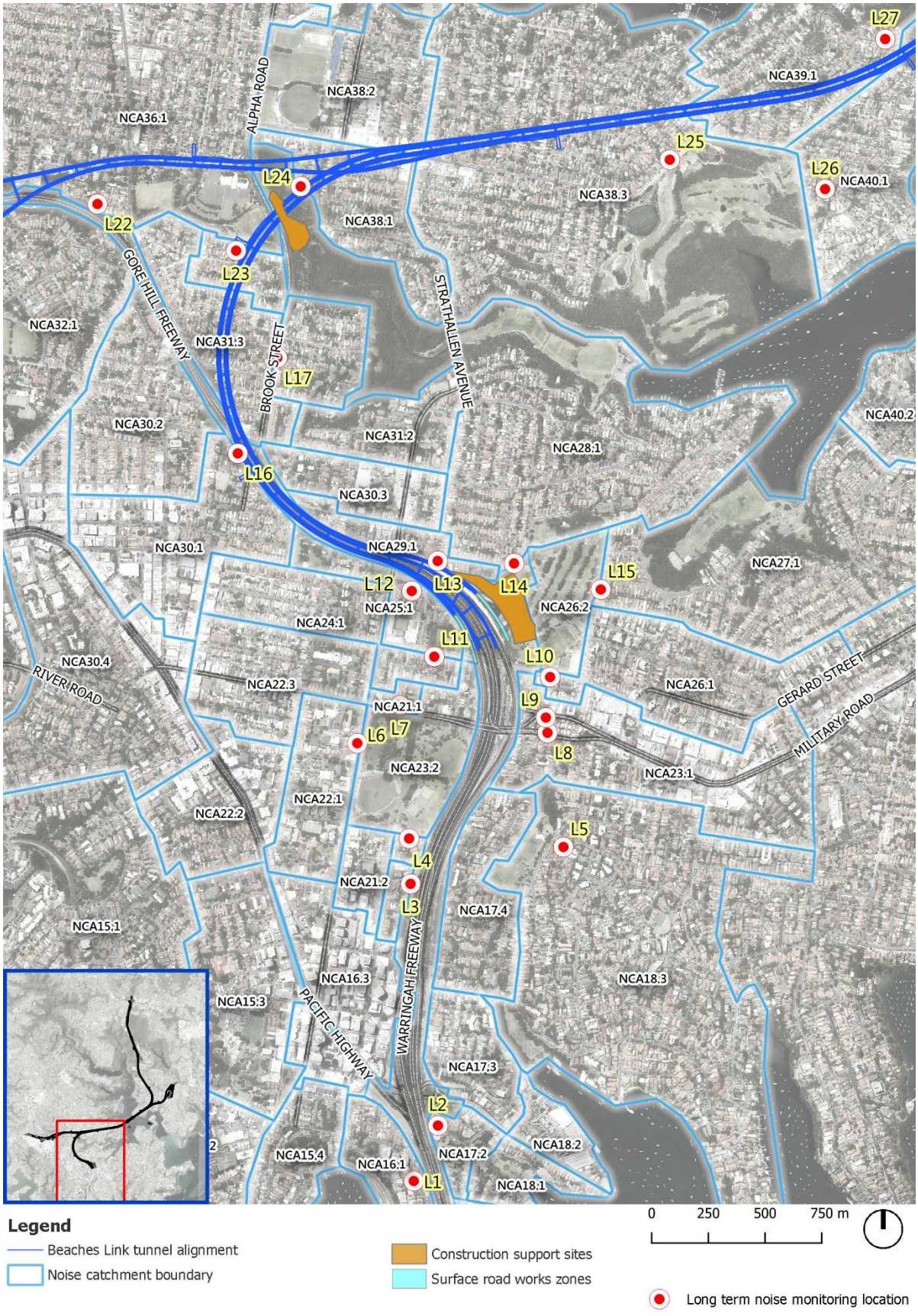


Figure 2-3 – Long term noise monitoring locations (mid)

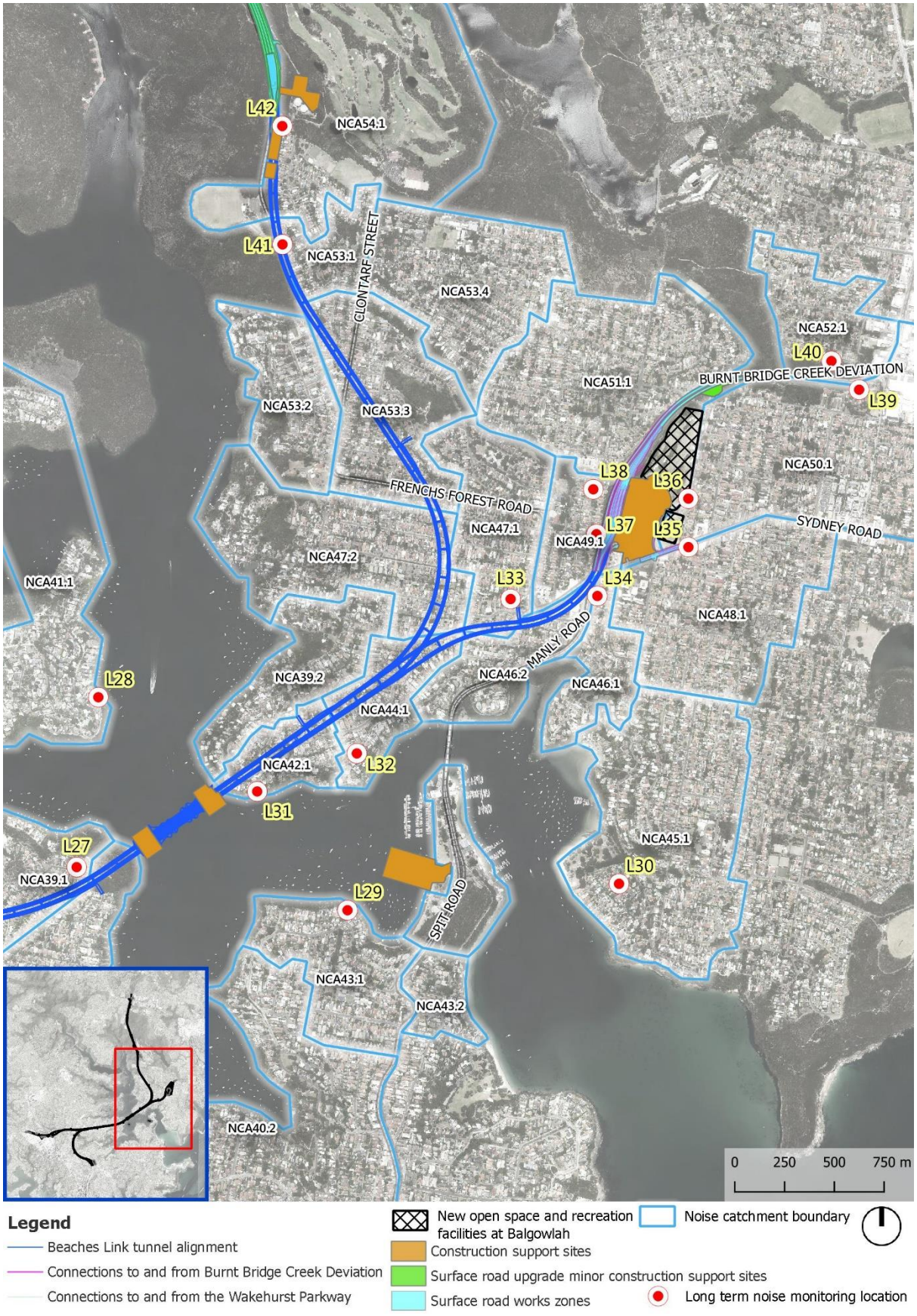


Figure 2-4 – Long term noise monitoring locations (north)

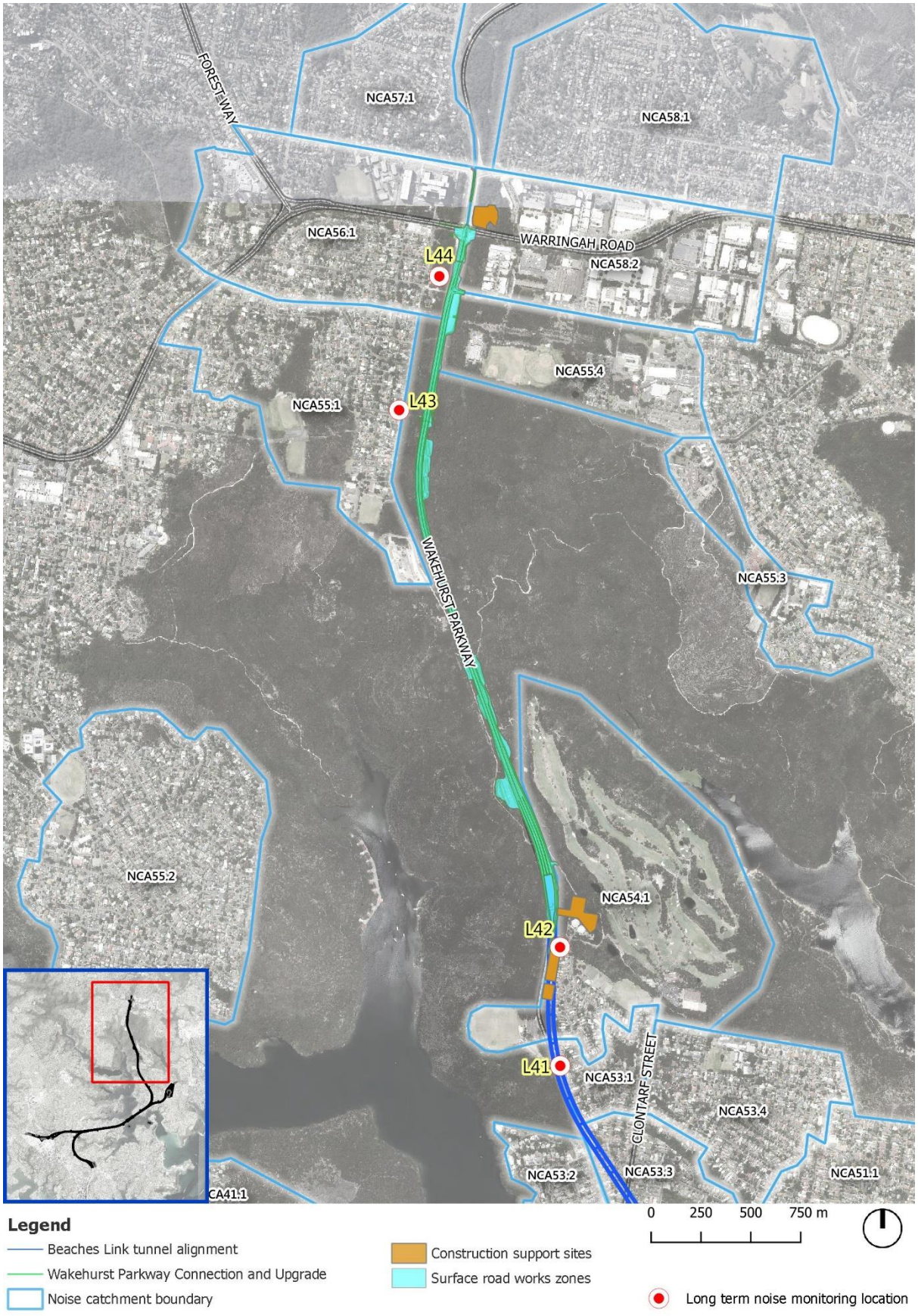


Table 2-1 – Long-term noise monitoring locations

Monitoring location ID	Address	Monitoring period	Description
Location L1	401/102 Alfred Street South, Milsons Point	14/09/2017 to 24/09/2017	Noise monitor located on the eastern facade of the fourth floor balcony. Noise environment dominated by traffic on the Warringah Freeway and Alfred Street, and rail noise.
Location L2	6 McDougall Street, Kirribilli	25/08/2017 to 05/09/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on the Cahill Expressway/Bradfield Highway and general neighbourhood and natural sounds.
Location L3	1/191-195 Walker Street, North Sydney	21/06/2017 to 01/07/2017	Noise monitor located on the eastern side of the property, on the ground floor and positioned in the free field. Noise environment dominated by traffic on the Warringah Freeway.
Location L4	91 Ridge Street, North Sydney	21/06/2017 to 02/07/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on the Warringah Freeway.
Location L5	14 Montpellier Road, Neutral Bay	19/07/2017 to 28/07/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by general neighbourhood noise and natural sounds.
Location L6	306 Miller Street, North Sydney	20/06/2017 to 03/07/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on Miller Street.
Location L7	1/1 Bardsley Gardens, Crows Nest	21/06/2017 to 02/07/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on Falcon Street.
Location L8	288 Falcon Street, Neutral Bay	25/08/2017 to 05/09/2017	Noise monitor located in the front yard and positioned approximately one metre away from the front facade. Noise environment dominated by traffic on Falcon Street.
Location L9	5 Military Road, Neutral Bay	25/08/2017 to 05/09/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on Military Road.
Location L10	317 Ernest Street, Cammeray	25/08/2017 to 05/09/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on Ernest Street.
Location L11	225 Ernest Street, Cammeray	25/08/2017 to 05/09/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on Ernest Street.
Location L12	77 Rosalind Street, Cammeray	08/09/2017 to 20/09/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on the Warringah Freeway.
Location L13	53 Bellevue Street, Cammeray	08/09/2017 to 20/09/2017	Noise monitor located in the western side yard and positioned in the free field. Noise environment dominated by traffic on the Warringah Freeway.
Location L14	12 Warringa Road, Cammeray	19/07/2017 to 28/07/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by general neighbourhood noise and natural sounds.
Location L15	57 Park Avenue, Cremorne	19/07/2017 to 26/07/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by general neighbourhood noise and natural sounds.
Location L16	18/22-24 Donnelly Road, Crows Nest	08/09/2017 to 20/09/2017	Noise monitor located in the rear yard and positioned in the free field. Noise environment dominated by traffic on the Warringah Freeway.

Monitoring location ID	Address	Monitoring period	Description
Location L17	79 Brook Street, Naremburn	20/06/2017 to 03/07/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on Brook Street.
Location L18	20/2 Parkes Road, Artarmon	07/09/2017 to 20/09/2017	Noise monitor located on the second floor balcony in the free field. Noise environment dominated by traffic on the Warringah Freeway.
Location L19	3/2 Cleland Road, Artarmon	08/09/2017 to 20/09/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on the Warringah Freeway.
Location L20	1 Chelmsford Avenue, Naremburn	08/09/2017 to 20/09/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on the Warringah Freeway.
Location L21	2 Burra Road, Artarmon	19/07/2017 to 28/07/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by noise from nature.
Location L22	16 Walter Street, Willoughby	19/07/2017 to 28/07/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on the Warringah Freeway.
Location L23	27 Garland Street, Naremburn	19/07/2017 to 28/07/2017	Noise monitor located on the rear balcony and positioned in the free field. Noise environment dominated by traffic on the Warringah Freeway.
Location L24	2 Pyalla Street, Northbridge	19/07/2017 to 28/07/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by noise from nature.
Location L25	375 Sailors Bay Road, Northbridge	19/07/2017 to 28/07/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on Sailors Bay Road.
Location L26	8 Wollombi Road, Northbridge	10/08/17 to 22/08/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by noise from nature.
Location L27	1 Tycannah Road, Northbridge	29/05/2017 to 14/06/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by noise from nature.
Location L28	8 Cheyne Walk, Castlecrag	20/06/2017 to 28/06/2017	Noise monitor located in the rear yard and positioned in the free field. Noise environment dominated by noise from nature.
Location L29	1 Delecta Avenue, Mosman	29/05/2017 to 13/06/2017	Noise monitor located in the rear yard and positioned in the free field. Noise environment dominated by noise from nature.
Location L30	14 Allenby Street, Clontarf	01/08/2017 to 10/08/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by noise from nature.
Location L31	73 Seaforth Crescent, Seaforth	15/09/2017 to 26/09/2017	Noise monitor located in the rear yard and positioned in the free field. Noise environment dominated by noise from nature.
Location L32	17 Seaforth Crescent, Seaforth	02/06/2017 to 27/06/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by noise from nature.
Location L33	2 Ross Street, Seaforth	29/05/2017 to 14/05/2017	Noise monitor located in the rear yard and positioned in the free field. Noise environment dominated by noise from nature.

Monitoring location ID	Address	Monitoring period	Description
Location L34	1/6 Whittle Avenue, Balgowlah	02/06/2017 to 20/06/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on Manly Road.
Location L35	469 Sydney Road, Balgowlah	13/06/2017 to 27/06/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on Sydney Road.
Location L36	14 Pickworth Avenue, Balgowlah	13/06/2017 to 27/06/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by traffic on Sydney Road.
Location L37	22 Hope Street, Seaforth	29/05/2017 to 13/06/2017	Noise monitor located in the rear yard and positioned in the free field. Noise environment dominated by traffic on Burnt Bridge Creek Deviation.
Location L38	49 Hope Street, Seaforth	29/05/2017 to 13/06/2017	Noise monitor located in the rear yard and positioned in the free field. Noise environment dominated by traffic on Burnt Bridge Creek Deviation.
Location L39	2 Pitt Street, Balgowlah	08/09/2017 to 19/09/2017	Noise monitor located in the side yard and positioned one metre from the facade. Noise environment dominated by traffic on Burnt Bridge Creek Deviation.
Location L40	3A Jacaranda Place, Manly Vale	14/06/2017 to 27/06/2017	Noise monitor located in the rear yard and positioned in the free field. Noise environment dominated by traffic on Burnt Bridge Creek Deviation.
Location L41	81 Wakehurst Parkway, Seaforth	31/05/2017 to 14/06/2017	Noise monitor located in the rear yard and positioned in the free field. Noise environment dominated by traffic on Wakehurst Parkway.
Location L42	96 Kirkwood Street, Seaforth	29/05/2017 to 13/06/2017	Noise monitor located in the rear yard and positioned in the free field. Noise environment dominated by traffic on Wakehurst Parkway.
Location L43	118 Bantry Bay Road, Frenchs Forest	29/05/2017 to 14/06/2017	Noise monitor located in the front yard and positioned in the free field. Noise environment dominated by noise from nature. See note 1.
Location L44	East of 63 Bantry Bay Road, Frenchs Forest	6/12/2013 to 20/12/2013	No noise monitoring was carried out at this location due to the presence of construction noise. See note 2.
Location L45	1/16 Munro Street, McMahons Point	01/08/2017 to 10/08/2017	Noise monitor located in the rear yard and positioned in the free field. Noise environment dominated by natural sounds and occasional passing motor boats.
Location L46	1/298 Pacific Highway, Greenwich	28/03/2019 to 13/04/2019	Noise monitor located in the front terrace and positioned in the free field. Noise environment dominated by traffic on Pacific Highway.
Location L47	23 Second Avenue, Lane Cove	28/03/2019 to 13/04/2019	Noise monitor located in the front yard and positioned in the free field. Noise environment contributed to by traffic on Pacific Highway.

Notes: 1. Location L43 has been used to represent background noise levels at the most northern NCAs, as:

- Construction work prevented reliable noise monitoring during the monitoring period of this project
- Review of monitoring for the Northern Beaches Hospital, Connectivity and Network Enhancements, Stage 2 Noise and Vibration Assessment (SLR, 2015) (logger locations NM6, NM7 and NM11) suggested that the levels measured at L43 were appropriate for those areas

2. Representative background noise levels at Location L44 have been adopted from the Northern Beaches Hospital, Connectivity and Network Enhancements, Stage 2 Noise and Vibration Assessment (SLR, 2015) (logger location NM9), as construction work prevented reliable noise monitoring during the monitoring period of this project.

2.5 Existing noise environment measurements

As detailed in Section 2.4, noise monitoring was carried out at locations along the project extent to quantify the existing noise environment in areas where receivers may potentially be affected by construction noise, and to determine the existing levels of road traffic noise along the project.

The equipment used for the long-term noise monitoring was RTA Technology RTA05/06/07 noise loggers which are based on the NTi Audio Type XL2 precision sound level analyser, a class 1 instrument with accuracy suitable for field and laboratory use.

A field calibration check of the instrument was carried out before and after measurements using a Bruel & Kjaer Type 4231 calibrator. No significant drift in calibration was observed.

All instrumentation complies with IEC 61672 (parts 1-3) 'Electroacoustics - Sound Level Meters' and IEC 60942 'Electroacoustics - Sound calibrators' and has current NATA certification (or if less than two years old, manufacturer's certification).

Weather information was obtained from the Bureau of Meteorology for the most suitable weather station nearest to each monitoring location for the monitoring period and any data adversely affected by rain, wind (more than five metres per second as per NPfI) or extraneous noise were discarded.

Rating Background Level (RBL) is the background noise level in the absence of proposed construction activities. This parameter represents the average minimum noise level during the daytime, evening and night time periods and is used to set the $L_{Aeq(15\ minute)}$ noise management levels for residential receivers. RBLs for each monitoring location presented in Figure 2-1 to Figure 2-4 were determined in accordance with the NPfI and are presented in Table 2-2. The noise monitoring locations are also presented in the maps in Annexure B.1.

The RBL is defined in the NPfI as:

> *"Rating background level (RBL) - the overall single figure background level representing each assessment period (day/evening/night) over the whole monitoring period (as opposed to over each 24 hour period used for the assessment background level). The rating background level is the level used for assessment purposes. Where the rating background level is found to be less than 30 dB(A) for the evening and night periods, then it is set to 30 dB(A); where it is found to be less than 35 dB(A) for the daytime period, then it is set to 35 dB(A)."*

The RBL is derived based on the measured time periods where the lowest 10th percentile background noise level occurs, representing the "quietest" period of the day, evening or night assessment period. During the more sensitive night time period for the types of urban and suburban receiver areas across the project, the RBL usually represents the period between 2.00am and 4.00am. For these areas, background L_{A90} noise levels typically decline with the reduction in traffic flow on nearby road corridors from around 11.00pm and onwards. When commuter traffic becomes more active again, background L_{A90} noise levels increases, typically reaching high points during the morning and afternoon traffic peak periods.

Table 2-2 also presents the existing L_{Aeq} ambient noise level for each of the day, evening and night periods in accordance with the NPfI. The L_{Aeq} level is the summation of all sound energy integrated over the sample period, encompassing all noise associated with the surrounding environment, from all sources near and far.

The ambient noise level represents all encompassing noise associated within a given environment at a given time, usually composed of sound from all sources near and far. The background noise is the term used to describe the underlying level of noise present in the ambient noise, representing how loud the quiet periods are during a measurement period. Figure 3-1 shows graphically how the ambient and background noise level varies over a typical week night, from 10.00pm to 7.00am, extracted from the data of a seven to 10 day monitoring period. This is contrasted with the RBL which is based on a single figure conservative representation of the background noise level over the total night period as described above.

Any weather affected data (due to wind or rain) was excluded from analysis in accordance with the NPfI exclusion procedures. The measured RBLs have been used to formulate noise objectives for the construction noise assessment and operational noise assessment of fixed facilities.

Table 2-2 – Long term noise monitoring results, dB(A)

Monitoring location ID	Address	L_{A90} Rating Background Level (RBL)			L_{Aeq} Ambient noise levels		
		Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Location L1	401/102 Alfred Street South, Milsons Point	60	60	50	63	62	58
Location L2	6 McDougall Street, Kirribilli	55	54	45	60	58	56
Location L3	1/191-195 Walker Street, North Sydney	73	71	55	76	75	72
Location L4	91 Ridge Street, North Sydney	52	52	45	57	57	52
Location L5	14 Montpellier Road, Neutral Bay	54	52	43	59	57	53
Location L6	306 Miller Street, North Sydney	52	47	36	65	63	58
Location L7	1/1 Bardsley Gardens, Crows Nest	53	49	41	68	67	63
Location L8	288 Falcon Street, Neutral Bay	61	54	44	69	68	65
Location L9	5 Military Road, Neutral Bay	58	54	44	72	71	67
Location L10	317 Ernest Street, Cammeray	58	54	41	69	66	62
Location L11	225 Ernest Street, Cammeray	56	52	37	68	66	61
Location L12	77 Rosalind Street, Cammeray	58	55	43	62	60	57
Location L13	53 Bellevue Street, Cammeray	64	63	47	67	67	64
Location L14	12 Warringa Road, Cammeray	47	45	37	54	51	48
Location L15	57 Park Avenue, Cremorne	49	48	39	59	57	54
Location L16	18/22-24 Donnelly Road, Crows Nest	58	56	38	62	61	58
Location L17	79 Brook Street, Naremburn	56	49	37	71	69	65
Location L18	20/2 Parkes Road, Artarmon	67	63	46	72	70	67
Location L19	3/2 Cleland Road, Artarmon	55	53	40	59	58	55
Location L20	1 Chelmsford Avenue, Naremburn	59	55	40	63	61	58
Location L21	2 Burra Road, Artarmon	44	44	37	53	50	46
Location L22	16 Walter Street, Willoughby	50	48	38	55	52	49
Location L23	27 Garland Street, Naremburn	45	44	34	53	52	48
Location L24	2 Pyalla Street, Northbridge	52	48	37	60	56	57
Location L25	375 Sailors Bay Road, Northbridge	43	40	36	66	63	58
Location L26	8 Wollombi Road, Northbridge	37	37	33	52	44	46
Location L27	1 Tycannah Road, Northbridge	37	34	28	52	43	43
Location L28	8 Cheyne Walk, Castlecrag	36	32	27	50	42	38
Location L29	1 Delecta Avenue, Mosman	45	43	36	52	50	46
Location L30	14 Allenby Street, Clontarf	40	38	33	52	48	44
Location L31	73 Seaforth Crescent, Seaforth	42	38	36	51	46	47
Location L32	17 Seaforth Crescent, Seaforth	50	49	40	55	54	49
Location L33	2 Ross Street, Seaforth	43	39	30	53	50	43
Location L34	1/6 Whittle Avenue, Balgowlah	58	54	37	65	63	61
Location L35	469 Sydney Road, Balgowlah	55	50	32	71	70	68
Location L36	14 Pickworth Avenue, Balgowlah	47	45	35	53	51	49
Location L37	22 Hope Street, Seaforth	45	42	31	53	52	48
Location L38	49 Hope Street, Seaforth	43	40	33	51	49	44
Location L39	2 Pitt Street, Balgowlah	47	45	30	53	50	48
Location L40	3A Jacaranda Place, Manly Vale	49	45	36	59	56	54

Monitoring location ID	Address	L_{A90} Rating Background Level (RBL)			L_{Aeq} Ambient noise levels		
		Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Location L41	81 Wakehurst Parkway, Seaforth	48	39	28	66	63	59
Location L42	96 Kirkwood Street, Seaforth	45	39	29	53	51	46
Location L43[5]	118 Bantry Bay Road, Frenchs Forest	46	40	30	56	54	47
Location L44[6]	East of 63 Bantry Bay Road, Frenchs Forest	53	48	34	61	57	52
Location L45	1/16 Munro Street, McMahons Point	42	41	38	52	46	44
Location L46	1/298 Pacific Highway, Greenwich	60	55	40	70	69	64
Location L47	23 Second Avenue, Lane Cove	39	37	31	57	51	46

Notes:
1. Day: 7.00am to 6.00pm Monday to Saturday and 8.00am to 6.00pm Sundays and Public Holidays
2. Evening: 6.00pm to 10.00pm Monday to Sunday and Public Holidays
3. Night: 10.00pm to 7.00am Monday to Saturday and 10.00pm to 8.00am Sundays and Public Holidays
4. As required by the NPfI, the external ambient noise levels presented are free-field noise levels. (ie no facade reflection)
5. L43 has been used to represent background noise levels at the most northern NCAs, as:
   - Construction work prevented reliable noise monitoring during the monitoring period of this project
   - Review of monitoring for the Northern Beaches Hospital, Connectivity and Network Enhancements, Stage 2 Noise and Vibration Assessment (SLR, 2015) (logger locations NM6, NM7 and NM11) suggested that the levels measured at L43 were appropriate for those areas
6. Adopted from the Northern Beaches Hospital, Connectivity and Network Enhancements, Stage 2 Noise and Vibration Assessment (SLR, 2015) (logger location NM9), as construction work prevented reliable noise monitoring during the monitoring period of this project.

The noise monitoring locations are presented in the maps in Annexure B.1 and Figure 2-1 to Figure 2-4. The complete results from the noise monitoring are presented in Annexure C.

2.6 Measured road traffic noise levels

The existing traffic noise levels at the monitoring locations where road traffic was the dominating noise source are summarised in Table 2-3 below. The locations are presented in Figure 2-1 to Figure 2-4 and the maps in Annexure B.1. The complete results from the noise monitoring are presented in Annexure C.

Noise levels are described in accordance with the requirements of *NSW Road Noise Policy* (Department of Climate Change and Water, 2011) (the RNP). The relevant descriptors for traffic noise are $L_{Aeq(15hr)}$ and $L_{Aeq(9hr)}$ which represent the existing day and night traffic noise levels, respectively.

At monitoring locations where the noise monitor was positioned in the free field (ie away from buildings), a +2.5 dB(A) correction was added to the measured road traffic noise levels to represent an equivalent road traffic noise level at a distance of one metre from a building facade, in accordance with the requirements of the RNP.

Table 2-3 – Measured traffic noise levels

Monitoring location ID	Address	Measured road traffic noise level, dB(A)	
		$L_{Aeq,15hour}$ (7.00am to 10.00pm)	$L_{Aeq,9hour}$ (10.00pm to 7.00am)
Location L2	6 McDougall Street, Kirribilli	62	58
Location L3	1/191-195 Walker Street, North Sydney	79	74
Location L4	91 Ridge Street, North Sydney	60	54
Location L6	306 Miller Street, North Sydney	67	61
Location L7	1/1 Bardsley Gardens, Crows Nest	70	66
Location L8	288 Falcon Street, Neutral Bay	71	68
Location L9	5 Military Road, Neutral Bay	74	70
Location L10	317 Ernest Street, Cammeray	71	65
Location L11	225 Ernest Street, Cammeray	70	64
Location L12	77 Rosalind Street, Cammeray	64	59
Location L13	53 Bellevue Street, Cammeray	70	66
Location L16	18/22-24 Donnelly Road, Crows Nest	65	60
Location L17	79 Brook Street, Naremburn	73	67
Location L18	20/2 Parkes Road, Artarmon	74	69
Location L19	3/2 Cleland Road, Artarmon	61	57
Location L20	1 Chelmsford Avenue, Naremburn	65	61
Location L34	1/6 Whittle Avenue, Balgowlah	67	64
Location L35	469 Sydney Road, Balgowlah	73	71
Location L36	14 Pickworth Avenue, Balgowlah	55	52
Location L37	22 Hope Street, Seaforth	56	51
Location L38	49 Hope Street, Seaforth	54	49
Location L39	2 Pitt Street, Balgowlah	55	51
Location L40	3A Jacaranda Place, Manly Vale	61	56
Location L41	81 Wakehurst Parkway, Seaforth	68	61
Location L42	96 Kirkwood Street, Seaforth	55	50
Location L43	118 Bantry Bay Road, Frenchs Forest	58	50
Location L46	1/298 Pacific Highway, Greenwich	72	66

Notes: 1. Noise levels presented are representative of road traffic noise level at one metre from a building facade, as per RNP
2. Only noise monitoring locations that are applicable to the assessment of road traffic noise have been presented.

3 Assessment objectives

This section presents the guidelines and policies adopted to assess airborne and ground-borne construction and operational noise and vibration impacts.

3.1 Construction noise and vibration guidelines and policies

Transport for NSW's *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) (the CNVG) provides guidance for the assessment and mitigation of construction noise and vibration. The CNVG refers to the policies, guidelines and standards presented in Table 3-1, which have been adopted in the construction noise and vibration assessment for the project.

Table 3-1 – Construction noise and vibration policies, guidelines and standards

Guideline/policy document	Assessment aspect
Construction Noise and Vibration Guideline (Roads and Maritime Services, 2016a)	Airborne noise, ground-borne noise and vibration impacts (including construction traffic within the construction support site boundary)
Interim Construction Noise Guideline (Department of Environment and Climate Change, 2009)	Airborne noise and ground-borne noise impacts (including construction traffic within the construction support site boundary)
Assessing Vibration: a technical guideline (Department of Environment and Climate Change, 2006)	Vibration amenity
British Standard BS 7385: Part 2-1993 *Evaluation and measurement for vibration in buildings Part 2: Guide to damage levels from groundborne vibration* (BSI, 1993)	Vibration impacts to structures and blasting impacts
German Standard DIN 4150-3 (2016) *Structural vibration – Effects of vibration on structures* (Deutsches Institut für Normung, 2016)	Vibration impacts to structures and blasting impacts
Australian Standard AS 2187.2-2006 *Explosives - Storage and use - Part 2 Use of explosives*	Blasting impacts
NSW Road Noise Policy (Department of Environment, Climate Change and Water, 2011)	Construction road traffic noise impacts (on public roads)
Noise Criteria Guideline (Roads and Maritime Services, 2015a)	Construction road traffic noise impacts (on public roads)

For details addressing the *NSW Sustainable Design Guidelines Version 4.0* (Transport for NSW, 2017) refer to Chapter 25 (Sustainability) of the environmental impact statement.

3.2 Assessment time periods

Noise management levels (NMLs) for the assessment of construction noise are usually derived from the existing noise environment of an area, excluding noise from the project, which is detailed in Section 2.5.

As the noise environment of an area varies over time, background noise levels need to be determined for the purpose of determining construction noise goals. For example, in a suburban or urban area the noise environment is typically at its minimum at 3.00am and at its maximum during the morning and afternoon traffic peak periods.

The ICNG refers to the NPfI, which has been superseded by the NPfI for outlining the standard time periods over which the rating background levels (RBL) are to be determined and noise impacts assessed. These standard time periods are:

- **Day** is defined as 7.00am to 6.00pm, Monday to Saturday and 8.00am to 6.00pm Sundays and Public Holidays
- **Evening** is defined as 6.00pm to 10.00pm, Monday to Sunday and Public Holidays
- **Night** is defined as 10.00pm to 7.00am, Monday to Saturday and 10.00pm to 8.00am Sundays and Public Holidays.

3.3 Construction noise and vibration guideline (CNVG) construction hours

Construction hours defined in the CNVG are reproduced in Table 3-2. While the standard construction hours are not mandatory, limiting construction works to within standard construction hours as much as practicable assists in managing noise or vibration impacts and provides lengthy respite periods while people are most likely to be relaxing or sleeping.

Table 3-2 – Summary of CNVG construction hours

Construction hours	Monday to Friday	Saturday	Sunday/Public holiday
Recommended standard construction hours			
Standard construction hours	7.00am to 6.00pm	8.00am to 1.00pm	No work
Construction activities with impulsive or tonal noise emissions	8.00am to 5.00pm[1]	9.00am to 1.00pm[1]	No work
Blasting	9.00am to 5.00pm	9.00am to 1.00pm	No blasting
Outside recommended standard construction hours			
Out-of-Hours Work (Day)	N/A	1.00pm to 6.00pm	8.00am to 6.00pm
Out-of-Hours Work (Evening)	7.00pm to 10.00pm	6.00pm to 10.00pm	6.00pm to 10.00pm
Out-of-Hours Work (Night)	10.00pm to 7.00am	10.00pm to 8.00am	10.00pm to 8.00am

Notes: 1. Works would be carried out in continuous blocks not exceeding three hours each with a minimum respite from those activities and works of not less than one hour between each block. 'Continuous' includes any period during which there is less than a one hour respite between ceasing and recommencing any of the work the subject of this condition.

3.4 Construction noise and vibration objectives

3.4.1 Construction airborne noise

The CNVG refers to the ICNG for the assessment of airborne noise impacts due to construction works and the establishment of NMLs.

The CNVG provides guidance for determining the type of construction noise assessment to be carried out for the project. There are two parts of the CNVG that are used to determine the type of assessment required to be carried out:

- Duration of the impact to affected receivers
- Number of affected receivers.

Based on the proposed duration of construction works and number of affected receivers, a quantitative assessment has been carried out in accordance with the CNVG.

Traffic noise on the major arterial roads is more continuous, rather than intermittent. Construction activities that generate sounds with similar characteristics to road traffic noise are likely to be less noticeable than sounds that are intermittent, impulsive or tonal.

The receivers most affected by construction noise are typically closest to the works, with direct line of sight. Further away, or at places that do not have line of sight, construction noise generally decreases faster with distance than road traffic noise.

3.4.1.1 Residential receivers

The CNVG intends to provide respite for residents exposed to excessive construction noise outside the recommended standard construction hours while allowing construction during the recommended standard construction hours without unnecessary restrictions.

Table 3-3, reproduced from the ICNG, sets out the NMLs and how they are applied at residential receivers.

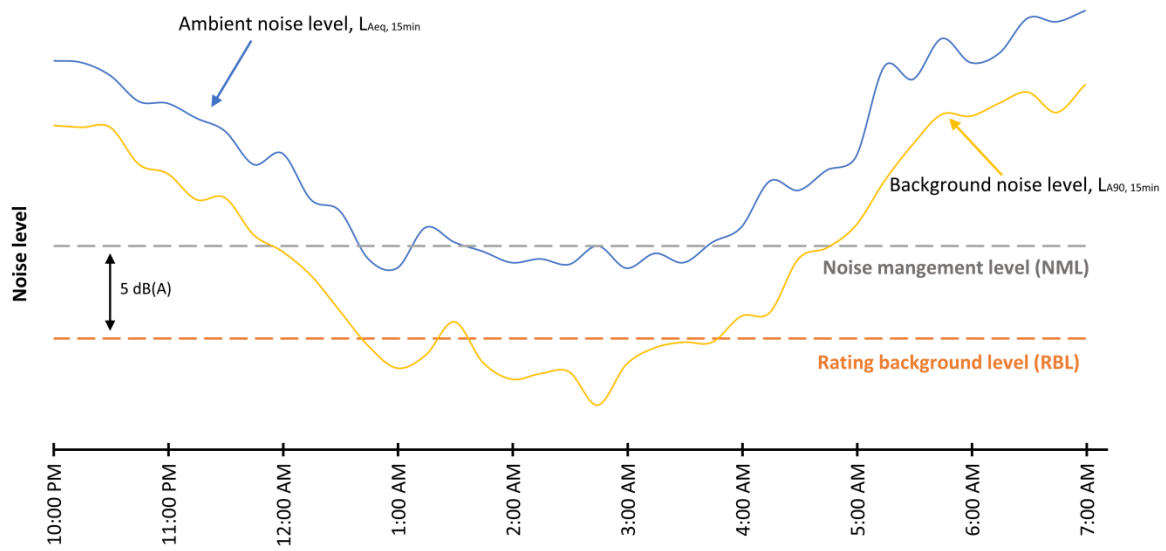
NMLs are based on the RBL: the overall whole number background noise level measured in each assessment period (during or outside the recommended standard construction hours). It is derived from measurements of the existing noise environment of an area, excluding noise from the project. The project RBLs are detailed in Section 2.5. The RBL represents the lowest 10^{th} percentile background noise levels over an assessment period, which is a conservative approach. Average noise levels are usually higher than the RBL, as suggested by the ambient L_{Aeq} noise measurements presented in Section 2.5.

To assess the extent of noise impacts it is important to consider the extent of the emergence of a noise above the background noise and whether there are times when there is a clear change in the noise environment. It is also important to consider how often high noise events occur at night and the predicted maximum noise levels at night.

Construction noise may be less distinguishable to a receiver when ambient noise levels are high. For example, during the day when existing road traffic noise is high, construction noise may be less noticeable than at night time when ambient noise levels are lower. At night, there are also times when ambient noise levels are typically higher, such as at the beginning of the night period between 10.00pm and 12.00am or at the end of the night period between 5.00am and 7.00am. Construction noise generated during these periods may be less noticeable than during the quietest period of the night, between 2.00am to 4.00am, as demonstrated in Figure 3-1.

The NML sits at 5 dB(A) above the RBL during this time period. The graph represents a typical week night. Background and ambient noise levels start dropping off after 10.00pm, reaching the lowest level in the period between 2.00am and 3.00am. From 4.00am noise levels start to rise again towards the morning peak hour period. The graph shows clearly that the RBL is not based on the lowest background noise level, but the typical lowest. This time period may change from night to night. The figure also shows that the ambient noise level (or L_{Aeq}) is typically 5 dB(A) above the background noise level and there are several periods of the night where the existing ambient noise level is higher than the NML. Refer to Annexure A, Section A.2 for some of the key acoustic concepts used in Figure 3-1.

Figure 3-1 – Typical ambient and background noise level variations compared with RBL and NML



To assess noise against the NMLs, the assessment adopts the equivalent sound pressure level indicator, L_{Aeq}, which is the energy average of noise over the 15 minute measurement period. For screening potential sleep disturbance at night, the assessment also uses the maximum noise level indicator, L_{Amax}, which accounts for instantaneous noise events. Refer to Annexure A, Section A.2 for an explanation of some of the key acoustic concepts used to assess construction noise.

The outcome of this approach coupled with worst case construction noise predictions (explained in sections 4.2.2 and 4.2.3) is that the emergence of construction noise above background noise will usually be overestimated compared with typical noise levels generated by construction activities. Assessment against the NML and sleep disturbance screening level can be used as effective ways to identify when noise impacts

need to be further mitigated and managed in order to protect receivers from annoyance for at least 90 per cent of the time.

Table 3-3 – Noise management levels at residential receivers

Time of day	Management level $L_{Aeq\ (15\ minute)}$ *	How to apply
Recommended standard hours: Monday to Friday 7.00am to 6.00pm Saturday 8.00am to 1.00pm	Noise affected RBL + 10dB	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured $L_{Aeq(15\ minute)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
No work on Sundays or public holidays	Highly noise affected 75 dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: - Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences - If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5 dB	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community. • For guidance on negotiating agreements see Section 7.2.2 (of the ICNG).

* Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 metres above ground level. If the property boundary is more than 30 metres from the residence, the location for measuring or predicting noise levels is at the most noise affected point within 30 metres of the residence. Noise levels may be higher at upper floors of the noise affected residence. As such, in this assessment all levels and facades of receiver buildings have been assessed.

Residential receivers are considered 'noise affected' where construction noise levels are greater than the NMLs. The noise affected level represents the point above which there may be some community reaction to noise. Where predicted and/or measured construction noise levels exceed NMLs all feasible and reasonable work practices would be applied to meet the NMLs. If construction noise is above $L_{Aeq(15\ minute)}$ 75 dB(A) at any residence at any time, that residential receiver is considered to be highly noise affected.

The construction NMLs for all residential receivers around the project are presented in Annexure B.2.

Long term residential premises such as aged care facilities are considered residential receivers, while the NML for short term accommodation receivers such as hotels is in Table 3-4. As outlined in the NPfI, a place where a person resides but which is associated with a commercial undertaking is not classified as a residential receiver, but as a commercial receiver. This includes receivers such as caretakers' quarters, hotels, motels, transient holiday accommodation and caravan parks.

For construction noise, where a building has multiple uses, the most stringent criteria has been adopted for the building. For example, where a building contains:

- Both commercial and residential units, the building is assessed against residential NMLs
- Commercial units and a childcare centre, the building is assessed against the childcare NML.

3.4.1.2 Other sensitive land uses

Table 3-4 sets out the NMLs for commercial, industrial and other noise sensitive receiver (OSR) locations, including commercial and industrial premises in accordance with the ICNG.

Table 3-4 – Noise management levels at other noise sensitive land uses

Land use[1]	Where objective applies	Noise management level $L_{Aeq\ (15\ minute)}$[2]
Classrooms at schools, and other educational institutions	Internal noise level	45 dB(A)[3,9]
Hospital wards and operating theatres	Internal noise level	45 dB(A)[4]
Places of worship	Internal noise level	45 dB(A)[3]
Childcare centre	External noise level	50 dB(A)[8]
Active recreation areas (eg sports fields/activities which generate their own noise and are generally less sensitive to external noise)	External noise level	65 dB(A)
Passive recreation areas (eg area used for low intensity and low noise producing activities such as reading or meditation which could be impacted by external noise)	External noise level	60 dB(A)
Community centres	Depends on the intended use of the centre.[5]	Refer to the 'maximum' internal levels in Australian/New Zealand Standard 2107:2016 '*Acoustics - Recommended design sound levels and reverberation times for building interiors*' (Standards Australia 2016) (AS/NZS 2107) for specific uses.)[5]
Commercial premises (including offices and retail outlets) [5,6]	External noise level	70 dB(A)[6,7]
Industrial premises	External noise level	75 dB(A)[7]
Special noise and/or vibration sensitive (eg laboratories, recording studios)[1]	Depends on the intended use	Refer to the 'maximum' internal levels in AS/NZS 2107 for specific uses.

Notes:
1. Where premises are noise sensitive and cannot be suitably classified by the categories in this table, it is recommended that the recommended 'maximum' internal noise levels presented in AS/NZS 2107 are adopted
2. NMLs apply when receiver areas are in use only
3. As per the ICNG and NPfI, it has been assumed that the difference between an internal noise level and the external noise level is 10 dB, assuming windows are open for adequate ventilation. An external NML has been defined on this basis
4. Medical centres and similar are classified as commercial premises
5. Community centres have been assessed to an external noise level of 60 dB(A). Depending upon the intended use of the centre, the noise management level may vary
6. Hotels and motels have been treated as commercial premises, except for during the night periods where they have been assessed for sleeping areas against a night time internal noise level of 40 dB(A), assuming closed windows with a 20 dB(A) outside to inside difference
7. The NML applies at the most affected occupied point on the premises
8. Refer to Section 3.4.1.2.2 for further details relating to childcare centres
9. Refer to Section 3.4.1.2.3 for further details relating to schools.

As the majority of OSRs operate mostly during standard construction hours, predicted noise levels and affected receiver counts are presented based on noise levels during standard construction hours.

3.4.1.2.1 Internal noise management levels

The ICNG states that:

> *"As a guide, the difference between the internal noise level and the external noise level is typically 10 dB with windows open for adequate ventilation"*

On the basis of the above and the general acceptance that most buildings provide a noise reduction of at least 10 dB(A) when windows are left at least 20 per cent open, where windows are operable and without providing additional treatment, a conservative 10 dB(A) reduction from external noise levels to internal noise levels has been adopted to determine equivalent external NMLs.

The external to internal noise reductions can vary largely for different buildings and facade construction types as there are a number of physical factors that can influence the level of noise reduction actually achieved from outside to inside a dwelling. For receiver buildings that are exposed to existing high levels of traffic noise, the facades would typically be sealed and consist of thick glazing and heavy facade construction materials. Sealed facades or facades with windows closed can provide external to internal noise reductions much greater than 10 dB(A). Noise reductions greater than 20–25 dB(A) are achievable where facades consist of standard to thick glazing and heavy facade construction (eg brick construction)The equivalent external NMLs will be refined following a detailed land use survey prior to the commencement of construction works.

Based upon a 10 dB(A) external to internal reduction, classrooms, hospital wards, operating theatres and places of worship would have the equivalent external NML of **55 dB(A)** (refer to Table 3-4). The construction details of a building need to be taken into account when converting an internal NML to an external noise level at the facade.

3.4.1.2.2 Childcare centres

The ICNG and AS/NZS 2107 do not provide specific construction noise criteria for childcare centres. Typically, sensitive areas within childcare centres are external/internal play areas and sleeping areas.

The Association of Australian Acoustical Consultants (AAAC) *Guideline for Child Care Centre Acoustics Assessment* (2013) recommends noise levels from external noise sources such as road, rail traffic and industrial sources that would be suitable for the various childcare centre spaces.

More detailed analysis may be required during construction planning to determine appropriate criteria for childcare centres depending on which spaces are noise affected, and if sleeping areas are close to works activities.

Considering the above NMLs, an external screening level of $L_{Aeq\ (15\ minute)}$ **50 dB(A)** has been adopted for assessing childcare centres. Where external noise levels are expected to exceed this screening level, further

analysis of the child care centre would be required to determine appropriate noise requirements based on the construction details and use of the child care centre building(s).

Where a childcare centre is located within an existing commercial building, with no external play areas, they have been identified as commercial premises. This approach assumes the existing commercial facade would provide enough transmission loss to protect the amenity of the childcare centre.

3.4.1.2.3 Schools

Schools are also typically made up of both indoor (ie classroom and teaching spaces) and external receiver types (ie external active or passive recreation areas). As the internal NML for classroom and teaching spaces presented in Table 3-4, assuming a 10 dB(A) external to internal reduction, is more stringent than the relevant external NMLs for external play area, the NML for educational receivers based upon the classroom and teaching spaces has been adopted for all assessments, as it would typically sufficiently manage noise impacts for the range of uses within an educational receiver.

3.4.1.3 Sleep disturbance

Maximum noise levels generated by construction activities have the potential to disturb sleep. Section 4.3 of the ICNG states:

> *Where construction works are planned to extend over more than two consecutive nights, and a quantitative assessment method is used, the analysis should cover the maximum noise level, and the extent and the number of times that the maximum noise level exceeds the RBL. Some guidance indicating the potential for sleep disturbance is in the NSW Environmental Criteria for Road Traffic Noise (EPA 1999).*
>
> *Factors that may be important in assessing the extent of impact on sleep include how often high noise events occur at night, the predicted maximum noise levels at night, whether there are times when there is a clear change in the noise environment (such as during early morning shoulder periods), and the degree of maximum noise levels above the background noise level at night*

The NSW Environmental Criteria for Road Traffic Noise (EPA, 1999) (ECRTN) has been superseded by the RNP. Although noise goals are not specifically provided in the RNP, the RNP includes a review of internal sleep arousal research and concluded that:

- L_{Amax} (the maximum A-weighted noise level) internal noise levels below 50–55 dB(A) are unlikely to awaken people from sleep (corresponding to approximately 60-65 dB(A) external noise level)
- One or two noise events per night, with maximum internal noise levels of 65–70 dB(A) (corresponding to approximately 75-80 dB(A) external noise level), are not likely to affect health and wellbeing substantially.

As such, external noise levels below 65 dB(A) are unlikely to awaken people. A conservative 10 dB(A) reduction from external noise levels to internal noise levels has been assumed, which is not always the case and could be greater than this as further outlined in Section 3.4.1.2.

The RNP aims to limit the level of sleep disturbance due to environmental noise, noting there is not enough evidence to change previous guidance than the $L_{AF1,\ 1\ minute}$ level of any noise should not exceed the ambient L_{AF90} noise level by more than 15 dB(A). It also notes that the L_{Amax} is better linked to sleep disturbance than other descriptors. This guidance takes into account the emergence of noise events but does not directly limit the number of such events or their highest level, which are also found to affect sleep disturbance.

Considering the ICNG and RNP guidance, an L_{Amax} sleep disturbance screening level of RBL + 15 dB(A) has been adopted for the project. Where predicted maximum noise levels are above the screening level, more detailed analysis has been carried out to identify:

- The likely number of events that might occur where the maximum noise level (L_{Amax}) exceeds RBL + 15 dB(A)
- Whether events exceed an 'awakening reaction' level of L_{Amax} 65 dB(A), and the likely number of these events
- The likely nature, distribution and frequency of these maximum noise level events during the night time period, with consideration also of existing maximum noise level events in the acoustic environment
- Potential feasible and reasonable noise mitigation measures to assist in reducing the number of maximum noise events above the screening level.

3.4.2 Construction related road traffic noise

3.4.2.1 Within the boundary of a construction support site

When heavy vehicles and other vehicles are operating within the boundary of a construction support site, road vehicle noise contributions are included in the overall predicted $L_{Aeq(15\ minute)}$ construction support site noise emissions. These noise objectives are outlined in Section 3.4.1.

3.4.2.2 Outside the boundary of a construction support site

When construction related traffic moves onto the public road network a different noise assessment methodology is appropriate, as vehicle movements are regarded as 'additional road traffic' rather than as part of the construction support site.

The CNVG requires an initial screening test to evaluate whether noise levels would increase by more than 2 dB(A) due to construction traffic or a temporary reroute due to a road closure. The RNP states that in assessing feasible and reasonable mitigation measures, an increase of up to 2 dB(A) represents a minor impact. Where increases are 2 dB(A) or less then no further assessment is required. Where noise levels increase by more than 2 dB(A) then further assessment is required using *Noise Criteria Guideline* (Roads and Maritime Services, 2015a) (the NCG). All feasible and reasonable noise mitigation and management measures would be implemented.

Consideration should be given to feasible and reasonable mitigation measures, the actual noise levels associated with construction traffic and whether these levels comply with the following road traffic noise criteria in the RNP:

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

For this assessment, it has been assumed that heavy vehicle movements occur generally during standard construction hours for construction support sites, where indicated. Where heavy vehicle movements are required outside recommended standard construction hours, this should be assessed further as required during detailed construction planning.

3.4.3 Construction related water traffic noise

There are no guidelines to assess noise from vessel movements in NSW. Nonetheless, an assessment of construction related water traffic noise is provided in Section 4.2.6.

3.4.4 Ground-borne construction noise

Ground-borne or regenerated noise as a result of construction activities is usually associated with tunnelling projects when equipment such as roadheaders, rock hammers and drilling rigs are operated underground. Ground-borne noise is usually not a substantial disturbance to building occupants during daytime periods due to higher ambient noise levels which can mask the audibility of ground-borne noise emissions. However, during the evening and night periods, ground-borne noise can be more prominent due to lower ambient noise levels and may result in adverse comments from building occupants. Table 3-5 summarises the CNVG ground-borne construction noise objectives for residential receivers, which are consistent with the ICNG.

Table 3-5 – Ground-borne noise objectives at residential premises

Period	Time	Internal $L_{Aeq(15\ minute)}$ ground borne Noise Management Level, dB(A)
Daytime	7.00am to 6.00pm	N/A - Human comfort vibration objectives only
Evening	6.00pm to 10.00pm	40
Night	10.00pm to 6.00am	35

For OSRs and commercial receivers such as offices and retail areas, the ICNG and CNVG do not provide guidance in relation to acceptable ground-borne noise levels.

For commercial receivers, internal ground-borne noise management levels were derived from the airborne NML presented in the ICNG for commercial premises and assuming a 20 dB(A) noise reduction from outside to inside to determine a suitable internal construction noise level. For other noise sensitive receivers, guidance has been taken from the recommended 'maximum' internal noise levels in AS/NZS 2107 to determine suitable internal NMLs.

For the purpose of this assessment ground-borne noise objectives for key ‘other’ noise sensitive land uses are identified below in Table 3-6.

Table 3-6 – Ground-borne NMLs at other noise sensitive land uses

Land Use	Internal $L_{Aeq(15\ minute)}$ Ground-borne NML, dB(A)[1]
Hospital wards and operating theatres	45
Childcare centres	40[2]
Classrooms at schools and other educational institutions	45
Places of worship	45
Community centre	45
Commercial premises (including offices)	50
Commercial premises (including retail outlets)	55
Other noise sensitive receivers	Refer to the 'maximum' internal levels in AS/NZS 2107 for specific uses

Notes: 1. Noise management levels only apply when receiver areas are in use

2. NML is based on the recommended internal level for indoor play or sleeping areas within childcare centres nominated in the AAAC Guideline (AAAC, 2013).

3.4.5 Construction vibration objectives

Construction vibration is associated with three main types of impact:

- Disturbance to building occupants
- Potential damage to buildings
- Potential disruption or damage to sensitive equipment in a building.

Generally, if disturbance to building occupants is controlled, there is limited potential for structural damage to buildings.

Vibration amplitude may be measured as displacement, velocity, or acceleration.

- Displacement (x) measurement is the distance or amplitude displaced from a resting position. The SI unit for distance is the metre (m), although common industrial standards include millimetres (mm)
- Velocity ($v=\Delta x/\Delta t$) is the rate of change of displacement with respect to change in time. The SI unit for velocity is metres per second (m/s), although common industrial standards include millimetres per second (mm/s). The Peak Particle Velocity (PPV) is the greatest instantaneous particle velocity during a given time interval. If measurements are made in three axes (x, y, and z), then the resultant PPV is the vector sum (ie the square root of the summed squares of the maximum velocities) regardless of when in the time history those occur
- Acceleration ($a=\Delta v/\Delta t$) is the rate of change of velocity with respect to change in time. The SI unit for acceleration is metres per second squared (m/s^2).

3.4.5.1 Human exposure to vibration

Tactile vibration potentially disturbing human occupants of buildings is managed by reference to *Assessing Vibration; a technical guideline* (DECC, 2006) (the AVTG). This document provides criteria which are based on the British Standard BS 6472-2008 *Evaluation of human exposure to vibration in buildings (1-80Hz)*.

Vibration sources are defined as continuous, impulsive or intermittent. Table 3-7 provides a definition and examples of each type of vibration.

Table 3-7 – Types of vibration

Type of vibration	Definition	Examples
Continuous	Continues uninterrupted for a defined period (usually throughout the day time and/or night time)	Machinery in constant use/operation, steady road traffic, continuous construction activity (such as roadheader excavation).
Impulsive	A rapid build-up to a peak followed by a damped decay that may or may not involve several cycles of vibration (depending on frequency and damping). It can also consist of a sudden application of several cycles at approximately the same amplitude, providing the duration is short (typically less than 2 seconds)	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, eg occasional dropping of heavy equipment, occasional loading and unloading.
Intermittent	Can be defined as interrupted periods of continuous or repeated periods of impulsive vibration that varies significantly in magnitude	Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer, they would be assessed against impulsive vibration criteria.

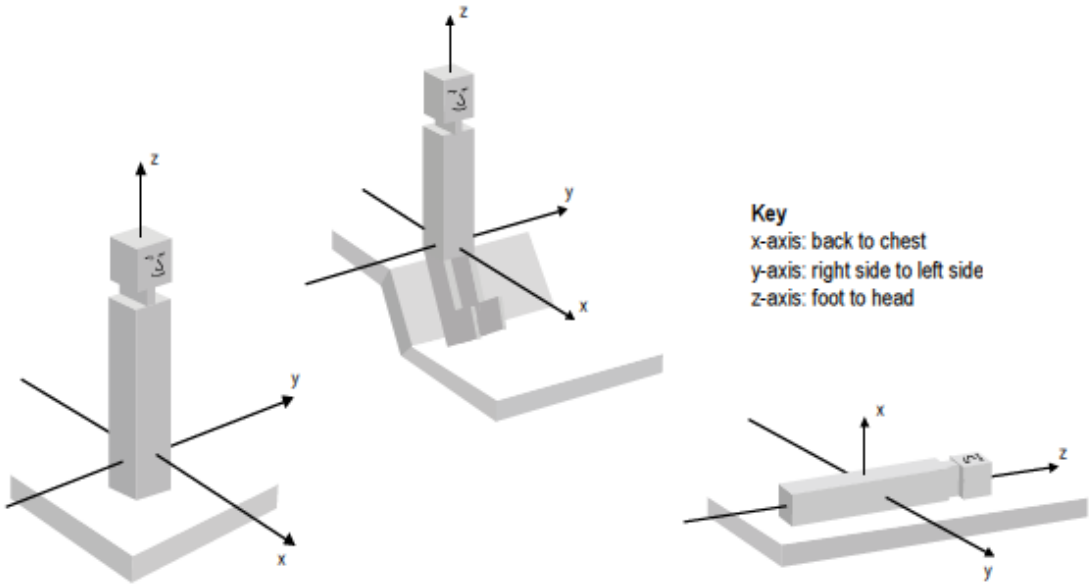
Source: *Assessing Vibration: a technical guideline* (Department of Environment and Climate Change, 2006).

The criteria are applied to a single weighted root mean square (rms) acceleration source level in each orthogonal axis. Section 2.3 of the guideline states:

> *"Evidence from research suggests that there are summation effects for vibrations at different frequencies. Therefore, for evaluation of vibration in relation to annoyance and comfort, overall weighted rms acceleration values of the vibration in each orthogonal axis are preferred (BS 6472)."*

When applying the criteria, it is important to note that vibration may enter the body along different orthogonal axes, ie x-axis (back to chest), y-axis (right side to left side) or z-axis (foot to head). The three axes are referenced to the human body. Thus, vibration measured in the horizontal plane should be compared with x- and y-axis criteria if the concern is for people in an upright position, or with the y- and z-axis criteria if the concern is for people in the lateral position.

Figure 3-2 – Orthogonal axes for human exposure to vibration



Source: *Assessing Vibration: a technical guideline* (Department of Environment and Climate Change, 2006)

Preferred and maximum values are defined in Table 2.2 of the guideline and are reproduced below for continuous (Table 3-8), impulsive (Table 3-8) and intermittent vibration (Table 3-9).

Table 3-8 – Preferred and maximum levels for human comfort (continuous and impulsive vibration)

Location	Assessment period[1]	Preferred values		Maximum values	
		z-axis	x- and y-axis	z-axis	x- and y-axis
Continuous vibration[3] (weighted rms acceleration, m/s^2, 1-80Hz)					
Critical areas[2]	Day or night time	0.005	0.0036	0.010	0.0072
Residences	Daytime	0.010	0.0071	0.020	0.014
	Night time	0.007	0.005	0.014	0.010
Offices, schools, educational institutions and places of worship	Day or night time	0.020	0.014	0.040	0.028
Workshops	Day or night time	0.04	0.029	0.080	0.058
Impulsive vibration[3] (Weighted rms acceleration, m/s^2, 1-80Hz)					
Critical areas[2]	Day or night time	0.005	0.0036	0.010	0.0072
Residences	Daytime	0.30	0.21	0.60	0.42
	Night time	0.10	0.071	0.20	0.14
Offices, schools, educational institutions and places of worship	Day or night time	0.64	0.46	1.28	0.92
Workshops	Day- or night time	0.64	0.46	1.28	0.92

Notes:
1. Daytime is 7.00am to 10.00pm and night time is 10.00pm to 7.00am
2. Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. There may be cases where sensitive equipment or delicate tasks require more stringent criteria than the human comfort criteria specify above. Stipulation of such criteria is outside the scope of their policy and other guidance documents (eg relevant standards) should be referred to. Source: BS 6472-2008
3. Source: Table 2.2, AVTG (Department of Environment and Climate Change 2006).

Table 3-9 – Preferred and maximum levels for human comfort (intermittent vibration)

	Assessment period1	Preferred values	Maximum values
Intermittent vibration (Vibration Dose Values, VDV, m/s$^{1.75}$, 1-80Hz)			
Critical areas[2]	Day or night time	0.10	0.20
Residences	Daytime	0.20	0.40
	Night time	0.13	0.26
Offices, schools, educational institutions and places of worship	Day or night time	0.40	0.80
Workshops	Day or night time	0.80	1.60

Notes: 1. Daytime is 7.00am to 10.00pm and night time is 10.00pm to 7.00am

2. Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. These criteria are only indicative, and there may be a need to assess intermittent values against the continuous or impulsive criteria for critical areas, as noted in BS 6472–1992

3. Source: Table 2.4, AVTG (Department of Environment and Climate Change 2006).

3.4.5.2 Structural damage to buildings

Potential structural damage of buildings by vibration is typically managed by ensuring vibration impacting the structure does not exceed certain limits and standards, such as British Standard BS 7385: Part 2 *Evaluation and measurement of vibration in buildings* (BSI, 1993) (BS 7385-2) and German Standard DIN 4150-3 *Structural vibration – Effects of vibration on structures* (DIN, 2016) (DIN 4150-3). As outlined in the CNVG, guidance for cosmetic damage of structures is provided in the BS 7385-2, while DIN 4150-3 has criteria of particular reference for heritage structures.

There is no current Australian Standard for assessing structural building damage caused by vibration.

BS 7385-2 can be used as a guide to assess the likelihood of building damage from ground vibration. The standard suggests levels at which 'cosmetic', 'minor' and 'major' categories of damage might occur. Damage consists of minor non-structural effects such as hairline cracks on drywall surfaces, hairline cracks in mortar joints and cement render, enlargement of existing cracks and separation of partitions or intermediate walls from load bearing walls. 'Minor' damage is considered possible at vibration magnitudes which are twice those given and 'major' damage to a building structure may occur at levels greater than four times those values.

BS 7385-2 is based on peak particle velocity and specifies damage criteria for frequencies within the range 4 Hz to 250 Hz, being the range usually encountered in buildings. At frequencies below 4 Hz, a maximum displacement value is recommended. The values set in the standard relate to transient vibrations and to low rise buildings. Continuous vibration can give rise to dynamic magnifications due to resonances and may need to be reduced by up to 50 per cent. Table 3-10 sets out the BS 7385-2 safe limits for cosmetic damage.

Table 3-10 – BS 7385-2 cosmetic damage safe limits

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	Un-reinforced 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

For most construction activities involving intermittent vibration sources such as rock hammers, piling rigs, vibratory rollers, excavators and the like, the predominant vibration energy occurs at frequencies greater than 4 Hz (and usually in the 10 Hz to 100 Hz range). On this basis, the following vibration level (PPV) has been adopted as the assessment criteria for sound structures:

- Reinforced or framed structures – 25 mm/s
- Unreinforced or light framed structures – 7.5 mm/s.

For assessment purposes, a conservative vibration damage screening level of **7.5 mm/s** has been adopted for **sound structures** to identify where further investigation is required.

For structures where the predicted and/or measured vibration levels are greater than shown above (peak component particle velocity) a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure is required during detailed construction planning to determine the applicable safe vibration level and approach to construction near the structure.

3.4.5.3 Heritage structures

Heritage items are considered on a case by case basis, and care should be taken as these structures can be difficult to repair in the case of damage. It should be noted that British Standard BS 5228-1:2009 *Code of practice for noise and vibration control on construction and open sites* (BSI, 2009) (BS 5228-1) states that 'a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive' when compared to other structures.

Where a structure is found to have defects, or is structurally unsound following an inspection, maximum vibration criteria are to be established for that specific structure for works to not further damage the structure. As stated previously, DIN 4150-3 provides guidance for structures that are sensitive to vibration (eg structurally unsound).

A conservative vibration damage screening level of **2.5 mm/s** has been adopted for **heritage structures**. This does not necessarily reflect that there would be a vibration impact on the structure if this level is exceeded. Instead, it is a suitable vibration level that can be used as part of the construction vibration management process to trigger further investigation.

Any heritage structure predicted to exceed the screening level would be further investigated during detailed construction planning, and appropriate vibration criteria for the structure adopted. If a heritage

building or structure is found to be structurally unsound (following inspection), the conservative cosmetic damage objective of 2.5 mm/s peak component particle velocity (from DIN 4150-3) would be considered, and appropriate protections put in place, as outlined in Section 6.8.

3.4.5.4 Damage to vibration sensitive equipment

Some high technology manufacturing facilities, hospitals and laboratories use equipment that is highly sensitive and susceptible to vibration, for example scanning electron microscopes and micro-electronic manufacturing facilities. In addition, buildings housing sensitive computer or telecommunications equipment may require assessment against stricter criteria than those nominated for building damage.

There is no explicit guidance on acceptable vibration levels for sensitive equipment, so recommended vibration levels should be obtained from instrument manufacturers. In the absence of equipment specific data provided by manufacturers, there are generic vibration limits that can be used to assess the impact of vibration generating activities on buildings housing vibration sensitive equipment.

Vibration Criterion (VC) curves are often referred to as they are generic and apply to all tools/equipment types within each category. The VC curves are defined over the frequency range 8 Hz to 100 Hz.

Table 3-11 summarises a range of suitable vibration limits that are applicable to buildings housing vibration sensitive equipment which may potentially be affected by construction works associated with the project.

Table 3-11 – Acceptable vibration limits on building structure housing sensitive equipment

Equipment requirements	Vibration limit[1] mm/s,		Description of use
	rms	Peak [4]	
Computer areas[2]	0.7	1.0	Barely perceptible vibration. Adequate for computer equipment accommodation environments.
Medical[2, 3]	0.1	0.14	Vibration not perceptible. Suitable in most instances for microscopes to 100X and for other equipment of low sensitivity.
VC-A[3]	0.05	0.07	Vibration not perceptible. Adequate in most instances for optical microscopes to 400X, microbalances, optical balances, proximity and projection aligners, etc.

Notes:
1. As measured in one-third octave bands of frequency over the frequency range 8 to 100 Hz. Vibration measured on the building structure near vibrating equipment or in areas containing sensitive equipment
2. Based on Australian Standard AS 2834-1995 *Computer Accommodation*
3. Colin G. Gordon '*Generic vibration criteria for vibration-sensitive equipment*' SPIE 3786 (1999)
4. In the absence of peak limits, rms limits are converted to Peak by conservatively assuming the vibration signal is sinusoidal and random with a nominal crest factor of 1.414.

3.4.5.5 Damage to buried utilities

Section 5.3 of DIN 4150-3 also sets out guideline values for vibration velocity to be used when evaluating potential effects of vibration on buried pipework. These values, which apply at the wall of the pipe, are reproduced and presented in Table 3-12. As part of detailed construction planning, these vibration limits should be considered (in consultation with the relevant utility service provider) to minimise the potential for damage to buried utilities from vibration impacts.

Table 3-12 – Acceptable vibration limits for effects of short-term vibration on buried pipework

Line	Pipe Material	Guideline values for vibration velocity measured on the pipe, mm/s
1	Steel (including welded pipes)	100
2	Clay, concrete, reinforced concrete, pre-stressed concrete, metal (with or without flange)	80
3	Masonry, plastic	50

Note: 1. Consideration must also be given to pipe junctions within the building structure as potential substantial changes in mechanical loads on the pipe must be considered.

For long-term vibration the vibration limits presented in Table 3-12 should be halved, as explained in Section 3.4.5.2.

Recommended vibration goals for electrical cables and telecommunication utilities such as fibre optic cables range from 50 mm/s to 100 mm/s. Although cables may sustain these vibration levels, the utilities they are connected to, such as transformers and switch blocks, may not. If such equipment is encountered during the construction process an individual vibration assessment should be carried out in consultation with the relevant utility service provider to assess the potential on the utility and confirm specific vibration limits to avoid potential harm.

3.4.6 Blasting noise and vibration management levels

Guidance in relation to acceptable overpressure and vibration from blasting is referenced in the ICNG, which specifies that the assessment should be based on the levels in *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration* (ANZEC, 1990) (ANZEC 1990). The CNVG refers to Australian Standard AS 2187.2-2006 *Explosives - Storage and use - Part 2 Use of explosives* (AS 2187.2-2006).

The blast vibration criteria identified in ANZEC 1990 are considered too conservative and not practical for application to this project. The criteria in ANZEC 1990 do not take into account the timeframe of the blasting in terms of annoyance. That is, for a short term project, eg blasting for tunnel construction, is assessed with the same criteria as a long term project, eg a mine site that may operate with blasting for several years. Several factors contribute to annoyance and discomfort caused by blasting. These include the loudness, duration and the number of events plus the time of day and the nature of the disturbance. Unlike ANZEC 1990, AS 2187.2-2006 provides airblast overpressure criteria and blast ground vibration limits for different type/length of blasting operations. The limits presented in AS 2187.2-2006 are identical to the ANZEC 1990 for long-term operations (lasting longer than 12 months) or more frequent blasts (greater than 20 blasts). This approach is consistent with the requirements included in the project Conditions of Approval from the Department of Planning and Environment (DPIE) for all stages of the WestConnex project stages in Sydney.

Table J4.5(A) and Table J5.4(A) of AS 2187.2-2006, reproduced in following sections, provide vibration and overpressure limits designed to safeguard human comfort from blasting, with consideration of the required duration of blasting for a project.

Table 3-13 and Table 3-15 show that the limits presented in AS 2187.2-2006 for long term projects (greater than 12 months) are similar to those in ANZEC 1990. Further guidance is provided where only a small amount of blasting is required or where blasting may occur for less than 12 months. AS 2187.2-2006 has therefore been adopted for the project.

3.4.6.1 Airblast overpressure

Airblast overpressure generated by blasting associated with the project should be carried so that the criteria specified in AS 2187.2-2006, reproduced in Table 3-13 and Table 3-14, is not to exceeded when measured at the most affected residence or other sensitive receiver.

Table 3-13 – Recommended airblast limits for human comfort (Table J5.4(A), AS 2187.2)

Category	Type of blasting operations	Peak sound pressure level (dBL)
Sensitive site[1]	Operations lasting longer than 12 months or more than 20 blasts	115 dBL for 95 per cent blasts per year. 120 dBL maximum unless agreement is reached with occupier that a higher limit may apply
Sensitive site[1]	Operations lasting for less than 12 months or less than 20 blasts	120 dBL for 95 per cent blasts. 125 dBL maximum unless agreement is reached with occupier that a higher limit may apply
Occupied non-sensitive sites, such as factories and commercial premises	All blasting	125 dBL maximum unless agreement is reached with the occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specifications or levels that can be shown to adversely affect the equipment operation

Notes: 1. A sensitive site includes houses and low rise residential buildings, theatres, schools, and other similar buildings occupied by people

2. The recommendations in Table J5.4(A) are intended to be informative and do not override statutory requirements with respect to human comfort limits set by various authorities. They should be read in conjunction with any such statutory requirements and with regard to their respective jurisdictions.

Table 3-14 – Recommended airblast limits for damage control (Table J5.4(B), AS 2187.2)[1]

Category	Type of blasting operations	Peak sound pressure level (dBL)
Structures that include masonry, plaster and plasterboard in their construction and also unoccupied structures of reinforced concrete or steel construction	All blasting	133 dBL maximum unless agreement is reached with the owner that a higher limit may apply
Service structures, such as pipelines, powerlines and cables located above the ground	All blasting	Limit to be determined by structural design methodology

Notes: 1. The recommendations in Table J5.4(B) are intended to be informative and do not override statutory requirements with respect to human comfort limits set by various authorities. They should be read in conjunction with any such statutory requirements and with regard to their respective jurisdictions.

3.4.6.2 Blast vibration – human comfort

The human response to vibration from blasting is considered in terms of the likelihood of complaint, so that an appropriate community consultation program can be initiated to advise potentially affected receivers of the likely impacts from blasting. AS 2187.2-2006 suggests a limit of 10 mm/s PPV for human comfort for operations lasting less than 12 months, as shown in Table 3-15.

Table 3-15 – Ground vibration limits for human comfort (Table J4.5(A), AS 2187.2)

Category	Type of blasting operations	Peak component particle velocity (PPV) (mm/s)
Sensitive site[1]	Operations lasting longer than 12 months or more than 20 blasts	5 mm/s for 95 per cent blasts per year 10mm/s maximum unless agreement is reached with the occupier that a higher limit may apply
Sensitive site[1]	Operations lasting for less than 12 months or less than 20 blasts	10 mm/s maximum unless agreement is reached with occupier that a higher limit may apply
Occupied non-sensitive sites, such as factories and commercial premises	All blasting	25 mm/s maximum unless agreement is reached with occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specifications or levels that can be shown to adversely affect the equipment operation

Notes:
1. A sensitive site includes houses and low rise residential buildings, theatres, schools, and other similar buildings occupied by people
2. The recommendations in Table J4.5(A) are intended to be informative and do not override statutory requirements with respect to human comfort limits set by various authorities. They should be read in conjunction with any such statutory requirements and with regard to their respective jurisdictions
3. The recommendations in Table J4.5(A) do not cover high rise buildings, buildings with long-span floors, specialist structures such as reservoirs, dams and hospitals, or buildings housing scientific equipment sensitive to vibration. These require special considerations, which may necessitate taking additional measurements on the structure itself, to detect any magnification of ground vibrations that might occur within the structure. Particular attention should be given to the response of suspended floors.

3.4.6.3 Blast vibration – structural damage

Ground vibration limits for control of damage to structures (excluding heritage buildings) from blasting as required under AS2187.2-2006 is shown in Table 3-16.

Table 3-16 – Ground vibration limits for control of damage to structures (Table J4.5(B), AS 2187.2)[1]

Category	Type of blasting operations	Peak component particle velocity (mm/s)
Other structures or architectural elements that include masonry, plaster and plasterboard in their construction	All blasting	Frequency-dependent damage limit criteria Tables J4.4.2.1
Unoccupied structures of reinforced concrete or steel construction	All blasting	100 mm/s maximum unless agreement is reached with the owner that a higher limit may apply
Service structures, such as pipelines, powerlines and cables	All blasting	Limit to be determined by structural design methodology

Notes:
1. The recommendations in Table J4.5(B) do not cover high rise buildings, buildings with long-span floors, specialist structures such as reservoirs, dams and hospitals, or buildings housing scientific equipment sensitive to vibration. These require special considerations, which may necessitate taking additional measurements on the structure itself, to detect any magnification of ground vibrations that might occur within the structure. Particular attention should be given to the response of suspended floors.

Transient vibration guide values for cosmetic damage in the AS2187.2-2006 are based on the BS 7385-2 which are presented in Table 3-17.

Table 3-17 – Transient vibration guide values for cosmetic damage (Table J4.4.2.1, AS 2187.2)

Group	Type of structure	Peak component particle velocity in frequency range of predominant pulse, mm/s	
		4Hz to 15Hz	15Hz and above
1	Reinforced or framed structures (industrial and heavy commercial buildings)	50	50
2	Un-reinforced or light framed structures (residential or light commercial type buildings)	15 (at 4Hz) to 20 (at 15 Hz)	20 (at 15 Hz) to 50 (above 15Hz)

Notes: 1. Values referred to are at the base of the building

2. For group 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.

To assess the likelihood of damage to heritage structures by blasting, and in the absence of specific unsound structure limits or limits for structures with particular sensitivity to vibration impacts, the structural damage screening level from general construction vibration impacts on heritage structures presented in Section 3.4.5.3 has been adopted for vibration impacts due to blasting.

Blasting has been assessed against a vibration level no greater than **(PPV) 2.5 mm/s for structurally unsound heritage structures**. This is a conservative approach to identify heritage items that need further inspection. Heritage structures identified within this screening limit would require a structural inspection and following this, an appropriate limit would need to be adopted during detailed construction planning in accordance with AS2187.2-2006 and/or BS 7385-2.

3.4.6.4 Blasting operation hours

The recommended standard construction hours of blasting in accordance with the CNVG are as following:

- 9.00am to 5.00pm Monday to Friday
- 9.00am to 1.00pm Saturday, however blasting for the project is not planned to occur on Saturday
- No blasting on Sunday or public holidays.

3.5 Operational noise and vibration

3.5.1 Operational noise and vibration guidelines and policies

The operational noise guidelines and policies, which have been adopted in the operational noise assessment for the project, are presented in Table 3-18.

Table 3-18 – Operational noise guidelines and policies

Guideline/policy document	Assessment aspect	Relevant Section
NSW Road Noise Policy (Department of Environment, Climate Change and Water, 2011)	Operational road traffic noise impacts	Section 7
Noise Criteria Guideline (Roads and Maritime Services, 2015a)	Operational road traffic noise criteria	Section 7
Application Notes – Noise Criteria Guideline (Roads and Maritime Services, 2016c)	Operational road traffic noise criteria	Section 7
Noise Mitigation Guideline (Roads and Maritime Services, 2015b)	Operational road traffic noise mitigation measures	Section 7
Noise Wall Design Guideline (Roads and Maritime Services, 2016d)	Operational road traffic noise mitigation measure	Section 7
At-Receiver Noise Treatment Guideline - Draft (Roads and Maritime Services, 2017a)	Operational road traffic noise mitigation measure	Section 7
Environmental Noise Management Manual (Roads and Traffic Authority, 2001)	Operational road traffic noise impacts	Section 7
Noise Model Validation Guideline (Roads and Maritime Services, 2018)	Operational road traffic noise model validation	Section 4.6.4
Development Near Rail Corridors and Busy Roads – Interim guideline (Department of Planning, 2008)	Operational road traffic noise impacts	Section 7
Noise Policy for Industry (Environment Protection Authority, 2017)	Fixed facilities noise impacts	Section 7.4
Noise Guide for Local Government (Environment Protection Authority, 2013)	Recreational facilities noise Impacts	Section 7.5

For details addressing the *NSW Sustainable Design Guidelines Version 4.0* (Transport for NSW, 2017) refer to Chapter 25 (Sustainability) of the environmental impact statement.

3.5.2 Operational road traffic noise criteria

Operational road traffic noise criteria are assigned to sensitive receivers using the Transport for NSW *Noise Criteria Guideline* (Roads and Maritime Services, 2015a) (the NCG). The assessment timeframe criteria are for the year of opening of the project and 10 years after opening.

The project assessment area extends to where noise levels are dominated by other roads that are not being assessed as part of the project as defined in the NCG. This is typically up to a maximum distance of 600 metres from the project works.

Residences may be assigned new, redeveloped, transition zone or relative increase criteria depending on how the project would influence traffic noise levels. The most stringent applicable criteria would be used in the assessment for each facade of the residence.

Criteria are based on the type of road development a residence is affected by due to the road project. In some instances, residences may be exposed to noise from new and redeveloped roads or different functional classes. In this instance the proportion of noise from each road is used to establish transition zone criteria and provides a smooth change in noise criteria between adjacent residences. A further check would be made to prevent large increases in noise level using the relative increase criteria.

The project involves the widening of the existing road corridors to accommodate portals to and from the tunnels and to increase the traffic carrying capacities of the existing roads. Noise from traffic travelling through the tunnels would be contained within the tunnels and would not impact noise sensitive areas on the surface.

The RNP and the NCG set road noise criteria based on the road's function in the road network and the type of road development.

The roads which form the project are classified as motorways or arterial roads because they handle through traffic bound for another locality and have characteristically heavy and continuous traffic flows. As such, the project contains the 'new road', 'redeveloped road' and 'transition zone' noise categories as described below:

New road

As per the NCG, a road is assessed as a 'new' road for any of the following cases:

- The project proposes road construction in an undeveloped corridor
- The road project changes the functional class of the road
- Widening, curve straightening or adjustment of the corridor occurs where the upgrade road pavement has been substantially realigned
- Duplication of an existing road where the new lanes have been substantially realigned from the existing corridor
- A bypass road extends beyond the existing road corridor.

The NCG defines substantial realignment of an existing road as a distance beyond a tolerance band that is six times the existing road's total lane width.

The project would involve the construction of a new access road that connects from a new signalised intersection on Burnt Bridge Creek Deviation to a new signalised intersection at Sydney Road/Maretimo Street. The access road will also provide local connectivity to the new and improved open space and recreation facilities. Receivers impacted by road traffic noise along the new access road would be subject to the 'new' road criteria.

Redeveloped road

As per the NCG, for a road to be considered 'redeveloped' rather than 'new', the existing road pavement should not be substantially realigned. Typical examples of road upgrades assessable under the 'redeveloped' noise criteria include:

- Widening/adjustment of the corridor where the road segment (including duplicated carriageway) has not been substantially realigned
- Duplication of a carriageway adjacent and parallel with the existing road corridor where the widened road has not been substantially realigned
- Duplication of a carriageway wholly within an existing corridor
- Introduction of on or off ramps to provide access through an intersection that was previously inaccessible for that direction.

The majority of surface roads associated with the project is an expansion of existing surface road corridors to increase the traffic carrying capacity within the road alignment of the existing roads. The 'redeveloped' road noise criteria would be applicable to these receivers.

Transition zone

In the areas presented in Annexure M, receivers may be exposed to noise from a redeveloped road, new road and/or an existing road. For these areas, 'transition zones' have been established accordingly in accordance with the NCG, which provide a gradual change in noise criteria according to the road type (redeveloped or new) which the receivers are most exposed to.

Relative increase criterion

A large increase in the existing level of traffic noise can cause a major change in the acoustic environment of a location. Under Section 8 of the NCG and Section 2.4 of the RNP, this is assessed using the 'Relative Increase Criterion' (RIC). The purpose of the RIC is to recognise the potential for such a change and provide a means to assess and mitigate for this type of noise impact.

Some receivers may not be currently impacted by traffic noise due to noise shielding provided by buildings located between the receiver and the road. Impacts would occur where the widened road corridor results in buildings being demolished, exposing receivers to traffic noise when they were previously well shielded. The traffic noise impact from the project would need to also comply with the RIC for these receivers.

The RIC is to be applied to the external areas of existing residential receivers impacted upon by the project. The RIC, as set out in the NCG and RNP applicable to this project, is reproduced as follows.

Table 3-19 – Relative increase criterion

Type of development	Total traffic noise level increase, dB(A)
Redevelopment of existing road	Existing traffic $L_{Aeq(period)}$ + 12 dB (external)

Notes: 1. 'Existing traffic' refers to the traffic noise levels for the relevant 'no build' scenario.

Importantly, the RIC should only be applied to receivers where the noise criteria are more stringent than the new or redeveloped road criteria. The RIC would only be applied for the project where existing traffic noise levels at the receiver are very low; for example:

- Day $L_{Aeq(15hour)}$ traffic noise ≤ 42 dB(A) for new and ≤ 47 dB(A) for redeveloped roads
- Night $L_{Aeq(9hour)}$ traffic noise ≤ 37 dB(A) for new and ≤ 42 dB(A) for redeveloped roads.

3.5.2.1 Operational road traffic noise criteria for residential receivers

A summary of the applicable traffic noise criteria in accordance with the NCG for residential receivers is presented in Table 3-20.

Table 3-20 – NCG criteria for residential receivers

Road category	Type of project/land use	Assessment criteria, dB(A)	
		Daytime (7.00am - 10.00pm)	Night time (10.00pm - 7.00am)
Freeway[4] / arterial/ sub-arterial roads	1. Existing residences affected by noise from new freeway/ arterial/sub-arterial road corridors	$L_{Aeq(15hour)}$ 55 (external)	$L_{Aeq(9hour)}$ 50 (external)
	2. Existing residences affected by noise from redevelopment of existing freeway/arterial/sub-arterial roads 3. Existing residences affected by additional traffic on existing freeways/arterial/sub-arterial roads generated by land use developments	$L_{Aeq(15hour)}$ 60 (external)	$L_{Aeq(9hour)}$ 55 (external)
	4. Existing residences affected by both new roads and the redevelopment of existing freeway/arterial/sub-arterial roads in a Transition Zone[1]	Between $L_{Aeq(15hour)}$ 55-60 (external)	Between $L_{Aeq(9hour)}$ 50-55 (external)
	5. Existing residences affected by increases in traffic noise of 12 dB(A) or more from new freeway/arterial/sub-arterial roads[2]	Between $L_{Aeq(15hour)}$ 42-55 (external)	Between $L_{Aeq(9hour)}$ 42-50 (external)
	6. Existing residences affected by increases in traffic noise of 12 dB(A) or more from redevelopment of existing freeway/arterial/sub-arterial roads[2]	Between $L_{Aeq(15hour)}$ 42-60 (external)	Between $L_{Aeq(9hour)}$ 42-55 (external)

Road category	Type of project/land use	Assessment criteria, dB(A)	
		Daytime (7.00am - 10.00pm)	Night time (10.00pm - 7.00am)
Local roads	7. Existing residences affected by noise from new local road corridors	$L_{Aeq(1hour)}$ 55 (external)	$L_{Aeq(1hour)}$ 50 (external)
	8. Existing residences affected by noise from redevelopment of existing local roads		
	9. Existing residences affected by additional traffic on existing local roads generated by land use developments		

Notes:
1. The applicable noise criteria for a particular receiver would be dependent on its location relative to where the new road joins the redeveloped road (transition zone). See Section 7.1 and Table 1 of *Noise Criteria Guideline* (Roads and Maritime Services, 2015a) for further information
2. The criteria at each facade are determined from the existing traffic noise level plus 12 dB(A)
3. L_{Aeq} noise levels represent the equivalent average energy noise level of the corresponding period
4. This covers motorways.

3.5.2.2 Operational road traffic noise criteria for non-residential receivers

The NCG also set criteria for the assessment of traffic noise on non-residential sensitive land uses such as schools, hospitals, places of worship and recreation areas. Given that there are non-residential sensitive land uses that may be potentially impacted by traffic noise from the project, the following criteria are applicable.

Table 3-21 – NCG criteria for non-residential sensitive land uses

Existing sensitive land use	Assessment criteria, dB(A)		Additional considerations
	Day (7.00am to 10.00pm)	Night (10.00pm to 7.00am)	
School classrooms	$L_{Aeq,1\ hour}$ 40 (internal) when in use	–	In the case of buildings used for education or health care, noise level criteria for spaces other than classrooms and wards may be obtained by interpolation from the 'maximum' levels shown in Australian/New Zealand Standard 2107:2016 *'Acoustics - Recommended design sound levels and reverberation times for building interiors'* (Standards Australia 2016).
Hospital wards	$L_{Aeq,1\ hour}$ 35 (internal)	$L_{Aeq,1\ hour}$ 35 (internal)	
Places of worship	$L_{Aeq,1\ hour}$ 40 (internal)	$L_{Aeq,1\ hour}$ 40 (internal)	The criteria are internal, ie the inside of a church. Areas outside the place of worship, such as a churchyard or cemetery, may also be a place of worship. Therefore, in determining appropriate criteria for such external areas, it should be established what in these areas may be affected by road traffic noise. For example, if there is a church car park between a church and the road, compliance with the internal criteria inside the church may be sufficient. If, however, there are areas between the church and the road where outdoor services may take place such as weddings and funerals, external criteria for these areas are appropriate. As issues such as speech intelligibility may be a consideration in these cases, the open space (passive use) criteria may be applied.

Existing sensitive land use	Assessment criteria, dB(A)		Additional considerations
	Day (7.00am to 10.00pm)	Night (10.00pm to 7.00am)	
Open space (active use)	$L_{Aeq,15\ hour}$ 60 (external) when in use	–	Active recreation is characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion. Passive recreation is characterised by contemplative activities that generate little noise (eg playing chess, reading) where benefits are compromised by external noise intrusion. In determining whether areas are used for active or passive recreation, the type of activity that occurs in that area and its sensitivity to noise intrusion should be established. For areas where there may be a mix of passive and active recreation, eg school playgrounds, the more stringent criteria apply. Open space may also be used as a buffer zone for more sensitive land uses.
Open space (passive use)	$L_{Aeq,15\ hour}$ 55 (external) when in use	–	
Childcare facilities	Sleeping rooms $L_{Aeq,1\ hour}$ 35 (internal) Indoor play areas $L_{Aeq,1\ hour}$ 40 (internal) Outdoor play areas $L_{Aeq,1\ hour}$ 55 (external)	–	Multi-purpose spaces, eg shared indoor play/sleeping rooms should meet the lower of the respective criteria. Measurements for sleeping rooms should be taken during designated sleeping times for the facility, or if these are not known, during the highest hourly traffic noise level during the opening hours of the facility.
Aged care facilities	–	–	Residential land use noise assessment criteria should be applied to these facilities

For non-residential receivers such as school classrooms, places of worship, childcare centres and hospitals, assessment criteria set out in the RNP applies to the interior space during its use. At this stage, since this assessment is only able to evaluate external noise exposure, internal criteria have been converted to the exterior of the building to facilitate the assessment of potential noise impact, assuming all classrooms, places of worship and hospital wards are located on the facade with the highest noise level and that windows are always open. When windows are open, it is generally accepted that the internal noise level is 10 dB(A) lower than the corresponding worst affected exterior location close to the facade. These non-residential receivers identified to exceed the external screening criterion in this assessment will require further investigation during further design development to confirm the extent of noise impact and eligibility for consideration of noise mitigation since the difference in noise from outside to inside can increase to more than 30 dB(A) depending on the building type, location of the room within the building, window type and whether the use of the space requires the window to be fully opened, slightly opened or closed.

3.5.2.3 Road traffic noise impacts from existing roads

The NCG provides guidance for assessing traffic noise from existing roads not subject to any redevelopment but is predicted to increase traffic noise levels by more than 2 dB(A) as a result of the project. An example of this is when traffic from the project uses the existing road as a detour resulting in an

increase in traffic volumes on the existing road, which in turn increases the traffic noise levels at affected receivers by more than 2 dB(A).

For these scenarios, the NCG states that the existing road criteria presented in Table 3-22 would apply.

Table 3-22 – NCG criteria for existing roads not subject to redevelopment

Existing Road Category	Target Noise Level, dB(A)	
	Day (7.00am to 10.00pm)	Night (10.00pm to 7.00am)
Freeway / motorway / arterial/ sub-arterial road	$L_{Aeq(15\ hour)}$ 60 (external)	$L_{Aeq(9\ hour)}$ 55 (external)
Local road	$L_{Aeq(1\ hour)}$ 55 (external)	$L_{Aeq(1\ hour)}$ 50 (external)

3.5.2.4 Maximum road traffic noise levels

Maximum noise levels generated by road traffic noise have the potential to cause disturbance to sleep. Although noise goals are not provided in the RNP, the RNP includes a review of internal sleep arousal research. The RNP concludes that there appears to be insufficient evidence to set new indicators for potential sleep disturbance due to road traffic noise. Nevertheless, Transport for NSW recognises the potential impacts and requires an assessment of maximum noise levels be made where impacts may occur during the night.

Guidance for assessing maximum noise levels is provided in Practice Note iii of the *Environmental Noise Management Manual* (RTA 2001) (ENMM). The maximum noise assessment should be used as a tool to help prioritise and rank mitigation strategies. It should not be used as a decisive criterion in itself and should not be used to aid in designing the degree of mitigation required.

The assessment considers the following:

- Calculation of maximum noise levels
- The extent to which the maximum noise levels for individual passing vehicles exceed the L_{Aeq} noise level for each hour of the night; ie L_{Amax} noise levels greater than 65 dB(A) where $L_{Amax} - L_{Aeq(1\ hour)} \geq 15$ dB(A).

At locations where road traffic is continuous rather than intermittent, the $L_{Aeq(9\ hour)}$ criteria for operational noise assessment should sufficiently account for sleep disturbance impacts. However, where the emergence of L_{Amax} over the ambient L_{Aeq} is equal to or greater than 15 dB(A), the $L_{Aeq(9\ hour)}$ criteria may not sufficiently account for sleep disturbance impacts.

3.5.3 Operational vibration

Vibration from traffic travelling through the tunnels and the operations of the fixed facilities would be considered insignificant and would not impact sensitive areas on the surface. This is further addressed in Section 7.5.

3.5.4 Operational fixed facilities noise

Noise from the operation of the fixed facilities associated with the project may adversely impact nearby affected sensitive receivers. The principal elements of fixed facilities would include:

- Tunnel ventilation fans located within motorway facilities
- Jet fans located throughout the mainline and ramp tunnels
- Egress passage ventilation fans
- Mechanical and electrical plant associated with substations, fire pump buildings, and wastewater treatment plant.

The above elements are considered industrial noise sources, as opposed to road traffic noise or construction noise sources.

3.5.4.1 Fixed facilities noise objectives

Noise impacts from the fixed facilities are to be assessed against the NSW Environment Protection Authority's (NSW EPA) NPfI. The NPfI sets a project noise trigger level for industrial noise sources that if exceeded, would indicate a potential noise impact on the community and would trigger a response of investigating feasible and reasonable noise mitigation and management measures. **The project noise trigger level is the lowest value of the project intrusive noise level and the project amenity level**. The project intrusive noise level aims to protect against substantial changes in noise levels, while the project amenity noise level seeks to protect against cumulative noise impacts from all industrial noise sources and maintain the amenity for a particular area of land use. The assessment is for total noise emissions from all noise sources associated with each fixed facility.

In addition to the project noise trigger levels, maximum noise levels are also assessed to determine the potential for sleep disturbance to residents, as required in accordance with the NPfI.

Assessment time periods

Criteria for the assessment of operational fixed facility noise are usually derived from the existing noise environment of an area, excluding noise from the project.

As the noise environment of an area almost always varies over time, background noise levels need to be determined for the purpose of determining project noise trigger levels. The NSW NPfI outlines the standard time periods over which the background noise levels are to be determined:

- **Day** is defined as 7.00am to 6.00pm, Monday to Saturday and 8.00am to 6.00pm Sunday and Public Holidays
- **Evening** is defined as 6.00pm to 10.00pm, Monday to Sunday and Public Holidays
- **Night** is defined as 10.00pm to 7.00am, Monday to Saturday and 10.00pm to 8.00am Sunday and Public Holidays.

Project intrusiveness noise level

According to the NPfI, the intrusiveness of a noise source may generally be considered acceptable if the equivalent continuous (energy-average) A-weighted level of noise from the source (represented by the L_{Aeq} descriptor), measured over a 15 minute period, does not exceed the background noise level measured in the absence of the source by more than 5 dB(A). The intrusiveness noise level seeks to limit the degree of change the new source adds to an existing noise environment. The intrusiveness noise level is applicable to residential premises only.

The intrusiveness noise level is summarised as follows:

- **$L_{Aeq,15\ minute}$ = Rating Background Level (RBL) plus 5 dB.**

Project amenity noise level

The recommended amenity noise levels presented in Table 2.2 of the NPfI represent the noise objectives for the total noise at a receiver location from industrial sources. The project amenity noise level represents the noise objective for a single industrial noise source at a receiver location.

To ensure total noise levels from industrial sources (existing and new) remain within the recommended amenity noise levels for an area, a project amenity noise level applies as follows:

- **Project amenity noise level = Recommended amenity noise level minus 5 dB(A).**

Given that the intrusiveness noise level is based on a 15 minute assessment period and the project amenity noise level is based on day, evening and night assessment periods, the NPfI provides the following guidance on adjusting the $L_{Aeq,period}$ level to a representative $L_{Aeq,15\ minute}$ level to standardise the time periods.

- **$L_{Aeq,15\ minute}$ = $L_{Aeq,period}$ + 3 dB.**

For this project, existing residential receivers that would be potentially affected by noise from the fixed facilities are considered to be 'urban residential' type receivers as the acoustical environment adjacent to all the fixed facility locations has through-traffic with characteristically heavy and continuous traffic flows during peak periods, as defined in the Table 2.3 of the NPfI. Furthermore, other land use receivers may also be impacted by noise from the fixed facilities. The applicable project amenity noise levels, based upon the NPfI, are presented in Table 3-23.

Table 3-23 – Project amenity noise levels

Receiver	Noise amenity area	Time of day	Amenity noise level $L_{Aeq(Period)}$, dB(A)	
			$L_{Aeq,\ Period}$	$L_{Aeq(15\ minute)}$
Residence	Urban	Day	60 – 5 = 55	55 + 3 = **58**
		Evening	50 – 5 = 45	45 + 3 = **48**
		Night	45 – 5 = 40	40 + 3 = **43**
	Suburban	Day	55 – 5 = 50	50 + 3 = **53**
		Evening	45 – 5 = 40	40 + 3 = **43**
		Night	40 – 5 = 35	35 + 3 = **38**

Receiver	Noise amenity area	Time of day	Amenity noise level $L_{Aeq(Period)}$, dB(A)	
			$L_{Aeq, Period}$	$L_{Aeq(15 minute)}$
Hotels, motels, caretakers' quarters, holiday accommodation, permanent resident caravan parks	See column 4	See column 4	5 dB(A) above the recommended amenity noise level for a residence for the relevant noise amenity area and time of day	
School classrooms - internal	All	Noisiest one hour period when in use	35 – 5 = 30	30 + 3 = **33**
Hospital ward	All	Noisiest one hour period		
- internal			35 – 5 = 30	30 + 3 = **33**
- external			50 – 5 = 45	45 + 3 = **48**
Place of worship - internal	All	When in use	40 – 5 = 35	35 + 3 = **38**
Area specifically reserved for passive recreation (eg national park)	All	When in use	50 – 5 = 45	45 + 3 = **48**
Active recreation area (eg school playground, golf course)	All	When in use	55 – 5 = 50	50 + 3 = **53**
Commercial premises	All	When in use	65 – 5 = 60	60 + 3 = **63**
Industrial premises	All	When in use	70 – 5 = 65	65 + 3 = **68**

In accordance with the NPfI, where existing transport noise (eg traffic noise) is high enough to make noise from an industrial source effectively inaudible and the existing traffic noise level is 10 dB(A) higher than the applicable recommended amenity noise level for the area, then in such cases the project amenity noise level would be derived as follows:

- **High traffic project amenity noise level = $L_{Aeq,period(traffic)}$ minus 15 dB(A).**

3.5.4.2 Annoying noise characteristics adjustments

Where the character of the industrial noise is assessed as particularly annoying (ie if it has an inherently tonal, low frequency, impulsive or is intermittent at night), then an adjustment would be added to penalise the noise for its potential increase in annoyance. The NPfI provides definitive procedures for determining whether a modifying factor should be applied. The definitions of the modifying factors applicable to the fixed facilities are presented in Table 3-24, reproduced from Fact Sheet C of the NPfI.

Table 3-24 – Modifying factor corrections

Factor	Assessment/ measurement	When to apply	Correction[1]	Comments
Tonal noise	One-third octave band analysis using objective method for assessing the audibility of tones in noise – simplified method (ISO1996.2-2007 – Annex D)	Level of one-third octave band exceeds the level of the adjacent bands on both sides by: • 5 dB or more if the centre frequency of the band containing the tone is in the range 500 to 10,000 Hz • 8 dB or more if the centre frequency of the band containing the tone is 160 to 400 Hz inclusive • 15 dB or more if the centre frequency of the band containing the tone is in the range 25 to 125 Hz	5 dB[2,3]	Third octave measurements should be carried out using unweighted or Z-weighted measurements. Note: Narrow-band analysis using the reference method in ISO1996-2:2007, Annex C may be required by the consent/regulatory authority where it appears that a tone is not being adequately identified, eg where it appears the tonal energy is at or close to the third octave band limits of contiguous bands.
Low frequency noise	Measurement of source contribution C-weighted and A-weighted level and on-third octave measurements in the range 10 to 160 Hz	Measure/assess source contribution C- and A- weighted $L_{A,T}$ levels over same time period. Correction to be applied where the C minus A level is 15 dB or more and: • Where any of the one-third octave noise levels in Table C2 are exceeded by up to and including 5 dB and cannot be mitigated at 2 dB(A) positive adjustments to measures/predicted A-weighted levels applies for the evening/night period • Where any of the one-third octave noise levels in Table C2 are exceeded by more than 5 dB and cannot be mitigated, a 5 dB(A) positive adjustment to measured/predicted A-weighted levels applies for the evening/night period and a 2 dB(A) positive adjustment applies for the daytime period.	2 or 5 dB[2]	A difference of 15 dB or more between the C- and A-weighted measurements identifies the potential for an unbalanced spectrum and potential increased annoyance. The values in Table C2 are derived from Moorhouse (2011) for DEFRA fluctuating low-frequency noise criteria with corrections to reflect external assessment locations.

Notes:
1. Corrections to be added to the measured or predicted levels
2. Where a source emits tonal and low-frequency noise, only one 5 dB correction should be applied if the tone is in the low-frequency range, that is, at or below 160Hz
3. Where narrow band analysis using the reference method is required, as outlined in column 5, the correction would be determined by the International Standard ISO 1996-2:2007 *Acoustics - Description, measurement and assessment of environmental noise - Part 2: Determination of environmental noise levels* (ISO,2007) (ISO1996-2).

3.5.4.3 Sleep disturbance

For operational noise, guidance for the assessment of maximum noise levels leading to sleep disturbance is taken from the NPfI. The NPfI states:

> *"The potential for sleep disturbance from maximum noise level events from premises during the night time period needs to be considered. Sleep disturbance is considered to be both awakenings and disturbance to sleep stages.*

Where the subject development/premises night time noise levels at a residential location exceeds:

- *$L_{Aeq,\ 15\ min}$ 40 dB(A) or the prevailing RBL plus 5 dB, whichever is greater, and/or*
- *L_{AFmax} 52 dB(A) or the prevailing RBL plus 15 dB, whichever is greater*

a detailed maximum noise level event assessment should be undertaken.

The detailed assessment should cover the maximum noise level, the extent to which the maximum noise level exceeds the rating background noise level, and the number of times this happens during the night time period. Some guidance on possible impact is contained in the review of research results in the NSW Road Noise Policy.

Other factors that may be important in assessing the extent of impacts on sleep include:

- *How often high noise events will occur*
- *The distribution of likely events across the night time period and the existing ambient maximum events in the absence of the subject site*
- *Whether there are times of day when there is a clear change in the noise environment (such as during early-morning shoulder periods).*

Maximum noise level event assessments should be based on the L_{AFmax} descriptor on an event basis under 'fast' time response.

The detailed assessment should consider all feasible and reasonable noise mitigation measures with a goal of achieving the above trigger levels."

For maximum noise level events, the NSW RNP identifies in its summary on sleep disturbance research to date that:

- *Maximum internal noise levels below 50–55 dB(A) are unlikely to awaken people from sleep*
- *One or two noise events per night, with maximum internal noise levels of 65–70 dB(A), are not likely to affect health and wellbeing significantly.*

The above references identify that internal noise levels of 50 to 55 dB(A), are unlikely to cause awakenings. On the assumption that there is a 10 dB(A) outside to inside noise loss through an open window (see Section 2.6 of the NPfI, p15), this indicates that external noise levels of L_{Amax} 60 to 65 dB(A) are unlikely to cause awakening reactions.

In summary, the sleep disturbance initial screening assessment in accordance with the NPfI has identified receivers that exceed:

- $L_{Amax} \geq L_{A90(15\ minute)}$ + 15 dB(A), except in cases where the screening criterion is below 52 dB(A), then 52 dB(A)
- $L_{Aeq} \leq L_{A90(15\ minute)}$ + 5 dB(A), except in cases where the screening criterion is below 40 dB(A), then 40 dB(A).

Where the L_{Aeq} and L_{Amax} levels exceed the screening criterion, further assessment would be carried out for possible sleep disturbance impacts.

3.5.5 Recreation facilities noise

Noise from the use of the new and improved open space and recreation facilities at Balgowlah could potentially impact nearby noise sensitive receivers.

In the absence of specific noise criteria, noise emissions from the open space and recreation facilities at Balgowlah was assessed against the *Noise Guide for Local Government* (Environment Protection Authority, 2013) (the NGLG). In accordance with the NGLG, noise emissions from the open space and recreation facilities were assessed for intrusive noise, as specified in the NPfI as follows:

- **$L_{Aeq(15\ minute)} \leq$ Rating Background Level (RBL) plus 5 dB**

The residential receivers most affected by noise from the open space and recreation facilities are located within Balgowlah in NCA 48.1 to the south and NCA 50.1 to the east. Based on the measured background noise levels at the monitoring locations corresponding to the affected NCAs, the applicable intrusiveness criteria are presented in the following table.

It is noted that the open space and recreation facilities are anticipated to operate during the day and evening periods (up to 10.00pm). Therefore, noise impacts would be assessed against the quieter evening period.

Table 3-25 – Applicable intrusiveness criteria

Noise catchment area	$L_{Aeq,15minute}$ noise criteria, dB(A)
NCA 48.1	50^1 + 5 = **55**
NCA 50.1	45^2 + 5 = **50**

Notes: 1. Monitored background noise level for the evening period at Location L35, representing NCA 48.1 (Balgowlah)
2. Monitored background noise level for the evening period at Location L36, representing NCA 50.1 (Balgowlah).

4 Assessment methodology

This section presents the methodology and assumptions adopted for the assessment of both the construction and operational noise and vibration impacts from the project. Construction works and predicted noise and vibration outcomes reported would be reviewed during further design development and construction planning to re-evaluate all mitigation and management measures as required.

4.1 Overview of method for assessing construction noise and vibration

The process for assessing construction noise and vibration impacts is detailed in Figure 4-1.

Figure 4-1 – Process for assessing construction noise and vibration

1. Determine noise and vibration objectives

For each key construction area:

- Identify noise sensitive receiver buildings **(building containing multiple receivers are considered as a single receiver for the purposes of this assessment**)
- Determine relevant noise and vibration objectives, with reference to Section 3.

2. Identify construction stages/scenarios

For each key construction area:

- Identify construction aspects or stages and key activities for each stage
- Including:
  - the site location
  - times of operation
  - processes involved
  - plant and equipment (including size and type).
- Identify other construction projects in the vicinity of the project to ensure cumulative noise and vibration impacts are managed, in particular in relation to work outside standard construction hours (out of hours work or OOHW).

3. Predict noise and vibration impacts	
Airborne construction noise	• Determine $L_{Aeq(15\ minute)}$ sound power levels based on construction scenarios for input to noise model (see below) • Establish noise model for construction activity/component • The noise model should include: - Height and location of sources and receivers - Distance attenuation (incorporating noise reflections and ground absorption) - Effects of noise shielding (topography, buildings, boundary fences, noise barriers etc) - Effects of feasible and reasonable standard noise mitigation and management measures and any incorporated noise treatment measures. • Calculate the $L_{Aeq(15\ minute)}$ noise levels from the proposed construction activities at each receiver and compare these with the construction noise objectives • For night time activities, calculate the maximum (L_{Amax}) noise levels and compare with L_{Amax} sleep disturbance criterion.
Ground-borne construction noise	• Determine the reasonable worst case location of each plant or equipment item likely to generate ground-borne noise in relation to each receiver • On the basis of ground-borne noise levels versus distance prediction curves for each plant item, determine the potential level of ground-borne noise at each building location.
Construction vibration	• Determine the reasonable worst case location of each vibration intensive plant or equipment item in relation to each receiver • Determine the reasonable worst case vibration intensive plant that would operate within each construction support site, and the minimum working distances for this plant item that would achieve the vibration screening levels for sound and unsound structures, and for human response, as presented in Table 4-11 • Assess if vibration intensive equipment could potentially be operating within the minimum working distances for nearby receivers or heritage items, and so potentially exceed recommended criteria. Note that minimum working distances may differ for heritage items.

4. Assess noise and vibration impacts	
Where predicted noise and vibration exceeds the objectives identified in Step 1.	• Identify appropriate reasonable/feasible standard mitigation measures (see Annexure G) • Predict noise levels at receivers, incorporating further mitigation and management measures to minimise the number of receiver locations where noise exceeds the NMLs • Review vibration intensive equipment and determine if and where vibration monitoring may be required during construction, as vibration sensitive equipment within minimum working distances may exceed recommended criteria • Identify additional potential mitigation measures for further consideration to manage residual impacts.

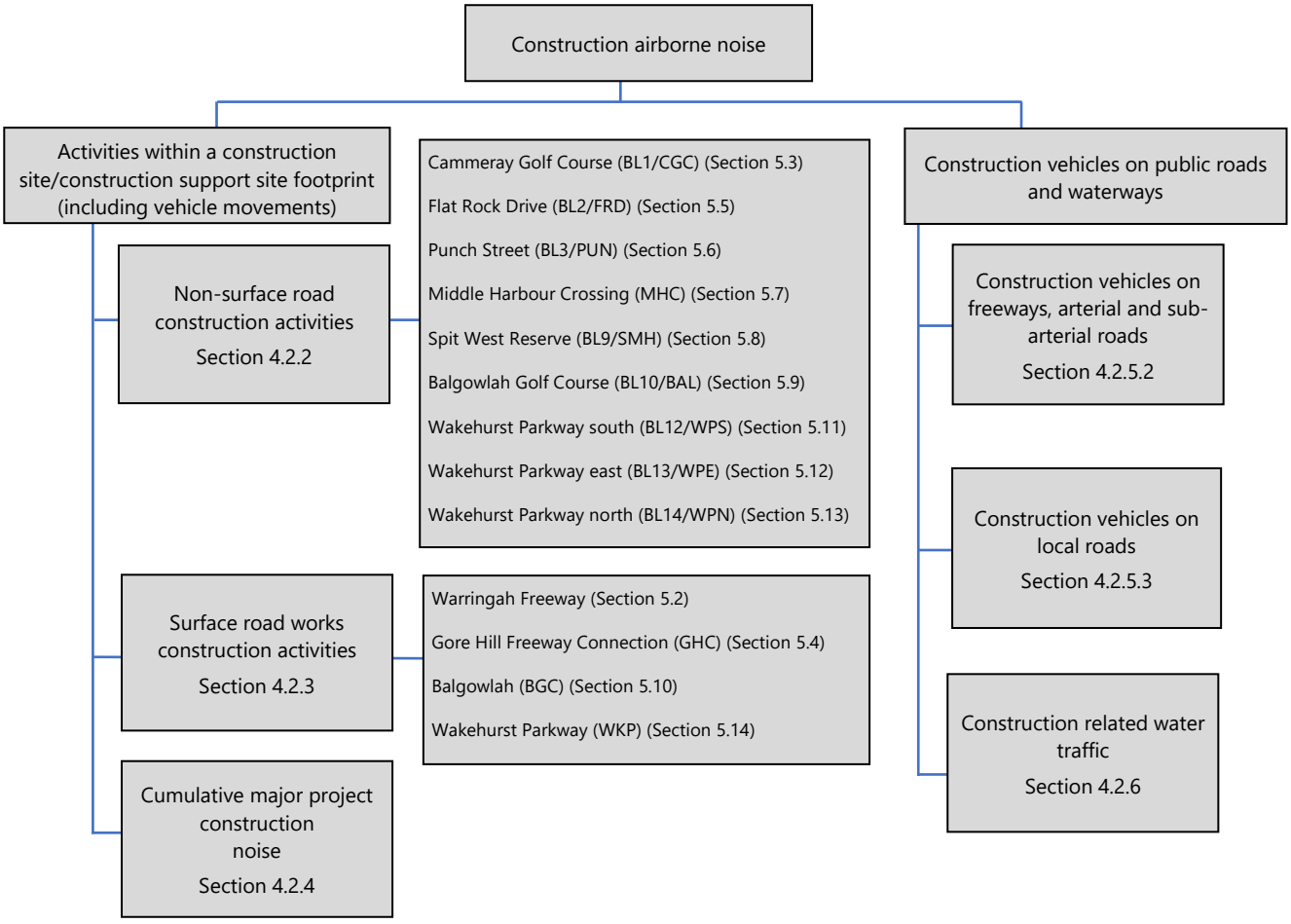
4.2 Airborne construction noise

An assessment of the potential level of construction noise impacts has been carried out to determine the degree of impacts and compliance with NMLs, whether noise mitigation measures would be required, and to determine appropriate management controls, based on proposed staging and activities.

Detailed specifications for required construction equipment would be determined during the detailed construction planning stages. This may change or influence the mitigation and management measures required to manage noise and vibration impacts. The type and number of plant and equipment associated with each assessment stage for the proposed works have been developed based on experience with similar construction projects and input from Transport for NSW.

Two different modelling approaches have been used in this assessment of construction airborne noise impacts. Presented in Figure 4-2 are the construction airborne noise methodologies used for the project construction sites and construction support sites, and the applicable report sections in which each item is addressed.

Figure 4-2 – Applicable construction airborne noise methodologies for construction works



4.2.1 Model development

Airborne noise impacts from activities associated with the construction works were assessed by modelling the noise sources, receiver building (a receiver building represents an individual building such as house or apartment building) locations, topographical features, and possible noise mitigation measures using a computer noise model developed for this project.

The model calculates the contribution of each noise source to each identified noise sensitive receiver building location surrounding the work site and allows for the prediction of the total noise from a work area or construction support site for the various stages of construction work.

The noise prediction model considers:

- Location of noise sources and sensitive receiver building locations
- Height of sources and receivers referenced to one metre digital ground contours for the site and surrounding area
- Each noise sensitive building in the project has been assessed separately, considering all facades, except educational institutions and similar with multiple buildings, which are considered as one noise sensitive receiver
- Sound Power Levels (SWL) of plant and equipment likely to be used during the various construction activities
- Separation distances between sources and receivers
- Ground type between sources and receivers
- Attenuation from barriers and topography (natural and purpose built), including existing road noise barriers
- Noise propagation calculated using the implementation of the noise propagation algorithm ISO 9613-2 *Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation* (ISO,1996) (ISO 9613-2), which incorporates moderately adverse meteorological conditions, implemented in accordance with ISO/TR 17534-3 *Acoustics - Software for the calculation of sound outdoors - Part 3: Recommendations for quality assured implementation of ISO 9613-2 in software according to ISO 17534-1* (ISO,2015) (ISO/TR 17534-3), based on a typical ground absorption of 0.5, and zero for hard/acoustically reflective areas such as water
- Feasible and reasonable noise mitigation/treatments and management measures that have been determined for the site (ie acoustic sheds, other acoustic attenuation, on site acoustic barriers).

Construction noise levels are assessed at the most noise affected facade and floor level of a receiver building. Construction noise levels experienced at other points on the building may be lower as demonstrated in the following figures, which show three typical scenarios where a receiver building is located 1) level with construction works, 2) at a lower ground level than the construction works and, 3) at a higher ground level than the construction works.

These figures help to demonstrate that for receivers that are further away from the construction works, or receivers that have increased acoustic shielding (ie nearby tall buildings) the potential noise levels would be less than those presented compared with highest predicted noise level for an individual receiver building.

Figure 4-3 – Noise propagation and acoustic shielding – Receiver buildings at same ground level as construction works (construction noise level, dB(A))

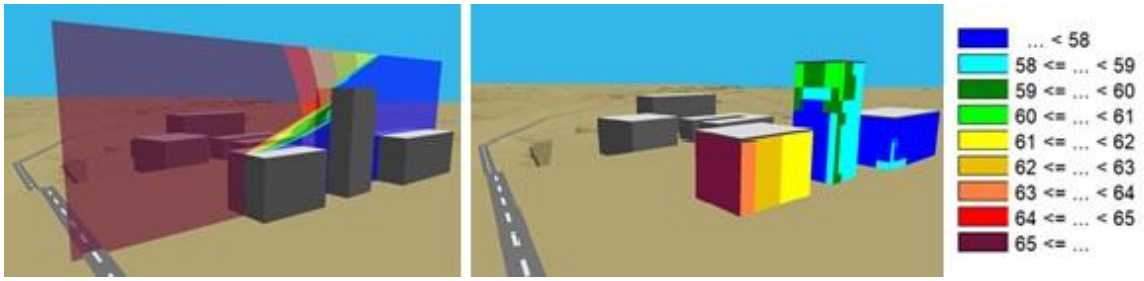


Figure 4-3 shows how noise from construction works located on a nearby road propagates away from the work site where the work site and the receiver building are at the same ground level (ie flat ground). Receiver buildings at the nearest high rise building would be exposed to similar construction noise across the entire exposed facade. The nearest buildings provide a noise barrier to the next row of buildings and the figure shows how lower floor levels would receive more substantial shielding from the building in front reducing construction noise levels.

High rise buildings may still be exposed to construction noise at the upper floor levels.

Receiver buildings further away from the construction work site, behind the nearest buildings would be exposed to substantially lower levels of construction noise (more than 15 dB(A) lower).

Figure 4-4 – Noise propagation and acoustic shielding – Receiver buildings at lower ground level than construction works (construction noise level, dB(A))



Construction noise propagating from a work site located on a nearby road at a higher ground level than the nearest receiver buildings (eg on an embankment) is demonstrated in Figure 4-4. In this example, the edge of the embankment partially shields construction noise to the lower levels of the nearest high rise building, while the upper levels of the building remain exposed to unshielded construction noise. Similarly, the noise barrier effect provided by the nearest buildings to those behind is also lessened, especially for high rise buildings, where the upper floor levels may be directly exposed to the construction work site. Receiver buildings further away from the construction site, behind the nearest buildings would be exposed to lower levels of construction noise but are more exposed than in the case presented in Figure 4-3. This is because

the buildings between this receiver and the construction work site have less of a barrier effect when the construction work site is elevated.

Figure 4-5 – Noise propagation and acoustic shielding – Receiver buildings at higher ground level than construction works (construction noise level, dB(A))

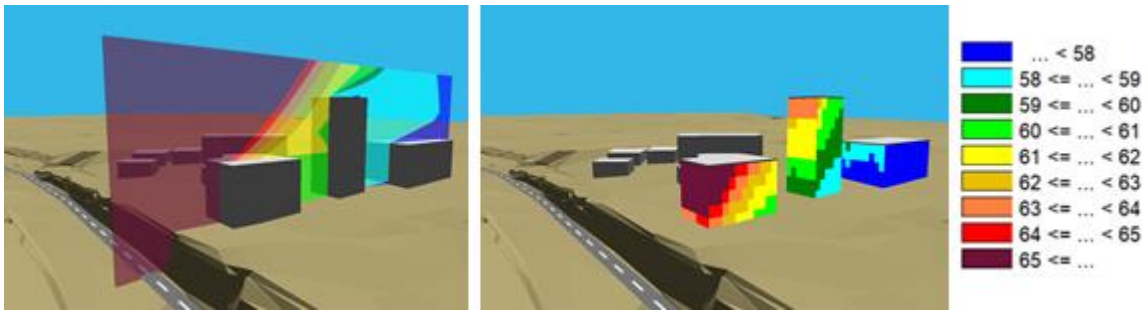


Figure 4-5 shows construction noise is propagating from a work site located on a nearby road at a lower ground level to the nearest receiver buildings (eg in a cutting). In this example the edge of the cutting partially shields construction noise to the lower levels of the nearest high rise building, while the upper levels of the building remain exposed to construction noise. Further to this, the noise barrier effect provided by the nearest buildings to those behind is increased, even to high rise buildings, where the upper floor levels are not directly exposed to the work site.

4.2.2 Construction support sites modelling

4.2.2.1 Construction noise sources

The type, number and typical operational intensity of plant and equipment associated with each of the assessed 'reasonable worst case' construction works scenarios are based on experience with similar major transport infrastructure projects and inputs from the project team as well as Transport for NSW. These are detailed in Annexure E for each construction support site.

Sound power levels for the plant and equipment modelled in this project are based on maximum levels presented in each of the construction assessment sections. These are based on Table A1 of Australian Standard 2436 - 2010 *Guide to Noise Control on Construction, Demolition and Maintenance Sites*, the CNVG, information from past projects, and information held in the Renzo Tonin & Associates (RT&A) library files from noise measurements and references.

Further details about the modelling assumptions for heavy vehicles operating within the construction support sites are detailed in Section 4.2.5.1.

4.2.2.2 Assessment scenarios

In developing a modelling scenario in accordance with the ICNG, the assessment assumes a 'reasonable worst case' set of operating plant and equipment that could occur during a 15 minute period. The assessment provides a typical representation of the potential construction noise levels for the project.

The assessment scenarios were developed to review the potential reasonable worst case impacts and are conservative, in that they assume all the equipment identified within a scenario would:

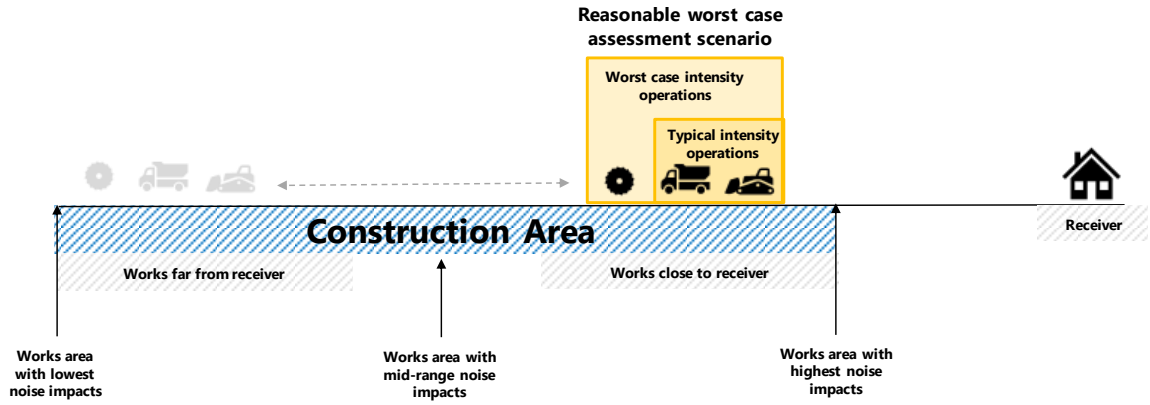
- Operate simultaneously
- Operate in a reasonable worst case condition (with mitigation or management included where noted) and in the worst case orientation, throughout a 15 minute period.

This is shown as the 'reasonable worst case assessment scenario' presented in Figure 4-6. This is conservative and unlikely to typically occur at all times and locations within work area or site. Further detailed construction planning will determine methodologies in specific locations in order to minimise noise impacts on nearby sensitive receivers.

Noise levels are likely to be lower during actual construction works. The actual noise emissions from the works and resulting noise levels at nearby receiver buildings would be influenced by:

- The location/distance of the plant/equipment with respect to the receiver building (see Figure 4-6)
- The on/off time of the plant/equipment
- The intensity with which the plant/equipment is working.

Figure 4-6 – Basis of noise and vibration assessment scenarios



The modelling result tables present the predicted noise levels for each NCA for each construction support site assessment and for each of the assessed 'reasonable worst case' assessment scenarios. These results present the range of predicted noise levels for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are expected to experience noise levels greater than the relevant NMLs. Links to these site specific assessments are included in Section 4.2.3.3 in Table 4-3.

Noise contours for key stages of each construction support site are included in Annexure H.1 representing the predicted construction noise levels at the ICNG assessment height of 1.5 metres above the local ground level.

4.2.2.3 Feasible and reasonable mitigation and management measures

Feasible and reasonable mitigation and management measures have been incorporated at the construction support sites as required by the Secretary's environmental assessment requirements (requirement 2(i)). Mitigation and management measures, including the indicative locations and heights of noise barriers and indicative acoustic performance requirements of site sheds and enclosures, have been identified in each construction support site assessment.

The indicative acoustic performance requirements have been identified for the site shed or enclosure construction and classified from low to very high, as presented in Table 4-1.

Table 4-1 – Indicative overall shed/enclosure element required acoustic performance

Shed/enclosure indicative acoustic performance	Indicative example constructions	Reference colour
Low	Single skin metal structure	
Medium	Double skin metal structure with air gap between skins	
High	Double skin structure with air gap, 1 skin metal/ 1 skin loaded vinyl or similar one side.	
	Proprietary light-weight concrete sandwich panel	
Very high	Specialist acoustic wall	
	Double skin composite large air gap metal structure	
	Concrete panel/specialist acoustic construction	

Various building elements are further detailed in each construction support site assessment. Each shed design is indicative of what would be needed to sufficiently reduce noise impacts at nearby sensitive receivers. The acoustic performance recommended assumes that no gaps or openings would compromise the overall acoustic performance of the structure. Enclosures, sheds and any openings would be designed to achieve relevant noise requirements during detailed construction planning.

Each construction support site would be reviewed during detailed construction planning with all mitigation and management measures reviewed and updated as required. Revised mitigation and management measures would be included in site specific CNVIS.

4.2.3 Surface road works modelling

4.2.3.1 Construction noise sources

The type, number and typical operational intensity of plant and equipment associated with each of the assessed construction works scenarios are based on experience with similar major transport infrastructure projects and inputs from Transport for NSW. For assessing surface road upgrade construction works, the equipment/plant listed in Annexure F represents the reasonable 'typical' and 'worst case' scenarios of equipment/plant operating simultaneously in any 15 minute period that has been assessed. Where plant items are not operating simultaneously, or for reduced times in a 15 minute period, noise impacts could be lower than predicted. Assumed sound power levels for the plant and equipment are outlined in Annexure F.

4.2.3.2 Modelling approach and assessment scenarios

Due to the large number and size of work areas and the variability of the types of construction activities associated with the surface road works, a slightly modified modelling approach has been used to assess and present the construction noise impacts for the surface road works.

As outlined in Section 4.2.1, the ICNG and CNVG recommends the assessment of a 'reasonable worst case' construction scenario. However, the reality of construction noise impacts is that they would vary greatly depending on the location of the construction works within the major works area, the distance between the noise sources and the nearby receivers, the noise intensity of the works, the time of day these specific activities take place and the changing noise character with all these variables. To capture this, assessment scenarios were developed to review the potential 'typical' and 'worst case' impacts. Figure 4-6 aims to visually represent the differences between these two assessments, and the impacts of construction variables on noise impacts. The assessment scenarios are considered conservative, in that they assume:

- All the equipment identified within a scenario would operate simultaneously
- The equipment operates at its loudest, in its worst case orientation without consideration of directivity, for the specific usage factor period shown in Annexure F during the 15 minute period
- All plant is operating in one location, while in actual fact plant may be scattered around the works area
- All plant is at closest location to each receiver ('Near' level, see Section 4.2.3.2.3), while in reality plant would more likely move around the works area and noise levels would reduce as plant moves away from a receiver.

These assumptions are conservative and unlikely to typically occur all at the same time for any extended length of time during the construction works. During actual construction works, noise levels are likely to be lower. The actual noise emissions from the works and resulting noise levels at nearby receivers would be influenced by:

- The location/distance of the plant/equipment with respect to the receiver (see Figure 4-6)
- The on/off time of the plant/equipment
- The intensity with which the plant/equipment is working.

Only NCAs for surface road work assessments where an exceedance of the NMLs has been predicted at a stage during the works have been presented. NCAs where compliance is achieved during all stages of the assessed works have not presented in the assessment result tables. Links to these site specific assessments are included in Section 4.2.3.3 in Table 4-3.

To achieve the requirements of the CNVG, ICNG and the Secretary's environmental assessment requirements, the following sections outline the key concepts used to assess the potential noise impacts from the surface road works across the project.

There are also potentially a number of areas outside of the major construction support sites and surface road upgrade areas where local area and utility adjustment works may be required. These works would be part of establishing construction support sites and could include utility identification works, electricity,

sewerage, communications connections and other utility adjustments, and local road works to support increased heavy vehicle movements and project requirements, such as intersection adjustments. These works would be in isolated locations and occur for relatively short periods. The final location and extent of some of these works are still being investigated and would be determined during detailed construction planning. As such, typical utility and local area work activities have been assessed to describe typical noise levels that would be associated with these works at the nearest sensitive receivers (see Section 5.15.1).

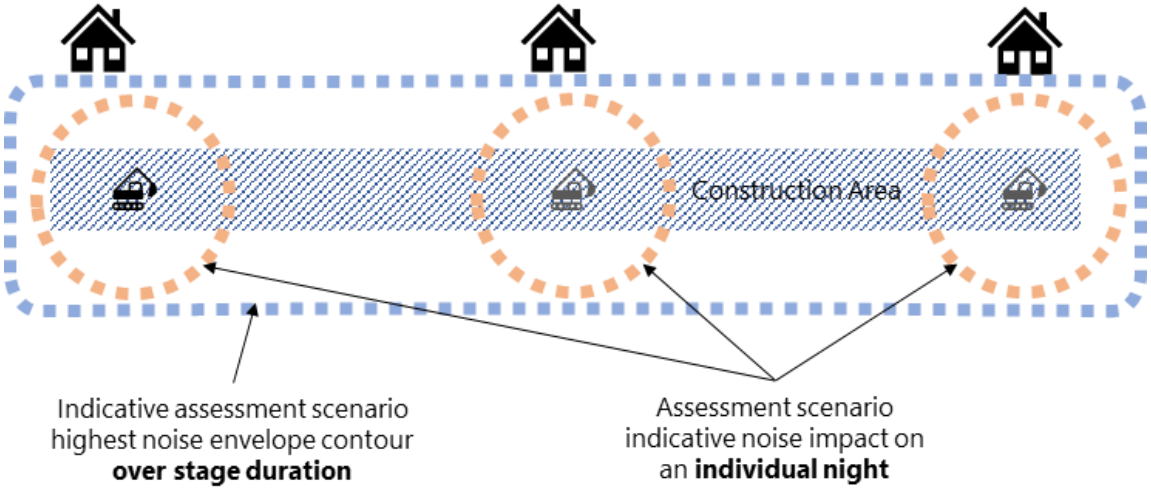
4.2.3.2.1 Highest noise level envelope

The noise impacts presented are the highest noise levels that could occur throughout a works stage. These noise levels assume that the assessed activities could occur anywhere within the assessed major works area, while in practice the construction works would generally only occur at a single location at any one time.

This means that predicted noise levels are only likely to occur when works are at the closest point in the works area to each receiver. Due to the size and extent of many of the works areas, the noise impacts may be lower than predicted as the construction activities move around or progress along the works area extent, as indicated in Figure 4-7.

Noise results are presented in Annexure H.2 as noise contour envelopes, which are the highest noise levels that could reasonably be expected to occur at the ICNG assessment height of 1.5 metres above ground level over the entire project, and do not show an individual 15 minute period during the day, evening or night.

Figure 4-7 – Indicative highest noise level envelope

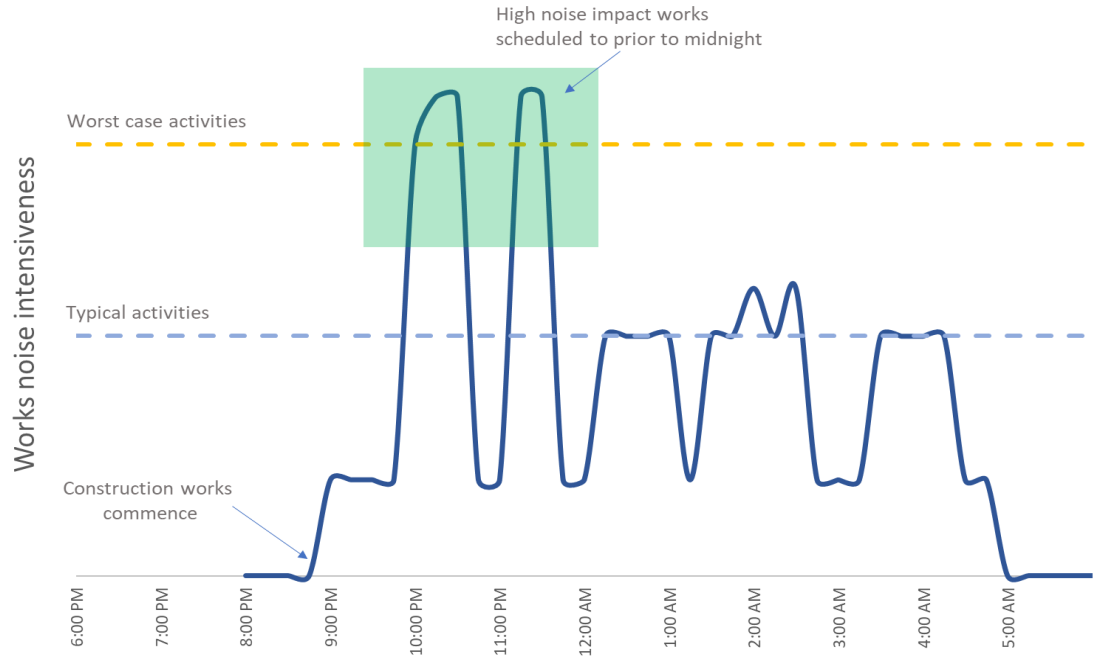


4.2.3.2.2 Typical and worst case noise impacts

For surface road works, an additional 'typical' scenario has been presented to represent the noise impacts when the loudest plant and equipment items (eg rock hammers or road saws) are not being used, but the works are still noise intensive. This is illustrated in Figure 4-6.

An indicative example of how noise intensive the works activities change and vary in time over an individual night is presented in Figure 4-8, showing how both 'typical' and 'worst case' impacts, may only occur for a small proportion of the night period.

Figure 4-8 – Example of indicative night construction works noise intensiveness – (eg utility relocations)



4.2.3.2.3 Near and far – variation in noise impacts due to location within works area

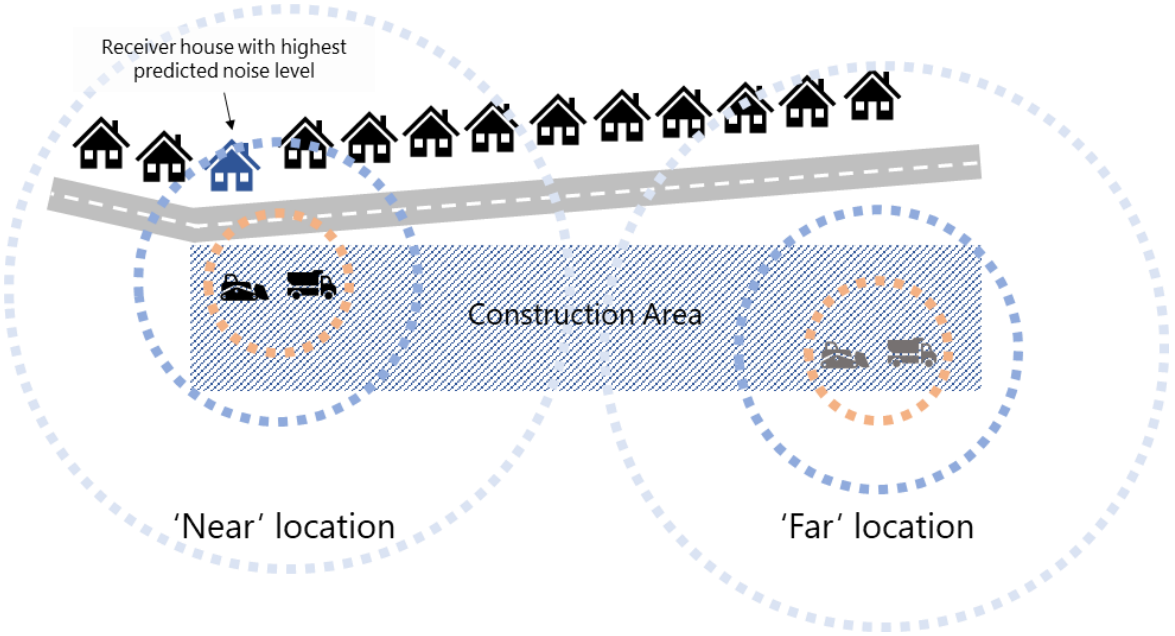
As discussed above, construction noise impacts vary based on the location of the noise intensive activities. The highest predicted impacts would not occur throughout the operation of an individual site, rather they would vary as the works take place in specific locations within the site.

The highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver are shown in the assessment as the 'Near' level. When works take place at the furthest location in the assessed work area, the noise impacts on that same receiver are presented as the 'Far' noise level. This concept is presented in Figure 4-9.

'Near' and 'Far' noise impacts may occur for progressive works such as road resurfacing activities, where the work moves along the road over the period of a night. For other work types, this may occur in various locations on various nights or periods in the construction stage.

The 'Far' noise level has been estimated based on a correction applied to the predicted 'Near' noise level. This correction takes into consideration both the smallest distance to receivers from a point in each works area, and the relative size of the works area for the nearest receiver in each NCA.

Figure 4-9 – Variation in impacts with works location within a works area



4.2.3.2.4 Surface road upgrade assessment table presentation

Figure 4-10 presents an example from the assessment tables to show how the assessment results from this modified approach are presented. It is important to note that the noise levels presented in these tables are for the receiver with the highest predicted noise level in each NCA. Predicted noise levels would be less than those presented where receivers:

- Are further away from the construction works or
- Have increased acoustic shielding (ie from nearby buildings and structures).

Figure 4-10 – Example predicted construction noise level table (surface road works)

Major works area/assessment reference				BGC1C_03	
Project stage duration				Typical	Worst case
Typical/worst case activity noise intensity				Far/Near	Far/Near
Suburb	NCA	Noise Management Level		Predicted noise levels, $L_{Aeq\ (15\ minute)}$	
		HNA	NML		
Neutral Bay	17.4	75	65	64 / 71	**74 / 81**
	18.3	75	64	48 / 51	59 / 61
	23.1	75	71	44 / 46	54 / 56
Cremorne	26.1	75	68	38 / 39	49
	27.1	75	59	< 35	40 / 41

Noise impact during **typical noise intensive activities** (eg without high impact equipment such as rock hammers)

Noise impact during **worst case noise-intensive activities** (eg with high impact equipment such as rock hammers)

Noise level at closest/highest impacted receiver building when noise-intensive works at the **closest point**.

Noise level at closest/highest impacted receiver building when noise intensive works are at the **furthest point**.

Where the predicted noise level from activities at the other end of the works area from the receiver ("Far") is less than 35 dB(A) only "<" is presented. Where a "-" is presented then construction works are not proposed during that period.

4.2.3.3 Airborne construction noise (activities within a construction site/construction support site footprint) assessment results

Site specific construction noise assessments have been carried out for each construction support site or major surface road upgrade area. Links to these site specific assessments are included in Table 4-3.

Table 4-2 – Site specific construction noise assessments

Location	Assessment method	Report section
Warringah Freeway road works	Surface road works (See 4.2.4.2)	Section 5.2.2
Cammeray Golf Course (BL1/CGC)	Construction support site (See 4.2.4.1)	Section 5.3.2
Gore Hill Freeway Connection road works (GHC)	Surface road works (See 4.2.4.2)	Section 5.4.2
Flat Rock Drive (BL2/FRD)	Construction support site (See 4.2.4.1)	Section 5.5.2
Punch Street (BL3/PUN)	Construction support site (See 4.2.4.1)	Section 5.6.2
Middle Harbour crossing (MHC)	Construction support site (See 4.2.4.1)	Section 5.7.2
Spit West Reserve (BL9/SMH)	Construction support site (See 4.2.4.1)	Section 5.8.2
Balgowlah Golf Course (BL10/BAL)	Construction support site (See 4.2.4.1)	Section 5.9.2
Balgowlah surface road works (BGC)	Surface road works (See 4.2.4.2)	Section 5.10.2
Wakehurst Parkway south (BL12/WPS)	Construction support site (See 4.2.4.1)	Section 5.11.2
Wakehurst Parkway east (BL13/WPE)	Construction support site (See 4.2.4.1)	Section 5.12.2
Wakehurst Parkway north (BL14/WPN)	Construction support site (See 4.2.4.1)	Section 5.13.2
Wakehurst Parkway surface road works (WKP)	Surface road works (See 4.2.4.2)	Section 5.14.2

4.2.4 Cumulative major project construction noise impact assessment

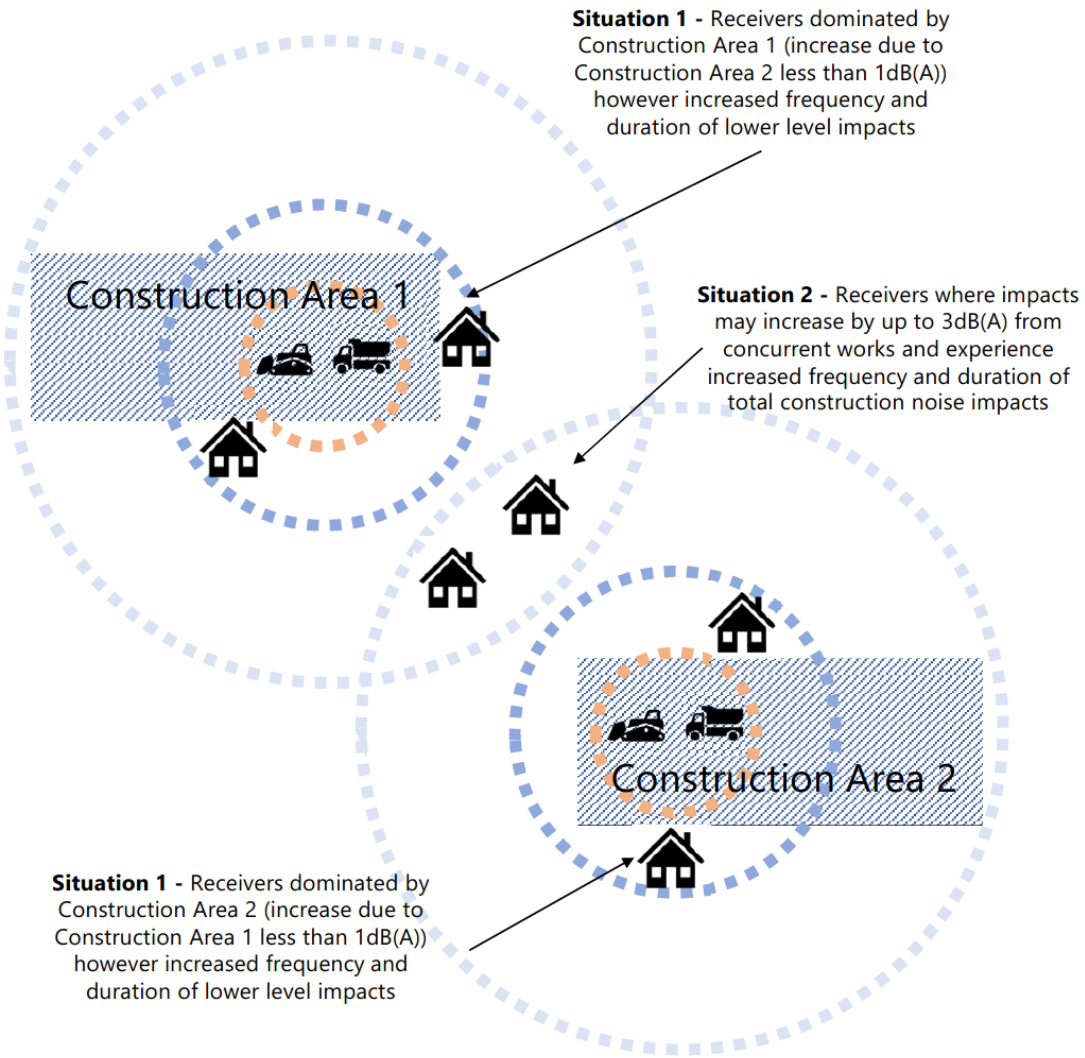
The CNVG identifies that for projects with long-term impacts, typically recommended additional mitigation measures become less effective. Subsequently, what are considered feasible and reasonable mitigation and management measures can vary based on the duration of construction noise impacts.

While impacts from one project or one construction site may be relatively short-term, when viewed in the context of all other nearby major construction works (within the project and external to the project), the overall duration of construction noise impacting a sensitive receiver may be much longer or more frequent. Typically, concurrent projects can impact nearby receiver locations in one of two ways, as also shown in **Figure 4-11**:

1. (**Figure 4-11**, Situation 1) – For receivers in close proximity to work areas, noise impacts would typically be dominated by the nearest construction work area, and any increases from concurrent works would result in minor increases (< 1 dB(A)). However, construction noise impacts at lower levels from the more distant work area can also impact these receivers, increasing the frequency and duration of total construction noise impacts.

2. (**Figure 4-11**, Situation 2) – For receivers not in close proximity to the work areas, but between the two sets of noise generating work areas, the total construction noise level that they could be exposed to from cumulative construction noise may be slightly more than from a single work area, by up to 3 dB(A). They are also likely to be exposed to a greater frequency of construction noise impacts

Figure 4-11 – Cumulative construction noise impacts



The following two assessment approaches have been used to assess the potential for cumulative noise impacts from construction projects, one applicable for the construction support sites, and the second approach is for the surface road works. These are described in the following sections.

4.2.4.1 Construction support sites

The following have been identified and included in the assessment of cumulative construction noise impacts from concurrent or consecutive sets of construction works at construction support sites:

1. Project program overlaps between construction support sites, surface road works and other major infrastructure projects (ie locations where nearby construction sites may be operating concurrently)
2. NCAs where there may be a greater frequency of noise impacts and slight increases in overall construction noise, typically for receivers not directly adjacent to the construction support site

3. Overlap of nearby major infrastructure projects with the construction support site being assessed, where there is potential impact on the same receivers both close to and further away from the construction support site.

This approach provides a full picture of potential construction noise impacts on these receivers to inform the development of feasible and reasonable mitigation and management.

4.2.4.2 Surface road works

As the surface road works can range over large works areas, and there are a range of construction activities that would take place in each work area, the level of cumulative noise impacts from concurrent works or from works that closely follow on one after the other (consecutive construction works) cannot be easily quantified. As such, the methodology used has been to identify the activities and locations where there is a greater potential for concurrent or consecutive construction noise impacts. The activities and locations would be further investigated during detailed construction planning to determine if concurrent or consecutive construction noise impacts are likely, and if further mitigation or management is required.

To assess cumulative construction noise impacts, NCAs where the 'typical' construction noise exceeds the NML, and where receivers within these NCAs could be considered 'noise affected' have been identified. This approach allows for clear identification for which works would result in the same NCA potentially noise impacted from each of the works, and as such with the potential for cumulative impacts.

4.2.4.3 Cumulative assessment results

Site specific cumulative construction noise assessments have been carried out for each construction support site or major surface road upgrade area. Links to these site specific assessments are included in Table 4-3.

Table 4-3 – Site specific cumulative construction noise assessments

Location	Assessment method	Report section
Warringah Freeway road works	Surface road works (See 4.2.4.2)	Section 5.2.2.4
Cammeray Golf Course (BL1/CGC)	Construction support site (See 4.2.4.1)	Section 5.3.2.6
Gore Hill Freeway Connection road works (GHC)	Surface road works (See 4.2.4.2)	Section 5.4.2.5
Flat Rock Drive (BL2/FRD)	Construction support site (See 4.2.4.1)	Section 5.5.2.6
Punch Street (BL3/PUN)	Construction support site (See 4.2.4.1)	Section 5.6.2.6
Middle Harbour crossing (MHC)	Construction support site (See 4.2.4.1)	Section 5.7.2.6
Spit West Reserve (BL9/SMH)	Construction support site (See 4.2.4.1)	Section 5.8.2.6
Balgowlah Golf Course (BL10/BAL)	Construction support site (See 4.2.4.1)	Section 5.9.2.6
Balgowlah surface road works (BGC)	Surface road works (See 4.2.4.2)	Section 5.10.2.5
Wakehurst Parkway south (BL12/WPS)	Construction support site (See 4.2.4.1)	Section 5.11.2.6
Wakehurst Parkway east (BL13/WPE)	Construction support site (See 4.2.4.1)	Section 5.12.2.6
Wakehurst Parkway north (BL14/WPN)	Construction support site (See 4.2.4.1)	Section 5.13.2.6
Wakehurst Parkway surface road works (WKP)	Surface road works (See 4.2.4.2)	Section 5.14.2.5

4.2.5 Construction related road traffic noise prediction methodology

This assessment methodology covers construction related traffic operating on the public road network. The assessment of noise impacts from traffic movements within the construction support site boundary are included in the overall assessment of construction support site noise emissions as per Section 4.2.2 for construction support sites, Section 4.2.3 for major surface road works and Section 4.2.4 for cumulative construction noise impacts.

Where feasible and reasonable, haulage routes would use arterial and sub-arterial roads.

Assessed heavy vehicle movements are based on the maximum projected number of movements during construction of the project, when construction works are well underway. During other stages of the project, there would be a reduced number of vehicles and a corresponding reduction in noise levels.

Two methodologies for the assessment of construction road traffic noise have been used, depending on whether construction road traffic is travelling on motorways, arterial and sub-arterial roads or local roads. Where applicable, the issue of construction vehicles exiting/entering construction support sites to/from public roads is also addressed below.

4.2.5.1 Construction heavy vehicle assumptions

A large range of heavy vehicles would be used as part of the construction works. For assessment modelling purposes, these have been separated into two categories (Table 4-4):

- Smaller heavy vehicles such as medium rigid trucks, which would typically be used for activities such as site deliveries
- Larger heavy vehicles such as heavy rigid trucks with dog trailer combinations (mainly used for spoil haulage), prime movers with trailer (such as for concrete, aggregate and sand delivery or oversized deliveries), and concrete agitators.

Table 4-4 – Heavy vehicle noise modelling assumptions for movements within construction support sites, entering/exiting the site from public roads (< 50 km/h) or moving slowly on local roads

Heavy vehicle type	Example vehicles	Sound power levels, dB(A)	
		SWL[1]	L_{Amax}[2]
Small heavy vehicle	Medium rigid trucks, medium flatbed delivery trucks	103	117 and 120
Larger heavy vehicle	Heavy rigid trucks with dog trailer combinations, prime movers with trailer, concrete agitators	108	117 and 120

Notes:
1. The noise source power level has been based on pass-by noise measurements in the field of similar heavy vehicles. The modelled levels are assumed to be average heavy vehicles operating at slow speeds (<20km/h) so as to include engine noise with various loads. Sound power levels of the heavy vehicles used for the project may differ and would be reviewed during detailed construction planning.
2. For maximum noise events from heavy vehicle movements both 117 dB(A) for heavy vehicle air brakes and 120 dB(A) for metal on metal bangs are assessed to consider both the impacts, or metal on metal bangs from heavy vehicle loads moving or shifting.

Typically, when within the boundary of a construction support site, heavy vehicles would not move faster than 10 kilometres per hour, so noise from the truck would be dominated by engine noise. When heavy

vehicles move off site, they would then accelerate away from the site at greater speeds. Noise source levels for heavy vehicles onsite, entering/exiting the site from public roads (less than 50 kilometres per hour) or moving slowly on local roads, have been based on noise measurements in the field of similar heavy vehicles travelling at low speeds when accelerating/decelerating with and without loads.

4.2.5.2 Construction traffic vehicles on freeways, motorways, arterial and sub-arterial roads

A large number of heavy vehicles already use the motorways, arterial and sub-arterial roads that would be used as construction traffic routes with substantial levels of existing traffic. The traffic using these roads is relatively constant during critical periods (ie night time). Noise levels for these roads have been calculated using the *Calculation of Road Traffic Noise (1988)* (CoRTN88) method to determine if the overall change in road traffic noise level caused by the project's construction vehicles could potentially be more than the 2 dB(A) initial screening test as per the CNVG.

4.2.5.3 Construction traffic on local roads

Existing road traffic noise levels from local roads is typically low. This assessment has assumed the project construction traffic noise from heavy vehicles would likely dominate the overall road traffic noise on these local roads. As such, the noise level from the project's heavy vehicles has been predicted and assessed directly against the RNP road traffic noise criteria.

Local roads are unlikely to have a substantial number of existing heavy vehicle movements and are likely to have intermittent traffic flows. A calculation method more suited to intermittent traffic acting like a moving point source at lower speeds (less than 50 kilometres per hour) has been used, with noise levels calculated based on the method presented in BS 5228-1, Section F.2.5, for moving vehicles using a regular well defined route. Local road traffic noise level predictions assumed the following:

- Heavy vehicles would travel along local roads (eg Punch Street at Artarmon) at lower than the posted speed for safety or vehicle limitation reasons, which is conservative for the duration of traffic noise impacts
- The SWL of the vehicle assessed was that of the reasonable worst case construction vehicle proposed to use the route, with consideration of the above point
- Road traffic noise levels were predicted at the facade of the nearest residential receiver building to the road. Receiver buildings at further distances are expected to experience lower noise levels than those predicted
- The British Standard does not include corrections for road grade; so the worst case gradient of the road was calculated, and a correction added to consider the sustained engine load at grade based on Table H-1 of Appendix H 'Grades' of the FHWA Traffic Noise Prediction Model Handbook (ref: NCHRP Report 117 Method). This includes noise level adjustments for heavy vehicles on grades ranging from no correction up to a 5 dB(A) adjustment for gradients over seven per cent.

For both assessment approaches, where local road traffic noise levels are predicted to increase by more than 2 dB(A) and exceed the RNP road traffic noise criteria for the corresponding road classification,

consideration should be given to applying feasible and reasonable noise mitigation and management measures to reduce potential noise impacts and preserve acoustic amenity at receivers near the road.

4.2.5.4 Construction vehicles exiting/entering construction support sites to/from public roads

Construction heavy vehicles either entering or exiting the construction support sites have the potential to add to the overall road traffic noise levels. A screening test has been carried out for the Balgowlah Golf Course construction support site (BL10) for the Sydney Road/Maretimo Street intersection and the new access road and Burnt Bridge Creek Deviation intersection to determine if the additional construction heavy vehicles would exceed RNP requirements. It was determined that there would be less than a 2 dB(A) increase in road traffic noise, satisfying RNP requirements.

As the specific construction methodology is not yet known, construction road traffic noise impacts associated with construction support site enter/exit areas should be further reviewed during the detailed construction planning phase.

4.2.5.5 Signalised intersections

The proposal includes new signalised intersections at the entrances of the following construction support sites.

- Flat Rock Drive construction support site (BL2) on Flat Rock Drive
- Balgowlah Golf Course construction support site (BL10) on Sydney Road
- Balgowlah Golf Course construction support site (BL10) on Burnt Bridge Creek Deviation
- Wakehurst Parkway east construction support site (BL13) on Wakehurst Parkway.

Signalised intersections usually do not increase road traffic noise impacts substantially at noise sensitive receivers. However, if the noise level during the day or the night is predicted to increase by more than 2 dB(A) as a result of signalising the intersections and the predicted noise level is higher than the guidelines for existing roads set out in Table 3 of the RNP, noise treatments should be provided where feasible and reasonable.

4.2.5.6 Construction road traffic noise assessments results

Site specific road traffic noise assessments have been carried out for each construction support site or major surface road upgrade area. Report section references to these site specific assessments are included in Table 4-5.

Table 4-5 – Site specific construction road traffic noise assessments

Location	Report section
Warringah Freeway road works	Section 5.2.3
Cammeray Golf Course (BL1/CGC)	Section 5.3.3
Gore Hill Freeway Connection road works (GHC)	Section 5.4.3
Flat Rock Drive (BL2/FRD)	Section 5.5.3
Punch Street (BL3/PUN)	Section 5.6.3
Middle Harbour crossing (MHC)	Section 5.7.3 (and Section 5.8.3)
Spit West Reserve (BL9/SMH)	Section 5.8.3
Balgowlah Golf Course (BL10/BAL)	Section 5.9.3
Balgowlah surface road works (BGC)	Section 5.10.3
Wakehurst Parkway south (BL12/WPS)	Section 5.11.3
Wakehurst Parkway east (BL13/WPE)	Section 5.12.3
Wakehurst Parkway north (BL14/WPN)	Section 5.13.3
Wakehurst Parkway surface road works (WKP)	Section 5.14.3

4.2.6 Construction related water traffic noise

As there are no guidelines for the assessment of noise from vessel movements in NSW. Barges would be operated and maintained to comply with the Protection of the Environment Operations (Noise Control) Regulation 2017, particularly Clauses 37 and 38 of the regulation which require vessels to have properly maintained noise controls. Marine construction vessels would also be required during construction. The indicative type and number of marine transport and construction vessel movements likely to be used during construction are presented in Table 4-6.

Table 4-6 – Indicative typical water based construction traffic movements

Site	Indicative vessel movements per day	Required movements outside of standard construction hours
Between Spit West Reserve (BL9) and Middle Harbour south (BL7) and Middle harbour north (BL8) cofferdams	• Twelve small boats for transporting construction workforce • Four barges for support of cofferdam dredging, piling and tube tunnel unit immersion • Three barges for disposal of dredged material to sea	No movements typically OOHW movements

Operating from the Spit West Reserve construction support site (BL9), barge and boat movements to and from project sites are expected to occur infrequently, with typically up to 19 movements a day and with no movements typically required at night. During the formation of concrete interface structures for the cofferdams, concrete delivery by ferry or barge may require up to 48 additional movements to those shown in Table 4-6 during standard construction hours. This is the peak movements that could occur and would last for approximately one week per cofferdam structure. As such, these movements would occur for a total period of approximately two weeks.

A small number of movements would be required outside of standard construction hours associated with immersed tube tunnel unit installation. Dredging activities would take place during standard construction hours, however, the transportation of dredged spoil to the disposal site may pass by noise sensitive receivers during the period outside of standard construction hours.

It is expected that noise from project barge movements would not cause substantial amenity or sleep disturbance impacts as it is unlikely that barge movements will occur during the night period.

4.3 Ground-borne construction noise

4.3.1 Ground-borne noise from tunnelling

4.3.1.1 Tunnelling methodology

The stages/operations proposed to be carried out for the construction of the mainline and ramp tunnels, cross passages, tunnel access declines and ventilations tunnels are summarised below. Noise generated from tunnelling activities associated with the project would vary depending on the excavation method used, the distance to the affected receiver and the geological formations and features in between. Table 4-7 provides a summary of likely tunnelling methods, followed by a description of what is typically involved with these tunnelling activities.

Table 4-7 –Tunnelling methodologies

Construction scenarios	Assumed plant and equipment
Mainline and ramp tunnels: Heading	Roadheader/s per tunnel Rock drilling
Mainline and ramp tunnels: Benching (including substations, niches, and utility and drainage trenches)	Roadheader/s per tunnel and/or Excavator with rock hammer attachment and/or Drill and blast (the adopted method would be confirmed before construction) (Section 4.5)
Cross passages	Roadheader per cross passage and/or Excavator with rock hammer attachment and/or Drill and blast (the adopted method would be confirmed before construction) (Section 4.5)
Tunnel access decline Ventilation tunnels	Roadheader

4.3.1.1.1 Roadheader tunnelling

Roadheaders would be launched from the tunnel support sites across the project to excavate the mainline tunnels, ramp tunnels, cross passages, tunnel access declines, substations and ventilation tunnels.

Between two and four roadheaders would be typically used to excavate the tunnel headings (top section of the tunnel up to the tunnel crown) for the two mainline tunnels and where feasible and reasonable, the rock along the lower section of the tunnel to the tunnel floor (called the bench). Roadheaders would also be used to excavate headings for ramp tunnels (and where feasible and reasonable, the ramp tunnel bench), cross passages and ventilation tunnels. Individual roadheaders would be separated by some distance

during tunnel excavation depending on ground conditions, tunnel support and contractor excavation methodology.

4.3.1.1.2 Rock drilling tunnel support – mainline and ramp tunnels

Ground support in the form of a canopy tube structure is required to be installed for the mainline and ramp tunnels. Once excavated, the rock of the roof of the tunnel would be progressively supported and secured using rock bolts. Large drill rigs would be required to install the rock bolts. A pilot bit and eccentric reamer would be employed to drill a hole large enough to accommodate a casing tube, which is driven in during the drilling process. When the end of the hole is reached, the direction of the rotation is reversed and the drill string can be retracted, leaving the casing tube behind.

4.3.1.1.3 Rock hammer tunnelling

One to two excavators with rock hammer attachments may be used to excavate the bench, cross passages, drainage areas and niches in the tunnel walls for tunnel operational infrastructure (eg substations). When excavating the bench the rock hammers typically follow around 100 metres behind the tunnelling roadheaders to remove the bench on the tunnel floor. Only an individual excavator with a rock hammer attachment would be undertaking excavation in any one area of the tunnel depending on ground conditions, tunnel support and contractor excavation methodology.

The bench is typically excavated out five metres below the tunnel crown level with an average advance rate of 20 to 30 metres per week. This can vary based on the rock type and the size of the tunnel.

4.3.1.1.4 Cross passage excavation

Cross passages between the two road tunnels would be required every 120 metres along the mainline and ramp tunnels. These can be excavated by either rock hammers or roadheaders.

4.3.1.2 Analysis methodology

Ground-borne noise impacts have been predicted based on calculation of the three dimensional minimum slant distance from the tunnel alignment to the base of each receiver structure.

The empirical algorithms used in roadheader, rock hammer and rock drill ground-borne noise and vibration modelling were developed and established to suit Sydney's geology. The algorithms have been developed from measurement data obtained from various recent Sydney based tunnelling projects and have subsequently been validated on these projects.

The predictions and subsequent assessment are based on typical geology for the area, comprising of Sydney sandstone with a varying depth of shale above. However, due to localised geological anomalies, foundation to footing interaction and the large range and variety of structures that exist (eg construction type, dimensions, materials, quality of construction, footing conditions etc), actual ground-borne noise and vibration levels may vary from what has been predicted. Verification measurements would be carried out at first opportunity following tunnelling commencement to check and verify the predictions.

Roadheader progress is estimated to be 20 to 30 metres a week depending on the type and size of the tunnel section. As such, the predicted noise levels are the peak noise levels that a receiver would be exposed to, and the noise is expected to drop away as the tunnelling moves further away from the receiver.

For rock hammer tunnelling works, the potential increased annoyance due to the percussive character associated with rock hammer excavation activities was accounted for by applying a +5 dB(A) correction to the predicted ground-borne noise levels. This approach is in accordance with the ICNG, and although any audible rock hammer ground-borne noise inside buildings is likely to be predominantly of low frequency character, rather than the more intrusive medium to high frequency airborne noise emitted from rock hammers, this approach is consistent with providing a conservative assessment.

As tunnelling progresses, the tunnelling equipment approaches or moves away from individual receiver locations. The predicted noise levels are the peak noise levels and the noise is expected to drop away as the tunnelling moves further away from the receiver, as shown in Figure 4-12 and Figure 4-13.

The scenarios listed in Table 4-7 would occur at different stages of tunnel construction in each tunnel tube. Therefore, receivers in the vicinity might experience ground-borne noise to varying degrees on multiple occasions throughout the overall construction duration.

Figure 4-12 – Indicative ground-borne noise impacts as tunnelling progresses

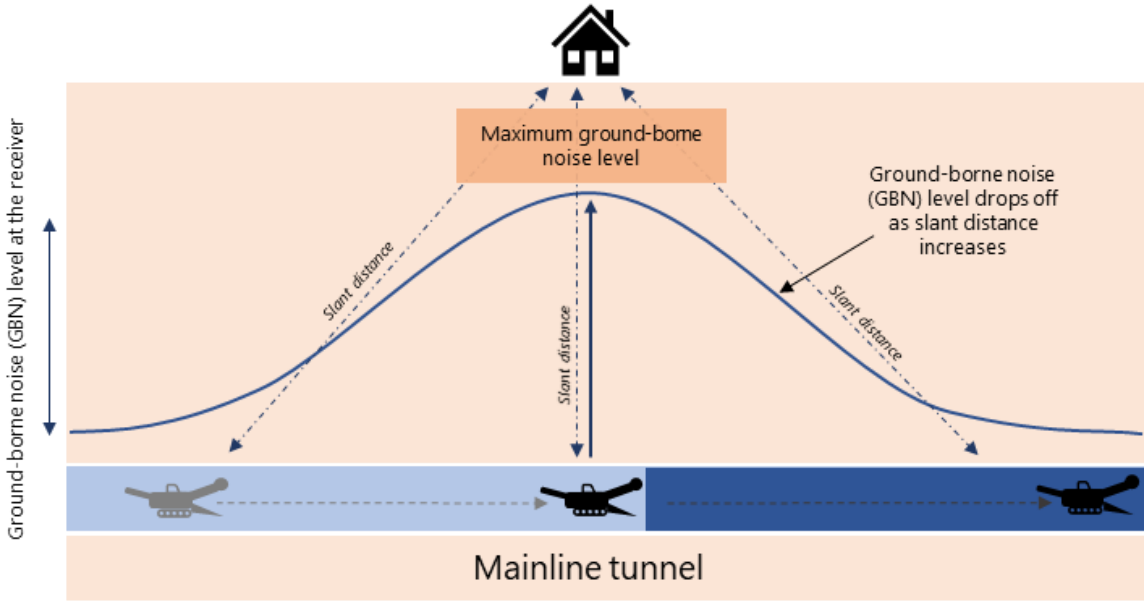
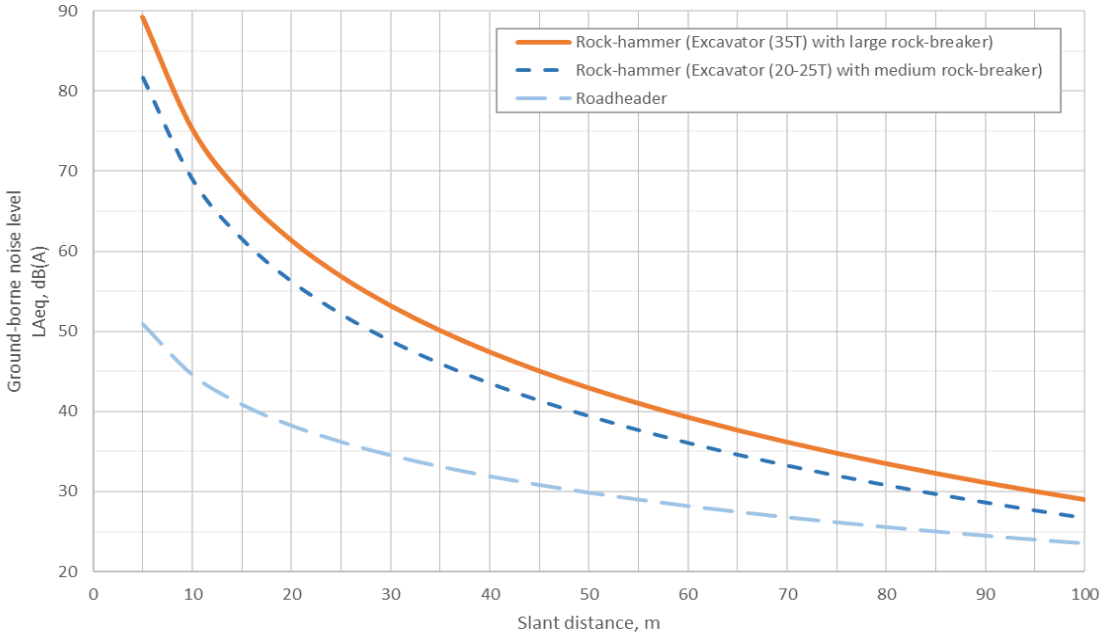


Figure 4-13 – Indicative ground-borne noise levels from tunnelling



Notes: 1. Rock hammer: algorithms used in ground-borne noise modelling have been developed from measurement data obtained from various Sydney projects.

2. Roadheader: Source: Australian Acoustical Society technical meeting - Tunnelling noise and vibration management, Wilkinson Murray, December 2003

4.3.1.3 Modelling inputs and assumptions

Noise generated from tunnelling activities associated with the project would vary depending on the excavation method used. Roadheader tunnelling is assumed to occur along the tunnel crown, while bench clearing activities usually occur along the tunnel floor and were assumed to occur at least five metres below the tunnel crown.

The predicted ground-borne noise and vibration levels are based on the noise modelling inputs and assumptions outlined in Table 4-8.

Table 4-8 – Construction ground-borne noise sources - tunnelling

Project component	Assessed plant and equipment
Mainline tunnels and ramps (including cross passages and substations)	Roadheader tunnelling
	Excavator with rock hammer attachment[1] (benching along tunnel floor)
Tunnel access decline tunnels Ventilation tunnels	Roadheader tunnelling

Note: 1. A 5 dB(A) penalty has been applied to predicted noise levels from 'particularly annoying' activities, namely rock hammering, in accordance with the ICNG

4.3.2 Ground-borne noise from surface construction activities

Ground-borne noise has the potential to be generated by vibration intensive surface activities within a construction support site, which would usually be activities that involve equipment listed in Table 4-11. However, as noted in the ICNG, the ground-borne NMLs for residential receivers:

> *"…indicate when management actions should be implemented. These levels recognise the temporary nature of construction and are only applicable when ground-borne noise levels are higher than airborne noise levels."*

Once all reasonable and feasible mitigation and management measures have been applied, and the airborne noise levels at impacted receivers still exceed the NML, then the additional mitigation measures outlined in the CNVG would be applied (refer to Section 6.10.1). These include measures such as notifications, briefings, respite offers or provision of periods, or alternative accommodation depending on the degree of exceedance of the NML.

During standard construction hours, the CNVG ground-borne noise level objectives are the same as the human comfort vibration objectives. The potential for the human comfort vibration objectives to be exceeded is assessed in detail for each construction work site in the relevant assessment section, as described in Section 4.4.2.

Outside standard construction hours:

- For the construction support sites across the project, no vibration intensive works are proposed outside of standard construction hours except for associated intersection works, and local area and utility works
- For the surface road works, intersection, local area and utility works associated with construction support sites, vibration intensive activities could take place outside standard construction hours. However, as limited fixed mitigation measures could be used for those works (see Section 5.1.6.1) it is likely that airborne noise levels would be higher than any ground-borne noise levels at all nearby sensitive receivers.

A screening test is presented in Table 4-9 for a typical vibration intensive activity during surface road works. For surface road works a five to 10 tonne excavator with small rock hammer attachment would typically be used. The ground-borne noise prediction equations are based on a 20 to 25 tonne excavator with a medium rock hammer for a conservative assessment.

Table 4-9 – Airborne noise impacts compared with ground-borne noise (GBN) impacts, for a typical surface road upgrade activity involving a rock hammer

Activity/ equipment	Assessment period	CNVG internal ground-borne NML, dB(A)	Distance, metres	Predicted GBN level, dB(A)[3,5,6]	Predicted airborne noise levels			Level by which internal airborne noise exceeds GBN, dB(A)
					$L_{Aeq\ 15\ minute}$ SWL, dB(A)	External airborne noise level, dB(A)	Internal airborne noise level[4]	
Excavator with medium rock hammer	Evening[1]	40	75	37	118	77	67 - 52	30 - 15
	Night[2]	35	100	32		75	65 - 50	33 - 18

Notes:
1. Evening is 6.00pm to 10.00pm Monday to Friday and 6.00pm to 10.00pm Saturday/Sunday/Public holiday
2. Night is 10.00pm to 7.00am Monday to Friday and 10.00pm to 8.00am Saturday/ Sunday/Public holiday
3. Includes a +5 dB(A) annoyance penalty
4. The range is based on an outside to inside noise reduction ranging from 10 dB(A) to 25 dB(A). Refer to Section 3.4.1.2 for a discussion of receiver building envelope noise reductions
5. Typically, for surface road works a five to 10 tonne excavator with small rock hammer attachment would be used. The ground-borne noise (GBN) prediction equations are based upon a medium rock hammer for a conservative assessment
6. Equations are based on propagation through Sydney sandstone, and assume no additional forms of attenuation or loss, as further explained in Section 4.3.1.2, such as localised geological anomalies, discontinuities, basements, variations in ground type, foundation to footing interaction, services etc. The presence of any of these elements can result in greater attenuation, and lower ground-borne noise levels (GBN), than predicted.

Table 4-9 presents both predicted construction ground-borne noise levels and airborne noise levels from vibration intensive construction activities at distances where ground-borne noise could potentially exceed the ground-borne noise management level. The results demonstrate that internal airborne noise levels from these activities, based on the most affected facade of the building, would likely be more than 10 dB(A) higher than the ground-borne noise level at the assessed distances. As the most affected facade of the building would be the trigger for applying additional mitigation measures for airborne noise, ground-borne noise impacts for that activity would also be managed.

Ground-borne noise impacts have not been assessed in detail for surface road works at construction support sites or surface road works areas, as airborne noise from these activities would likely dominate noise levels at nearby receivers.

Management measures to address airborne noise impacts at affected receivers are also likely to manage associated ground-borne noise impacts, as identified in Section 6.10. For example:

- Respite from construction activities that are both high noise and vibration intensive, such as rock hammering, would provide respite from both high airborne noise levels and associated ground-borne noise
- Similarly, programming of noisy work can reduce ground-borne noise during sensitive times
- Quieter, less vibration emitting plant, and plant of the smallest necessary size or power rating would produce less airborne and ground-borne noise
- Alternative accommodation would remove building occupants from substantially ground-borne noise affected buildings during night periods

- Effective community consultation and notification can educate receivers on what to expect so they are not alarmed if they notice ground-borne noise.

Additionally, if ground-borne noise is detected above the relevant NML, additional mitigation measures would be provided in line with the CNVG.

4.3.3 Site specific ground-borne noise assessments

Assessment of ground-borne noise for the mainline and ramp tunnels is presented in Section 5.16.

Site specific ground-borne noise assessments have been carried out for each construction support site or major surface road upgrade area. Links to these site specific assessments are included in Table 4-10. Specific assessments were not done where noise impacts would be controlled by airborne noise impacts, as explained above (see Table 4-9).

Table 4-10 – Site specific ground-borne construction noise assessments

Location	Report section
Warringah Freeway surface road works	Section 5.2.4
Cammeray Golf Course (BL1/CGC)	Section 5.3.4
Gore Hill Freeway Connection surface road works (GHC)	Section 5.4.4
Flat Rock Drive (BL2/FRD)	Section 5.5.4
Punch Street (BL3/PUN)	Section 5.6.4
Middle Harbour crossing (MHC)	Section 5.7.4
Spit West Reserve (BL9/SMH)	Section 5.8.4
Balgowlah Golf Course (BL10/BAL)	Section 5.9.4
Balgowlah surface road works (BGC)	Section 5.10.4
Wakehurst Parkway south (BL12/WPS)	Section 5.11.4
Wakehurst Parkway east (BL13/WPE)	Section 5.12.4
Wakehurst Parkway north (BL14/WPN)	Section 5.13.4
Wakehurst Parkway surface road works (WKP)	Section 5.14.4

4.4 Construction vibration prediction methodology

The vibration generated from construction works would vary depending on the level and type of activity carried out at each site during each activity. Unlike noise, it is difficult to 'predict' vibration. There are many variables from site to site, for example soil type and conditions, sub surface rock, building types and foundations, and actual plant on site.

The data relied on in this assessment are taken from a database of vibration levels measured at various sites or obtained from other sources (eg BS 5228-1). They are not specific to this project as final vibration levels are dependent on many factors. Potential vibration experienced by receivers or that could impact vibration sensitive structures and items for this project would be dependent on separation distances, the intervening soil and rock strata, dominant frequencies of vibration and the receiver structure.

4.4.1 Minimum working distances

As a guide, indicative minimum working distances for typical items of vibration intensive plant and equipment are provided in Table 4-11 below from the CNVG and other sources. The minimum working distances are quoted for the purpose of minimising:

- Cosmetic damage (referenced from BS 7385-2 and DIN 4150-3)
- Human response (referenced from the ATVG).

The minimum working distances for 'cosmetic' damage nominated in Table 4-11 have been derived based on the adopted screening levels and criteria presented in Section 3.4.5. These are to be complied with at all times, unless further monitoring and validation is used to determine different site specific minimum working distances which achieve the criteria presented in Section 3.4.5

Table 4-11 – Recommended minimum working distances for vibration intensive plant and equipment

Plant item	Rating/activity description	Recommended minimum working distance (metres)		
		Cosmetic damage		Human response[3]
		Structurally sound[1] (eg residential and light commercial)	Structurally unsound[2] (eg unsound heritage structures)	
Vibratory roller	< 50 kN (typically 1-2 tonne)	5	11	15-20
	< 100 kN (typically 2-4 tonne)	6	13	20
	< 200 kN (typically 4-6 tonne)	12	15	40
	< 300 kN (typically 7-13 tonne)	15	31	100
	> 300 kN (typically 13-18 tonne)	20	40	100
	> 300 kN (typically > 18 tonne)	25	50	100
Compactor [4]	32 tonne (non-vibratory)	15	30	40
Bulldozer [4]	D10 with ripper	2	10	20
Excavators [4]	< 30t (travelling/digging)	10	15	15
Small hydraulic hammer	300 kg - 5 to 12 tonne excavator	2	5	7
Medium hydraulic hammer	900 kg - 12 to 18 tonne excavator	7	15	23
Large hydraulic hammer	1600 kg - 18 to 34 tonne excavator	22	30 [4]	73
Vibratory pile driver	Sheet piles	2 - 20	5 - 30	20 - 50
Impact piling [5]	Typical driven pile [9]	20	30	110
Impact piling [5, 7]	338kJ per stroke (23 tonne hammer with 1.5 metre stroke)	70	140 [8]	330 [10]
Pile boring	≤ 800 mm	2	5	N/A
Jackhammer	Handheld	1	3	5
Roadheader [4]	Tunnelling	5	5	10
Rock drilling [4]	Tunnelling	5	5	10

Plant item	Rating/activity description	Recommended minimum working distance (metres)		
		Cosmetic damage		Human response[3]
		Structurally sound[1] (eg residential and light commercial)	Structurally unsound[2] (eg unsound heritage structures)	
Hydraulic hammer[4]	Tunnelling (35 tonne excavator benching with large rock hammer)	10	20	50
Heavy vehicle traffic	On uneven construction haul roads	5	10	20
Blasting operations[6]		Based on charge size – see Note 6		

Notes:
1. Referenced from either the CNVG or against the criteria in BS 7385-2
2. Criteria referenced from DIN 4150-3 (including heritage items)
3. Referenced from either the CNVG or the criteria referenced in the AVTG
4. Measurement from Renzo Tonin and Associates database
5. Vibration levels from piling can be strongly dependent upon site ground condition, and are influenced by variables such as pile diameter, hammer weight, stroke length, and rock types. Vibration levels for proposed piling operations must be verified at the proposed site prior to undertaking the required piling works to determine the suitable required minimum working distances. Approximate working distances based on US Department of Transportation Federal Transit Administration Noise and vibration manual vibration levels, and minimum working distances calculated using BS 5228-1.
6. To be determined during test blasts to establish appropriate propagation characteristics for the site and increase the accuracy of blasting predictions and confirmed, refer to Section 6.11
7. Assuming ground is very stiff and cohesive, dense granular soil, or fill containing objects which are large relative to the pile cross-section. Based on 338kJ per stroke (23 tonne hammer with 1.5 metre stroke)
8. Minimum working distance is based on the DIN 4150-3 requirement for short-term vibration impacts of 3 mm/s PPV
9. Referenced to a 'typical' pile driver (impact) taken from US Department of Transportation Federal Transit Administration Noise and vibration manual.
10. Based on a pile driving duration of 1.5 hours per day.

4.4.2 Screening assessment

A screening assessment has been carried out across the construction work areas, for the most vibration intensive works that could occur as part of the project. This assessment has assumed that the most vibration intensive works could occur anywhere across the construction areas. The purpose of this assessment is to act as a screening test to determine if further investigation should occur during detailed construction planning to review vibration impacts because of:

1. The types of vibration intensive works that could occur

2. The proximity of vibration sensitive item/building/structures.

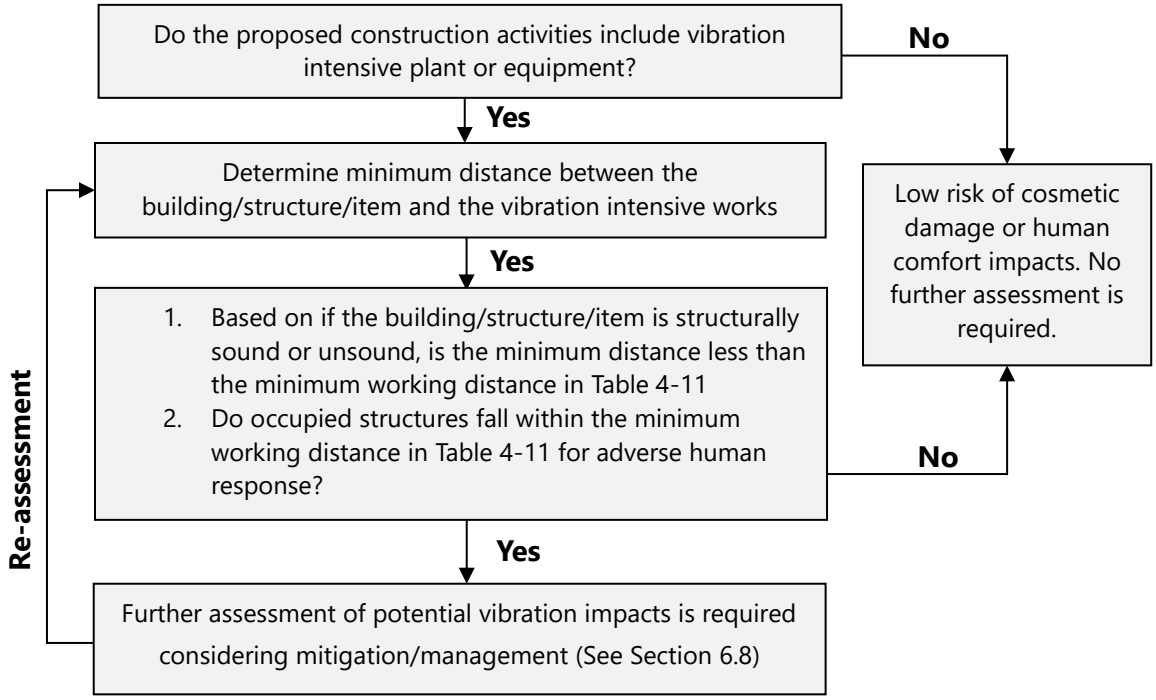
If items or structures are within the screening test minimum working distances, then the mitigation and management measures outlined in Section 6.8 should be reviewed and adopted where required. The process of this screening assessment is presented in Figure 4-14.

As detailed at the beginning of Section 4.4, potential vibration levels experienced nearby to project construction works would be dependent on separation distances, the intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. As such, potential vibration impacts from all project construction should be reviewed during further design development and construction planning.

Heritage items that have been included as part of the screening assessment are based upon the heritage study areas identified in the Technical working paper: Non-Aboriginal heritage assessment report (Appendix J of the environmental impact statement) and Technical working paper: Aboriginal cultural heritage assessment report (Appendix L of the environmental impact statement). These define a study area as the construction footprint plus areas within 50 metres of the footprint. The study area includes the mainline tunnel alignment, ramps and tunnel shafts, all operational ancillary facilities and construction support sites (including tunnel access declines). Maritime heritage items have been based upon the study area presented in the Technical working paper: Maritime heritage assessment report (Appendix K of the environmental impact statement). Heritage items outside of this study area have not been included in the screening assessment.

All AHIMS sites identified within the unsound structure minimum working distance were unable to be assessed during archaeological assessment of the study area due to property access constraints. As such the location and presence of items used in the screening assessments is assumed. Specific locations and the presence of sensitive items should be confirmed during detailed construction planning and potential impacts would be managed in accordance with mitigation measures presented in Technical working paper: Aboriginal cultural heritage assessment report (Appendix L of the environmental impact statement).

Figure 4-14 – Vibration screening assessment procedure considering minimum working distances



4.4.3 Site specific vibration assessments

Site specific vibration screening assessments have been carried out for each construction support site, major surface road upgrade areas and the mainline and ramp tunnels, to determine how many vibration sensitive receivers may be within the potential worst case minimum working distances, using the minimum working distances in Table 4-11. Links to the site specific assessments are included in Table 4-12.

Table 4-12 – Site specific vibration assessments

Location	Report section
Warringah Freeway road works	Section 5.2.5
Cammeray Golf Course (BL1/CGC)	Section 5.3.5
Gore Hill Freeway Connection road works (GHC)	Section 5.4.5
Flat Rock Drive (BL2/FRD)	Section 5.5.5
Punch Street (BL3/PUN)	Section 5.6.5
Middle Harbour crossing (MHC)	Section 5.7.5
Spit West Reserve (BL9/SMH)	Section 5.8.5
Balgowlah Golf Course (BL10/BAL)	Section 5.9.5
Balgowlah surface road works (BGC)	Section 5.10.5
Wakehurst Parkway south (BL12/WPS)	Section 5.11.5
Wakehurst Parkway east (BL13/WPE)	Section 5.12.5
Wakehurst Parkway north (BL14/WPN)	Section 5.13.5
Wakehurst Parkway surface road works (WKP)	Section 5.14.5
Mainline and ramp tunnels	Section 5.16.2

4.5 Construction blasting noise and vibration

Refer to Section 3.4.6 and Section 5.17 in regard to construction blasting noise and vibration that would occur across the project where its deemed for blasting to be an appropriate excavation method.

Blasting for tunnelling would be investigated during further design development and construction planning if proposed by the construction contractor. If proposed, detailed assessments should be carried out to demonstrate how compliance with the relevant noise and vibration criteria would be achieved.

4.6 Operational traffic noise prediction methodology

4.6.1 Noise modelling scenarios

To conduct the noise assessment, a number of specific traffic scenarios were required to be modelled and compared. The assessment considers both the 'build' (with the project) and 'no build' (without the project) scenarios for the year of opening (assumed to be 2027) and 10 years after opening (2037). Table 4-13 summarises the scenarios that were modelled.

Table 4-13 – Noise modelling scenarios

Modelled scenario	Description
2027 Opening year	
'Do minimum 2027'	'No Build' opening year of the Beaches Link and Gore Hill Freeway Connection project **WITH** the WestConnex, **WITHOUT** the project, Western Harbour Tunnel and Warringah Freeway Upgrade, Sydney Gateway and the M6 Motorway
'Do something 2027'	'Build' opening year of the Beaches Link and Gore Hill Freeway Connection project **WITH** the project, Warringah Freeway Upgrade, and WestConnex, **WITHOUT** the Western Harbour Tunnel, Sydney Gateway and the M6 Motorway

Modelled scenario	Description
'Do something cumulative 2027'	'Build' opening year of the Beaches Link and Gore Hill Freeway Connection project **WITH** the project, Western Harbour Tunnel and Warringah Freeway Upgrade, WestConnex, Sydney Gateway and the M6 Motorway (Stage 1)
2037 Design year (10 years after opening)	
'Do minimum 2037'	'No Build' design year of the Beaches Link and Gore Hill Freeway Connection project **WITH** the WestConnex, **WITHOUT** the project, Western Harbour Tunnel and Warringah Freeway Upgrade, Sydney Gateway and the M6 Motorway
'Do something 2037'	'Build' design year of the Beaches Link and Gore Hill Freeway Connection project **WITH** the project, Warringah Freeway Upgrade, and WestConnex, **WITHOUT** the Western Harbour Tunnel, Sydney Gateway and the M6 Motorway
'Do something cumulative 2037'	'Build' design year of the Beaches Link and Gore Hill Freeway Connection project **WITH** the project, Western Harbour Tunnel and Warringah Freeway Upgrade, WestConnex, Sydney Gateway and the full M6 Motorway

4.6.2 Noise modelling inputs

Building heights

Building height information in the study area based on LiDAR data was used for the assessment. Details of single and multi-storey buildings including building footprints and heights were input to the noise model based on high resolution aerial photography, the supplied building height, supplemented by desktop and field surveys.

Road pavement

Road pavement information was sourced from the reference design. When pavement surfaces are not dense graded asphalt or similar, corrections are included in the noise model, typically reflecting a noise increase for concrete pavements and a noise decrease for quiet pavements. The road pavement surfaces for the project would be confirmed during further design development and would consist of various types of wearing courses and appropriate noise corrections were used in the prediction of future traffic noise levels.

Traffic flow and composition summary

Traffic classification surveys were carried out by Matrix Traffic and Transport Data Pty Ltd (ref. N3227 – Sydney ATC) at numerous locations along the project route concurrently with the long term traffic noise monitoring discussed in Section 2.6. In accordance with Transport for NSW procedures, the traffic data obtained were used for the validation process of the traffic noise model. Results of the traffic classification surveys are presented in Annexure D.

The traffic volumes used for the traffic noise predictions and assessment have been based on traffic data provided by Transport for NSW.

4.6.3 Noise modelling methodology

Noise modelling was carried out using the Road Traffic Noise Module in the SoundPLAN (version 8.0) noise modelling software. This noise modelling software is recognised and accepted by both Transport for NSW and the NSW EPA.

The traffic noise prediction model is based on a method developed by the United Kingdom Department of Environment entitled *Calculation of Road Traffic Noise (1988)* known as the CoRTN88 method. This method has been adapted to Australian conditions and extensively tested by the Australian Road Research Board, The University of New South Wales and Transport for NSW. The model predicts noise levels for free flowing traffic and a modified method has been developed which enables an accurate prediction of noise from high heavy vehicle exhausts to be taken into account.

The method predicts the $L_{A10\ (1\ hour)}$ noise levels, and a correction of -3 dB(A) is applied to obtain the $L_{Aeq\ (1\ hour)}$ noise levels. The $L_{Aeq\ (1\ hour)}$ noise levels for the daytime 15 hour period from 7.00am to 10.00pm are then determined to derive the daily $L_{Aeq\ (15\ hour)}$ noise level. Similarly, the $L_{Aeq\ (1\ hour)}$ noise levels for the night time nine hour period from 10.00pm to 7.00am are then determined to derive the night time $L_{Aeq\ (9\ hour)}$ noise level.

Parameters and assumptions used in the noise model are presented in Table 4-14.

Table 4-14 – Summary of noise modelling parameters and assumptions

Parameters	Inputs
Model geometry	
Source height	Three source heights: • 0.5 metres for car exhausts/engines and car/heavy vehicle tyre noise • 1.5 metres for heavy vehicle engines • 3.6 metres for heavy vehicle exhausts.
Ground topography at receiver and road	• Topographic contours presented in one-metre intervals within road corridor • Topographic contours presented in two-metre intervals outside road corridor and within 600 metres from the project.
Road geometry	Reference design models.
Noise sensitive receiver locations, building heights, angle of view	• Detailed building height surveys provided by project team • Other details from aerial and terrestrial photography, supplemented by limited site checks and survey.
Receiver heights	• 1.5 metres above ground level to represent 1.5 metres above ground floor level • 4.5 metres above ground level to represent 1.5 metres above first floor level for double storey premises • 1.5 metres above floor level for all receiver floors of all multilevel dwellings including high rise apartment buildings.
Existing noise barriers	Existing noise barrier heights and locations based on aerial and terrestrial photography and site checks where necessary.
Road pavement surface	Road surfaces comprise the following: • Dense Graded Asphalt (DGA) • Continuously Reinforced Concrete Pavement (CRCP) • Stone Mastic Asphalt (SMA).

Parameters	Inputs
Reflections from existing barriers, structures and cuttings on opposite side of road	• Determined from review of design drawings and aerial photography complemented with site checks • Detailed within CoRTN algorithms.
Traffic parameters	
Traffic volumes and mix	Traffic volumes for daytime 15-hour and night time 9-hour and corresponding light and heavy vehicle mix provided by project team.
Vehicle speeds	Detailed posted speed data provided by project team.
Non-project arterial roads	Non-project arterial roads up to 600 metres from the project have been considered
Corrections to model	
L_{A10} to L_{Aeq} correction	-3 dB
Road surface correction	Where applicable, the following corrections were applied relevant to standard DGA: • 0 dB(A) for DGA • 0 dB(A) for Stone Mastic Asphalt with 10 mm aggregate (SMA10) • -2 dB(A) for Open Graded Asphalt (OGA) • +3 dB(A) for Concrete Pavement (CRCP or PCP).
Tunnel portal correction:	A correction is applied to the road noise source adjacent to the tunnel portals to provide a conservative estimate of the noise contribution from the portal.
Facade correction	+2.5 dB(A), when modelling to one metre from building facades (RNP Table 7 (p17)).
Traffic mix correction	Corrections to account for the composition of heavy vehicle types along the road are determined based on a method developed by Transport for NSW and implemented on this project (J. Peng *et al*, 2017)
SoundPLAN noise model settings	
Calculation method	Ray tracing method
Ground absorption factor	0 for water surfaces and 0.5 for other areas
Maximal search radius	3000 metres for contours and 1000 metres for individual predictions
For noise contour maps	• Grid space = 50 metres • Height above ground =1.5 metres and 4.5 metres • Grid Interpolation = Not used

4.6.4 Noise model validation

The noise model validation process provides confidence that the noise model prepared for the existing situation represents the real world as accurately as possible within the limitations of the traffic noise prediction algorithms used in the computer noise modelling software. The validated noise model would be used to predict and assess the future traffic noise levels from the project and provide confidence in recommending applicable noise mitigation measures.

The noise model was validated using the long-term traffic noise monitoring results presented in Table 2-3 and the concurrent traffic classification counts. Table 4-15, Table 4-16, Table 4-17 and Table 4-18 summarise the results of the traffic noise model validation for the areas representing the Gore Hill Freeway Connection, the Warringah Freeway, the connections to and from Burnt Bridge Creek Deviation and the connections to and from the Wakehurst Parkway, and, respectively, providing a comparison between the modelled traffic

noise levels for existing conditions and the measured traffic noise levels during daytime (7.00am to 10.00pm) and night time (10.00pm to 7.00am).

Table 4-15 – Noise model verification results for the Warringah Freeway

Location	$L_{Aeq(15\ hour)}$ Daytime noise level			$L_{Aeq(9\ hour)}$ Night time noise level		
	Measured	Modelled	Variation	Measured	Modelled	Variation
L2 – 6 McDougall Street, Kirribilli	59.9	61.3	1.4	55.8	57.1	1.3
L3 – 1/191-195 Walker Street, North Sydney	76.1	76.6	0.5	71.3	72.5	1.2
L4 – 91 Ridge Street, North Sydney	57.3	57.8	0.5	52.0	53.6	1.6
L6 – 306 Miller Street, North Sydney	64.1	65.1	1.0	57.9	57.1	-0.8
L7 – 1/1 Bardsley Gardens, Crows Nest	67.9	68.6	0.7	62.9	62.6	-0.3
L8 – 288 Falcon Street, Neutral Bay	71.4	73.0	1.6	68.0	68.9	0.9
L9 – 5 Military Road, Neutral Bay	71.2	72.3	1.1	67.5	67.3	-0.2
L10 – 317 Ernest Street, Cammeray	68.5	69.4	0.9	62.6	62.1	-0.5
L11 – 225 Ernest Street, Cammeray	67.3	68.6	1.3	61.3	61.3	0.0
L12 – 77 Rosalind Street, Cammeray	61.6	62.8	1.2	56.7	57.3	0.6
L13 – 53 Bellevue Street, Cammeray	67.2	68.3	1.1	63.6	62.9	-0.7
L16 – 18/22-24 Donnelly Road, Crows Nest	62.0	63.6	1.6	57.7	58.4	0.7
L17 – 79 Brook Street, Naremburn	70.4	70.6	0.2	64.2	64.3	0.1
		Mean	**1.0**			**0.3**

Notes: 1. Free field monitoring locations do not include +2.5 dB(A) correction for facade reflections.

Table 4-16 – Noise model verification results for Gore Hill Freeway Connection

Location	$L_{Aeq(15\ hour)}$ Daytime noise level			$L_{Aeq(9\ hour)}$ Night time noise level		
	Measured	Modelled	Variation	Measured	Modelled	Variation
L18 – 20/2 Parkes Road, Artarmon	71.3	73.3	2.0	66.5	68.5	2.0
L19 – 3/2 Cleland Road, Artarmon	59.1	60.3	1.2	54.9	55.4	0.5
L20 – 1 Chelmsford Avenue, Naremburn	62.6	63.5	0.9	58.2	58.6	0.4
		Mean	**1.4**			**0.9**

Notes: 1. Free field monitoring locations do not include +2.5 dB(A) correction for facade reflections.

Table 4-17 – Noise model verification results for connections to and from Burnt Bridge Creek Deviation

Location	$L_{Aeq(15\ hour)}$ Daytime noise level			$L_{Aeq(9\ hour)}$ Night time noise level		
	Measured	Modelled	Variation	Measured	Modelled	Variation
L35 – 469 Sydney Road, Balgowlah	70.7	70.1	-0.6	68.0	66.9	-1.1
L36 – 14 Pickworth Avenue, Balgowlah	52.9	53.6	0.7	49.3	49.1	-0.2
L39 – 2 Pitt Street, Balgowlah	55.8	57.2	1.4	51.5	52.6	1.1
L40 – 3A Jacaranda Place, Manly Vale	58.6	60.7	2.1[1]	53.9	56.0	2.1[1]
		Mean	**0.9**			**0.5**

Notes: 1. Marginal over prediction due to localised thick vegetation between the monitoring location and road source
2. Free field monitoring locations do not include +2.5 dB(A) correction for facade reflections.

Table 4-18 – Noise model verification results for connections to and from the Wakehurst Parkway

Location	$L_{Aeq(15\ hour)}$ Daytime noise level			$L_{Aeq(9\ hour)}$ Night time noise level		
	Measured	Modelled	Variation	Measured	Modelled	Variation
L41 – 81 Wakehurst Parkway, Seaforth	64.4	65.2	0.8	58.3	58.6	0.3
L42 – 96 Kirkwood Street, Seaforth	51.9	52.4	0.5	45.3	45.6	0.3
L43 – 118 Bantry Bay Road, Frenchs Forest	54.9	54.7	-0.2	48.3	48.4	0.1
		Mean	**0.4**			**0.2**

Notes: 1. Free -field monitoring locations do not include +2.5 dB(A) correction for facade reflections.

The noise model validation results presented in the above tables show that the noise model output results for each assessment area are generally in good agreement with noise monitoring for the daytime and night time periods, so a reasonable level of confidence can be placed on the noise model for predicting future traffic noise levels for the daytime and night time periods. In addition, on average the noise model is predicting slightly higher noise levels than actual measured noise levels, indicating that the noise model is conservative in its predictions.

The exception is Location L40 for the connections to and from Burnt Bridge Creek Deviation area, where the daytime and night time variations are 2.1 dB(A) indicating that the noise model predicts traffic noise levels higher than actual noise levels measured at the monitoring location. However, a review of the site information suggests that thick vegetation located between the noise monitoring location and the road may have contributed to lower measured noise levels.

Overall, the mean variations between measured and modelled results for the daytime and night time periods are within the ±2 dB(A) allowance for traffic noise model validation.

Therefore, for the prediction of day and night time traffic noise levels, no calibration factors are required to be included when generating the operational noise predictions for future traffic noise scenarios.

4.7 Operational road traffic noise mitigation

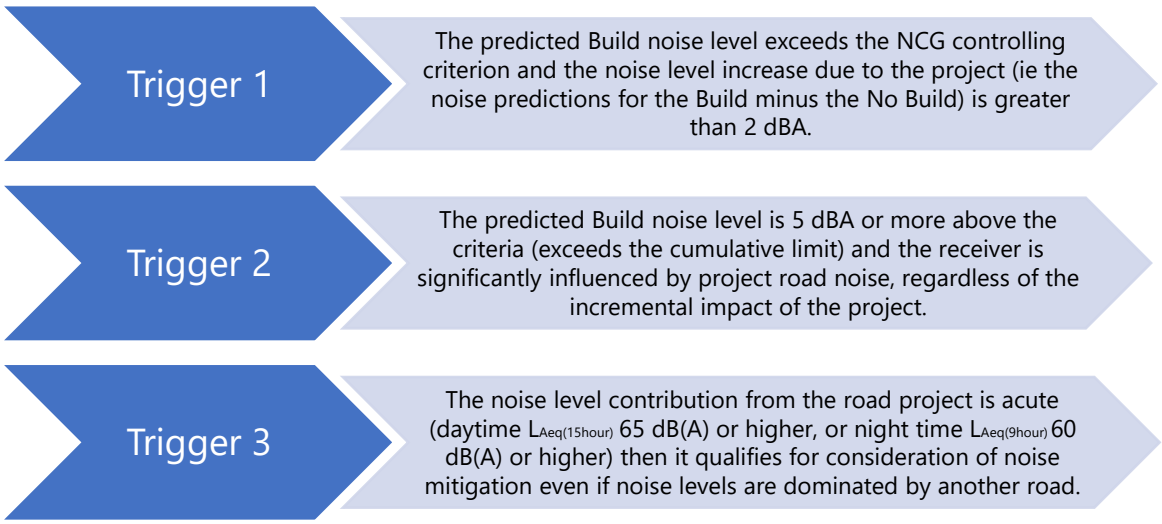
In determining the applicable road traffic noise mitigation measures for the project, the results of the assessment between the 'Do minimum' (without the project) and the 'Do something cumulative' (with the project and all additional projects) scenarios have been used for the affected receivers impacted by the project. Given that the 'Do something cumulative' (with project) scenario represents all the currently proposed major road infrastructure projects being operational, the determination of the applicable road traffic noise mitigation measures for the project using this method would be considered conservative, representing a worst case scenario.

The Transport for NSW *Noise Mitigation Guideline* (Roads and Maritime Services, 2015a) (the NMG) provides guidance in managing and controlling road traffic generated noise and describes the principles to be applied when reviewing noise mitigation. The NMG recognises that the criteria recommended by the NCG are not always practicable and that it is not always feasible or reasonable to expect that they should be achieved.

The NMG notes that the most effective way of minimising noise from vehicles and traffic is to control vehicle noise at the source. Where source measures are not practical, or do not provide sufficient noise reduction, additional methods are required to reduce levels to within acceptable margins. Such additional methods may include the use of path controls, such as noise barriers, and at-property controls, such as acoustic treatment of residences.

The NMG provides three triggers where a receiver may qualify for consideration of noise mitigation (beyond the adoption of road design and traffic management measures). These triggers are shown in Figure 4-15.

Figure 4-15 – NMG noise mitigation triggers



The eligibility of receivers for consideration of additional noise mitigation is determined before the benefit of additional noise mitigation (for example quieter pavement and noise barriers) is included. The

requirement for the proposal is to provide feasible and reasonable additional mitigation for these eligible receivers.

The NMG provides a methodology for identifying reasonable and feasible noise mitigation options for road projects. In accordance with the NMG, once noise has been minimised by feasible and reasonable methods during the corridor planning and road design stages, receivers with residual exceedances of the NCG criteria are assessed to determine if these receivers qualify for consideration of additional noise mitigation.

Potential noise mitigation measures are identified for receivers that qualify for consideration of noise mitigation measures, in the order of preference as follows:

1. Quieter pavement surfaces
2. Noise mounds
3. Noise walls
4. At-property treatments.

The priority of mitigation measures recognises the importance of providing protection to both external and internal areas of a receiver and also the degree of visual impact. For it to be considered reasonable to provide quieter pavement surfaces, noise mounds and/or noise walls, there needs to be four or more closely spaced receivers that would benefit from these mitigation measures. At-property noise mitigation may replace at road mitigation, subject to a reasonable and feasible assessment, in the following circumstances:

- Isolated single residences or isolated groups of closely spaced residences
- Where the affected community expresses a preference for at-property treatment and the cost is less than a combination of a barrier and at-property treatment
- Where quieter pavement surfaces are not appropriate based on the likely traffic conditions and vehicle speeds
- Where noise barriers cannot achieve the level of noise mitigation (insertion loss) required
- Where there are engineering constraints influencing the construction of noise barriers
- Where use of noise mounds is limited due to space restrictions
- Where the only applicable noise criteria are internal (eg places of worship, hospitals or schools and childcare facilities where play areas meet external criteria)
- Where other noise mitigation measures have been shown not to be feasible or reasonable
- Where noise barrier height can be limited due to visual amenity considerations.

A combination of at-road mitigation and at-property treatment can provide the most reasonable overall noise reduction for an affected community when consideration is given to cost, urban design, overshadowing, other environmental considerations, and engineering constraints with the maximum

barrier. The process of deriving the most effective combination of noise barrier height and at-property treatment is described in detail in Section 8 of the NMG.

4.7.1 Quieter pavements

With the general exception of motorcycles, for all vehicles in a reasonable state of maintenance, tyre/road interaction represents the main source of noise at constant speeds in excess of around 30-50 kilometres per hour for cars and 40-80 kilometres per hour for trucks (RTA, 2001). The type of road surface can have a substantial impact on traffic noise generated by pavement tyre/road interaction.

Quieter pavements could be used to aid in reducing tyre/road noise at the source and provide a reasonable noise reduction for large areas of receivers, where exceedance of the relevant traffic noise criteria is predicted.

4.7.2 Noise barriers

Following the adoption of a quieter pavement as the first method of noise mitigation, noise barriers are the next preferred form of mitigation in accordance with the NMG. The NMG states the following key points in relation to noise barriers:

"Noise barriers should be considered where there are four or more closely spaced receivers."

AND

"Barrier heights above 8 metres will not be considered"

AND

"As a guide noise walls or mounds are considered to be a reasonable noise mitigation option where they are capable of providing an insertion loss of:

- *5 dB(A) at representative receivers for heights up to 5 metres high*
- *10 dB(A) at representative receivers for heights above 5 metres and up to 8 metres high"*

Noise barrier options were assessed in accordance with the process described in Section 8 of the NMG. The outcomes of the barrier assessment are presented in Section 7.2.2 and Annexure Q.

4.7.3 Property treatments

At-property treatments are generally limited to acoustic treatment of the building elements (doors, windows, vents, etc) or courtyard fences where they reduce noise to habitable rooms. The installation of courtyard fences close to the dwelling may also provide some mitigation for outdoor living spaces.

The overall goal of the at-property treatment is to provide similar acoustic amenity and internal noise levels to those experienced within a receiver where the external noise criteria have been met.

In most instances, assuming brick construction and standard glazing, this goal equates to internal noise levels with windows closed that are around 20 dB(A) less than the external noise criteria. In practice there would be some variation in reduction due to the design of the existing building and other limitations such as building condition. A 20 dB(A) goal results in internal noise levels that are consistent with guidance in other policies and Standards. These include the State Environmental Planning Policy (Infrastructure) 2007 and Australian/New Zealand Standard 2107:2016 '*Acoustics - Recommended design sound levels and reverberation times for building interiors*' (Standards Australia 2016) (AS/NZS 2107). The 20 dB(A) goal also provides protection against a large increase in internal noise level in accordance with the NCG and RNP relative increase criterion.

For non-residential noise sensitive receivers such as schools, hospitals, places of worship and childcare centres equivalent external noise goals are based on a 10 dB(A) reduction from external noise levels to internal noise levels when windows are left 20 per cent open, which has been conservatively adopted to allow external assessments. At-property treatment for non-residential noise sensitive receivers have been based on this conservative assessment.

4.8 Operational fixed facilities

Fixed facilities associated with other major road infrastructure projects similar in design to this project typically incorporate the following types of plant and equipment:

- **Ventilation outlet** – ventilation fans located within the buildings to supply and exhaust air to and from the tunnels (including egress passages) would be the main source of noise from these facilities. The fans would generally consist of jet fans with attenuators incorporated. These facilities are anticipated to operate 24 hours per day, seven days a week
- **In-tunnel jet fans** – jet fans would typically be located throughout the tunnels. However, only jet fans located near the tunnel portals would potentially impact sensitive receivers as noise emanates out of the portal openings. Jet fans are anticipated to operate 24 hours per day, seven days a week
- **Substations** – substations would typically house transformers and mechanical plant to provide ventilation and cooling for the transformers. Substations are anticipated to operate 24 hours per day, seven days a week
- **Wastewater treatment plant and fire pump buildings** – pumps and blowers within the wastewater treatment plants and fire pump buildings would be the main source of noise from these buildings. Plant and equipment associated with the wastewater treatment plants are to be enclosed within buildings and are anticipated to operate 24 hours per day, seven days a week, while fire pump buildings would operate during emergencies and periodic maintenance.

Indicative SWL data for the typical plant and equipment associated with the fixed facilities for the project that have been used for modelling purposes are presented in Table 4-19. Type of plant and equipment to be used for the fixed facilities would be refined during further design development.

Table 4-19 – Indicative sound power levels of fixed facility plant and equipment, dB re. 1pW

Plant item	Octave band centre frequency, Hz – dB(lin)								Overall dB(A)
	63	125	250	500	1k	2k	4k	8k	
Ventilation outlet[1]	105	88	62	50	45	54	65	68	105
Tunnel jet fan	108	100	64	87	95	91	87	87	109
Substation (4 x 3.15mVA transformers)	81	89	79	73	73	71	-	-	90
Wastewater treatment plant (blower and pump)	99	94	95	93	93	92	85	75	98

Notes: 1. Sound power level presented is at the outlet and assumes all appropriate attenuators (eg circular silencers, rectangular silences, acoustic louvres and the like) are installed

2. Plant and equipment sound power levels are indicative and subject to final selection during further design development.

4.9 Recreation facilities

The design of the new and improved open space and recreation facilities at Balgowlah are subject to further consultation with stakeholders. A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council will take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities. This consultation will be separate to the consultation for the environmental impact statement. The initial design proposes the following facilities:

- AFL/cricket oval (enlarged Balgowlah Oval)
- Hockey field
- Soccer field
- Cricket nets
- Netball courts
- Children playgrounds
- Car parking area
- Amenities.

Indicative SWL data for activities associated with the open space and recreation facilities that have been used for modelling purposes are presented in Table 4-20 The proposed uses and activities for the open spaces and recreation facilities would be refined during further design development.

Table 4-20 – Indicative sound power levels of recreational activities

Noise Source	SWL, dB(A)
Activities on multi-sports oval including spectators	100
Activities on soccer field including spectators	100
Activities on hockey field including spectators	100
Activities on netball court (per netball court)	85
Activities in cricket nets (per cricket net)	81
50 Children playing in children's playground (per playground)	97
Traffic movement within car parking area (420 movements/hr)[1]	89

Notes: 1. Based on 210 cars in and 210 cars out in a one hour period.

5 Construction noise and vibration assessment

This section documents the assessment of noise and vibration impacts resulting from construction of the project.

5.1 Overview

5.1.1 Description of assessed works

Construction noise and vibration impacts from major construction support sites and the major surface road works areas located at the Warringah Freeway, Gore Hill Freeway Connection, Balgowlah and Wakehurst Parkway have been assessed separately. Minor construction support sites supporting the major surface road works have been assessed as part of the surface work areas.

Potential noise and vibration impacts from the construction of the mainline and ramp tunnels have been assessed, including blasting. Other construction works required for the project outside of the major construction zones such as local area and utility adjustment works, and truck marshalling areas are addressed. An overview of the proposed construction support sites across the project is shown in Figure 1-3.

5.1.2 Overview of construction program

Subject to planning approval, construction of the project is planned to commence in 2023 and is expected to take around six years to complete, as presented in Table 5-1.

Table 5-1 – Overall Beaches Link and Gore Hill Freeway Connection project – indicative program and timeline

Stage	Indicative construction timeframe																			
	2023				2024				2025				2026				2027				2028			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Early works and site establishment	■	■	■	■	■	■	■	■	■															
Construction of driven tunnels		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■								
Installation of immersed tube tunnels		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■								
Tunnel fitout and finishing						■	■	■	■	■	■	■	■	■	■	■	■	■	■					
Construction of operational facilities						■	■	■	■	■	■	■	■	■	■	■	■	■	■					
Surface road works		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■							
Testing and commissioning										■	■	■	■	■	■	■	■	■	■	■				
Site rehabilitation and demobilisation										■	■	■	■	■	■	■	■	■	■	■				
Open space and recreation facilities at Balgowlah (subject to further consultation)		■	■	■	■	■	■	■	■									■	■	■	■	■	■	

Table 5-2 summarises the construction activities and estimated timeframe for construction works that have been assessed. The likelihood for works to be completed during standard construction hours or as OOHW is also identified. Figure 1-3 shows the location of major works areas and construction support sites associated with the project.

Table 5-2 – Construction activities and indicative timeframes of activities/construction works

Location	Construction scenarios	Approx. duration of works at any locality	Construction hours of work standard/OOHW
Tunnel construction support sites			
BL1 – Cammeray Golf Course (CGC) BL2 – Flat Rock Drive (FRD) BL3 – Punch Street (PUN) BL10 – Balgowlah Golf Course (BAL) BL13 – Wakehurst Parkway east (WPE)	Early works and site establishment/ demolition works	30 months	Standard and OOHW where works are required within public road corridor
	Access decline excavation and support	Up to 6 months	Standard
	Tunnel construction support	Up to 48 months	Standard and OOHW to support 24 hour tunnelling
	Tunnel mechanical and electrical fitout	Up to 18 months	Standard
	Tunnel commissioning and site rehabilitation	Up to 30 months	Standard
	Construction of permanent operational facilities (where applicable)	Up to 48 months	Standard
Surface road works			
Warringah Freeway surface road works Construction support site • BL1 - Cammeray Golf Course (CGC) Gore Hill Freeway Connection (GHC) Construction support sites • BL4 - Dickson Avenue (GHC0D) • BL5 - Barton Road (GHC0B) • BL6 - Gore Hill Freeway median (GHC0C) Balgowlah surface road works (BGC) Construction support sites • BL11 - Kitchener Street (BGC8) Wakehurst Parkway surface road works (WKP) Construction support sites • BL12 - Wakehurst Parkway south (WPS) • BL14 - Wakehurst Parkway north (WPN) Local road work	Early works	4 to 5 months	Standard and OOHW
	Utilities, sewerage and local area upgrade works	Up to 30 months	Standard and OOHW
	Road work	Up to 30 months	Standard and OOHW for road tie ins and traffic switches
	Bridge and concrete works (cut and cover, ramp pavements, tunnelling concrete support, bridge demolition/construction)	Up to 18 months	Standard and OOHW
	Construction of permanent operational facilities (where applicable)	Up to 48 months	Standard

Location	Construction scenarios	Approx. duration of works at any locality	Construction hours of work standard/OOHW
Mainline and ramp tunnelling			
Cammeray to Middle Harbour Middle Harbour to Balgowlah and Killarney Heights Ramp tunnels to Gore Hill Freeway Connection	Mainline and ramp tunnels: Heading	Up to 48 months	24 hours
	Mainline and ramp tunnels: Benching		24 hours
	Cross passages		24 hours
	Mechanical and electrical fitout		24 hours
Middle Harbour crossing construction support site			
BL9 – Spit West Reserve (SMH)	Early works and site establishment	6 months	Standard
	Dredging and Middle Harbour crossing support	Up to 18 months	Standard
	Cast and fitout tunnel units	Up to 18 months	Standard and OOHW
	Support tunnel unit immersion	9 months	Standard and OOHW
Middle Harbour crossing			
Middle Harbour crossing Middle Harbour south cofferdam (BL7/MHC(S)) Middle Harbour north cofferdam (BL8/MHC(N)) Temporary mooring facility east of Clive Park in Middle Harbour	Cofferdam construction	Up to 24 months	Standard
	Pile moorings	9 months	Standard
	Construction of interface structure and remove cofferdam structures	12 months	Standard
	Dredging and tube tunnel foundations	Up to 18 months	Standard
	Immersed tube tunnel piled supports	9 months	Standard
	Tunnel unit immersion	6 months	Standard and OOHW

5.1.3 Construction work hours for specific activities

The project construction works required outside of operational roadways would generally be carried out during the CNVG standard construction hours when above ground, while tunnelling activities would generally be carried out 24 hours a day, seven days per week. A summary of the various construction activities that would be carried out and the proposed construction hours is presented in Table 5-3.

Table 5-3 – Overview of project construction works hours

Activity	Construction hours	Comment/exceptions
Tunnelling, tunnel support, excavation and underground haulage and activities		
Tunnelling, underground excavation and tunnel support	Up to 24 hours a day, seven days a week	Activities that support tunnelling works may need to occur 24 hours a day, up to seven days a week, including deliveries. Spoil handing outside standard construction hours would be carried out within an acoustic shed. Aboveground work supporting underground construction activities (eg concrete pumping, truck loading) are expected to be required 24 hours a day, up to seven days a week where noise mitigation is in place. Surface activities outside of an acoustic shed would typically be limited to standard construction hours unless they achieve the NMLs. Oversized deliveries would typically be carried out at night.
Underground construction and tunnel fitout	Up to 24 hours a day, seven days a week	Activities that support underground construction and tunnel fitout would occur 24 hours a day, up to seven days a week Deliveries for underground construction and tunnel fitout would occur 24 hours a day, up to seven days a week.
Dredging and excavation of the seabed, and barge movements for associated marine spoil transportation	Standard construction hours	Dredging works would be carried out typically during standard construction hours for the duration of dredging works Barge loading would occur during standard construction hours; however, spoil transportation may extend beyond standard construction hours.
Barge movements for transport of immersed tube tunnel units	24 hours a day, for set periods	Ferry barges to transport immersed tube tunnel units from the casting facility at the Spit West Reserve construction support site (BL9) to a temporary mooring east of Clive Park.
Immersed tube tunnel construction	Standard construction hours	Large concrete pours may require occasional extended hours
Immersed tube tunnel installation	24 hours a day, for set periods	Carried out during closures of Middle Harbour. This is likely four partial closures and two full closures, each for a continuous period of between 24 - 48 hours.
Cofferdam construction	Standard construction hours	Construction of the cofferdam and interface structure would be carried out typically during standard construction hours
Construction traffic for material supply and spoil removal		
Construction traffic for material supply and spoil removal	Standard construction hours (occasional night works) Concrete deliveries outside standard construction hours	Spoil haulage and concrete deliveries would generally be carried out during standard construction hours. Some haulage/deliveries (including concrete deliveries) to and from the construction support sites would be required during the night time (up to 24 hours per day, seven days per week) to support construction activities, particularly underground tunnelling activities, at: • Cammeray Golf Course (BL1/CGC) • Flat Rock Drive (BL2/FRD) • Punch Street (BL3/PUN) • Balgowlah Golf Course (B10/BAL) • Wakehurst Parkway east (BL13/WPE)

Activity	Construction hours	Comment/exceptions
Surface road works activities (not specified elsewhere)		
Warringah Freeway surface road works	Up to 24 hours a day, seven days a week	Works are required to be carried out up to five consecutive days per week along the length of the works
Gore Hill Freeway Connection surface road works	Up to 24 hours a day, seven days a week	Works are required to be carried out up to five consecutive days per week along the length of the works
Balgowlah surface road works	Up to 24 hours a day, seven days a week	Some construction works are required out of hours to minimise impacts to the road network
Wakehurst Parkway surface road works	Up to 24 hours a day, seven days a week	Some construction works are required out of hours to minimise impacts to the road network
Demolition and surface construction activities	Standard construction hours	Demolition and surface construction activities would typically be carried out with standard construction hours where feasible and reasonable. Non-disruptive preparatory work, repairs or maintenance may be carried out outside standard construction hours. Activities requiring the temporary closures of roads or to accommodate road network requirements may need to be carried out outside standard construction hours.
Blasting and rock hammering		
Blasting	Standard construction blasting hours	Blasts would be limited to one single detonation in any one day per receiver group, unless otherwise agreed by the NSW EPA.
Rock hammering (with potential for impulsive or tonal noise impact at a sensitive receiver)	Standard construction hours	Respite periods would be provided and programmed to minimise the frequency and duration of extended rock hammering activities with the potential for impulsive or tonal noise emissions. Rock hammering and other high impact noise activities could also occur outside these standard daytime construction hours if authorised by an Environmental Protection Licence.
Other activities		
Minor activities	At any time	Includes activities that do not lead to an exceedance of the applicable NML at an affected receiver.
Activities authorised by an Environment Protection Licence	As specified in the Environment Protection Licence	Construction activities would be managed as required by the Environment Protection Licence.
Out of hours works for safety and operational reasons	At any time, subject to individual requirements	Specific management measures would be developed for each relevant activity or group of activities to manage potential impacts on sensitive receivers. This would include use of respite periods where appropriate. Examples would be works operating under a road occupancy licence.
Emergency or directed activities	At any time	Activities carried out if required to prevent an imminent injury or loss of life or environmental damage.

5.1.4 Required tunnel construction and fitout work outside of standard construction hours

Work in tunnels, and other underground activities, would occur 24 hours per day, seven days a week. On site acoustic treatment such as site hoarding and acoustic sheds are proposed to control noise emitted by tunnelling and tunnel support activities outside standard construction hours. 24 hour spoil handling would be required to support tunnelling works. Spoil handling at the surface would typically occur within acoustic sheds outside standard construction hours to minimise potential noise impacts.

Tunnelling using roadheaders would occur 24 hours per day, seven days a week, due to each excavation cycle taking around eight to 10 hours. Once complete, it would be supported immediately to ensure the tunnel is stable and minimise any potential ground movement where required.

This ground support for tunnelling (including the excavation of cross passages and ventilation tunnels) would include shotcrete and rock bolts where required. For sections of the alignment, not installing ground support immediately could result in ground movement in the tunnel, excessive settlement at the surface and create an unsafe working environment. Where required, the concrete deliveries for this ground support may also be required outside standard construction hours to enable concreting works to be completed safely.

During the tunnel fitout stage, deliveries of mechanical and utilities services would be required. In order to support the installation of these components within the tunnel 24 hours per day, seven days a week, which would shorten the overall duration of the project, deliveries outside of standard hours may be required. These deliveries are relatively low noise impact, and delivery trucks would move directly into the tunnel via the acoustic shed thereby minimising noise emissions within the construction site footprint.

5.1.5 Other work outside standard construction hours

There are five categories of work (other than tunnelling) that typically may be required to be carried out outside of the standard construction hours:

- The **delivery of oversized plant or structures** that police or other authorities determine require special arrangements to transport along public roads
- **Emergency work** to avoid imminent injury or the loss of life or damage to property, or to prevent environmental harm
- **Maintenance and repair of public infrastructure** where disruption to essential services and/or considerations of worker safety do not allow work within standard construction hours
- **Public infrastructure works** that shorten the length of the project and are supported by the affected community
- Works where a proponent demonstrates and justifies **a need to operate outside the recommended standard construction hours**.

The above categories would apply to specific stages of the construction of the project works for various reasons. For example, the works within the existing road network would need to be carried out outside standard construction hours in order to limit impacts on the traffic network during peak periods, and for both worker and road user safety.

Construction road work on major roads typically must occur under a road occupancy licence granted by the Transport Management Centre (or similar). This would apply extensively to parts of the project, mostly the Gore Hill Freeway Connection and Warringah Freeway surface road works with elements of the Balgowlah and Wakehurst Parkway surface road works. Road occupancy licences specify the allowable working hours and typically require the road works to occur outside standard construction hours when traffic volumes are low.

For site specific construction activities that are required to take place outside of standard construction hours, further justification has been included in the "Construction duration and working hours" section for the site.

5.1.6 Surface road works and road interface works

As part of the project construction works, surface upgrades of interfacing roads are required, which cover the following:

- Warringah Freeway
- Gore Hill Freeway
- Burnt Bridge Creek Deviation
- Wakehurst Parkway.

Surface road works would be required for the following:

- The tunnel portals at Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway
- Realignment and upgrade of the Wakehurst Parkway
- The site establishment at Cammeray Golf Course construction support site (BL1)
- Construction of the new access road at Balgowlah to connect the tunnel portals to Sydney Road and provide local connectivity to the new and improved open space and recreation facilities
- Local road upgrades at Artarmon, Seaforth and Balgowlah in the vicinity of tunnel connections.

Earthworks would be completed using conventional methods of road construction. The general earthworks method would include:

- Vegetation clearance and topsoil stripping. Mulched vegetation and topsoil would be stockpiled for later re-use in site rehabilitation and landscaping works
- Areas of new cut and fill to design levels and widening of existing cuts and embankments. This may include the construction of retaining walls and reinforced soil walls. Construction of road embankment fills may involve the reuse of tunnel spoil
- Installation of road drainage infrastructure.

5.1.6.1 Surface road works and road interface works required outside standard construction hours

Where feasible and reasonable, works would be programmed during standard construction hours; however, large sections of works across the project, especially for the Gore Hill Freeway and the Warringah Freeway, would be required to take place outside standard construction hours to minimise the potential for significant and widespread traffic disruption.

For the Warringah Freeway surface road works and the Gore Hill Freeway Connection surface road works there is a need to undertake construction work within a live traffic corridor with existing high traffic flows which would require extensive night time road works. For the Balgowlah surface road works and the Wakehurst Parkway surface road works a majority of works can be undertaken during standard construction hours. However, some works within these surface works areas would need to take place under a road occupancy licence (ROL) and outside standard construction hours to ensure:

- The safety of construction personnel working in the road alignment
- The operational integrity of the road network is sustained during period of high traffic volumes.

For the Warringah Freeway surface road works and the Gore Hill Freeway Connection surface road works, Transport for NSW are planning to maintain a requirement to undertake these works over periods of up to five calendar nights to minimise overall disruption to nearby residents and the overall duration of the project's construction program. This approach is based on the outcomes of extensive consultation with the affected receivers. The CNVG suggests that it may be beneficial to increase the work duration or number of nights worked to complete the project more quickly. It also allows for consideration of at-receiver noise mitigation for longer term impact. However, no further details on the implementation are provided.

There are a number of features of the Warringah Freeway surface road works and the Gore Hill Freeway Connection surface road works which require works outside standard construction hours. These include:

- The need for the operation and capacity of the Warringah Freeway to be maintained, especially during morning and afternoon traffic peaks. Noting that the Warringah Freeway is the highest trafficked road in Australia.
- ROLs issued by the Transport Management Centre can influence the programming and sequencing of works. ROLs for Warringah Freeway are typically issued in blocks of consecutive nights/weeks to ease driver wayfinding and for safety reasons.
  - This allows the users of Sydney's busiest road to become familiar with the temporary traffic arrangements
  - It minimises the amount of advertising and sign-posting required for the potentially significant road changes associated with Warringah Freeway
- The nature of works means that it needs to be complete within a certain window. For example:
  - Demolition/modification of a bridge
  - Trenching and pavement replacement
- High residential population density along the Warringah Freeway and Gore Hill Freeway corridor, includes many high rise properties. Many of these receivers are currently affected by high levels of road traffic noise (> 60 dB(A) $L_{Aeq,9hr}$). Therefore, some of these receivers have facades which currently perform well acoustically due to council requirements. In addition, some eligible receivers would be offered at-receiver noise mitigation treatment to reduce operational noise impacts from the projects pending a property assessment.

A large part of night work would include noise intensive activities such as concrete and rock hammering, concrete cutting and rock drilling. The temporary nature of works under a ROL means there are limited

opportunities to install fixed noise mitigation (ie acoustic sheds, acoustic enclosures, large temporary barriers) as the road needs to be fully operational the following day.

The baseline in the CNVG is for the provision of respite by restricting night-time works to no more than two consecutive nights. The impact of working only two consecutive nights compared with five consecutive nights per week would result in greater inefficiencies and the need for longer periods of night work. The macro level impact of restricting works to two consecutive nights would be an extension in the project's construction program by an estimated nine months resulting in a longer period of impact experienced by the community.

However, carrying out construction works over five calendar nights along the Warringah Freeway surface road works and the Gore Hill Freeway Connection surface road works does not mean that there would be five calendar nights of noise impacts on any one sensitive receiver location for the entire five calendar night period. As further detailed in the mitigation and management for surface road works in Section 6.4, by staging the construction works along the road corridor over different nights, where feasible and reasonable, it is possible to provide receivers with respite from construction noise while continuing to undertake project construction works over a continuous period.

Transport for NSW are preparing a framework to manage construction noise associated with the Warringah Freeway surface road works and the Gore Hill Freeway Connection surface road works, as detailed in Section 6.4.9. The framework relates only to the works that require a ROL within the road corridor of the Warringah Freeway and Gore Hill Freeway Connection, including overpasses and connections. It is proposed to be applied after the mitigation measures outlined in the CNVG and ICNG are applied, including but not limited to at-source controls, best practices, equipment selection and scheduling.

5.2 Warringah Freeway surface road works

5.2.1 Construction works overview

5.2.1.1 Summary of construction works

The key features of the Warringah Freeway road works include construction of the Beaches Link portal structures and associated ramps and road tie ins. Project works within the Warringah Freeway would be likely timed to occur in conjunction with staged surface works in the area for the Warringah Freeway Upgrade project so as to limit disruption to traffic and duration of noise impacts for the adjacent community.

The construction footprint along the Warringah Freeway and Gore Hill Freeway extends from North Sydney in the south to Naremburn in the north. There would also be minor construction activities such as local road works (eg pavement, linemarking, tie in works) and utility adjustment works required that would take place for relatively short periods (less than one month) in areas within or adjacent to the Warringah Freeway road corridor. These would occur during standard hours where practicable. However, these works would likely be required to take place outside standard construction hours to minimise potential traffic and road safety impacts. Impacts from these types of works have been assessed separately, which is presented in Section 5.15.1. During the works the Cammeray Golf Course construction support site (BL1) would be support the works.

5.2.1.2 Nearby noise and vibration sensitive receivers

Figure 5-1 presents the site location, nearby noise sensitive receivers, and the NCA boundaries. The NCAs that are in proximity to the Warringah Freeway road works area are NCA 21.1 through to NCA 31.3. Refer to Annexure B.1 for more detailed information on the nearby noise sensitive receivers and the NCA boundaries.

5.2.1.3 Construction works program

The assumed timeframe for the Warringah Freeway surface road works is presented in Table 5-4 and Table 5-5, subject to project approval. The works would take place from the beginning of 2025 until the middle of 2026. The location of the assessment works areas is presented Figure 5-1.

Table 5-4 – Warringah Freeway surface road works – indicative program and timeline

Project component	Indicative construction timeframe																							
	2022				2023				2024				2025				2026				2027			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Warringah Freeway road works																								

Table 5-5 – Warringah Freeway surface road works – indicative duration of construction work

Works area	Activity reference (Figure 5-2)	Indicative duration of works
Beaches Link cut and cover portal structures and associated ramps (northbound)	WFU2H_10	12 months
Beaches Link cut and cover portal structures and associated ramps (southbound)	WFU2H_11	12 months

Figure 5-1 – Warringah Freeway surface road works area, nearby noise sensitive receivers and noise catchment area (NCA) boundaries

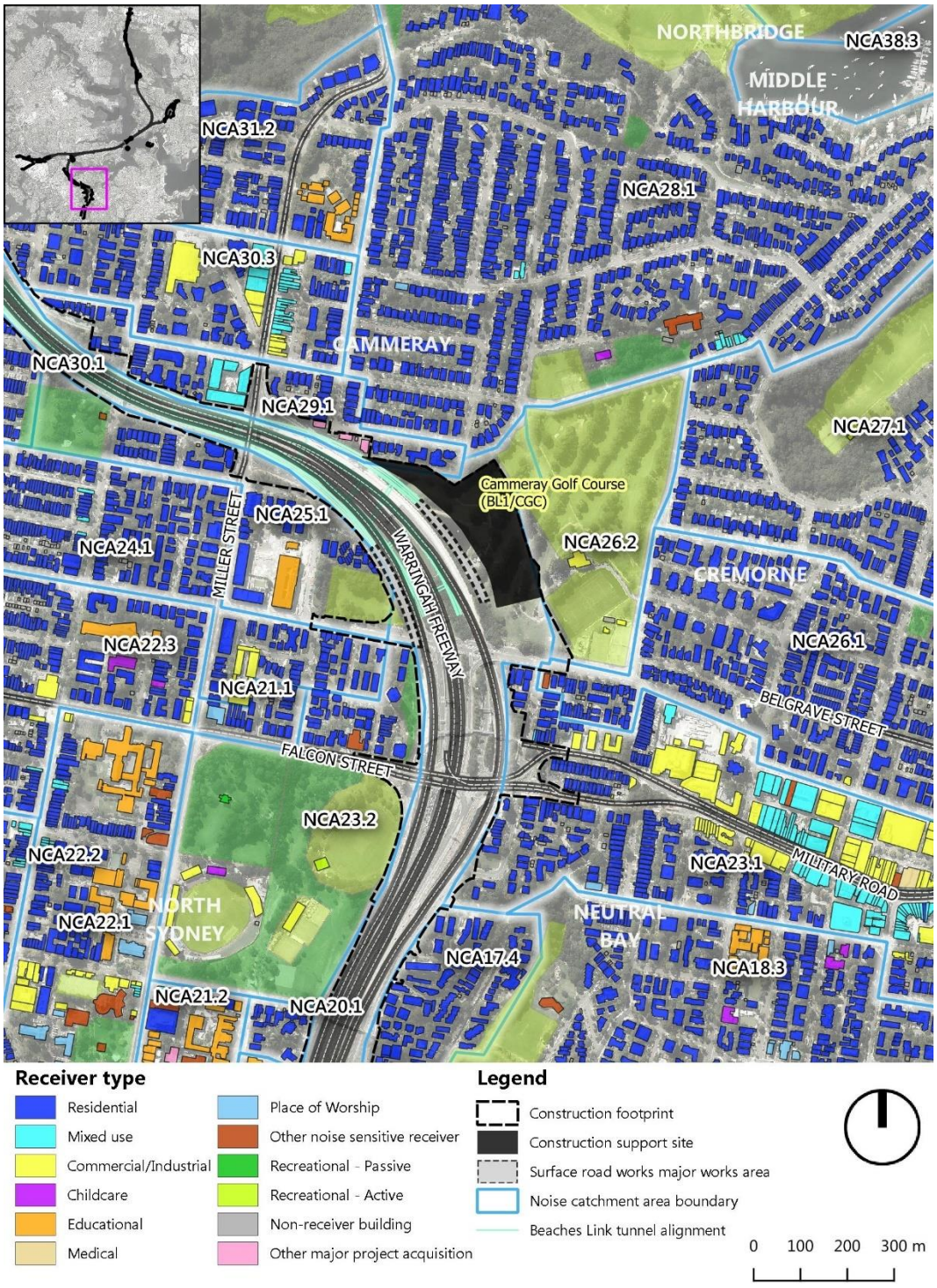
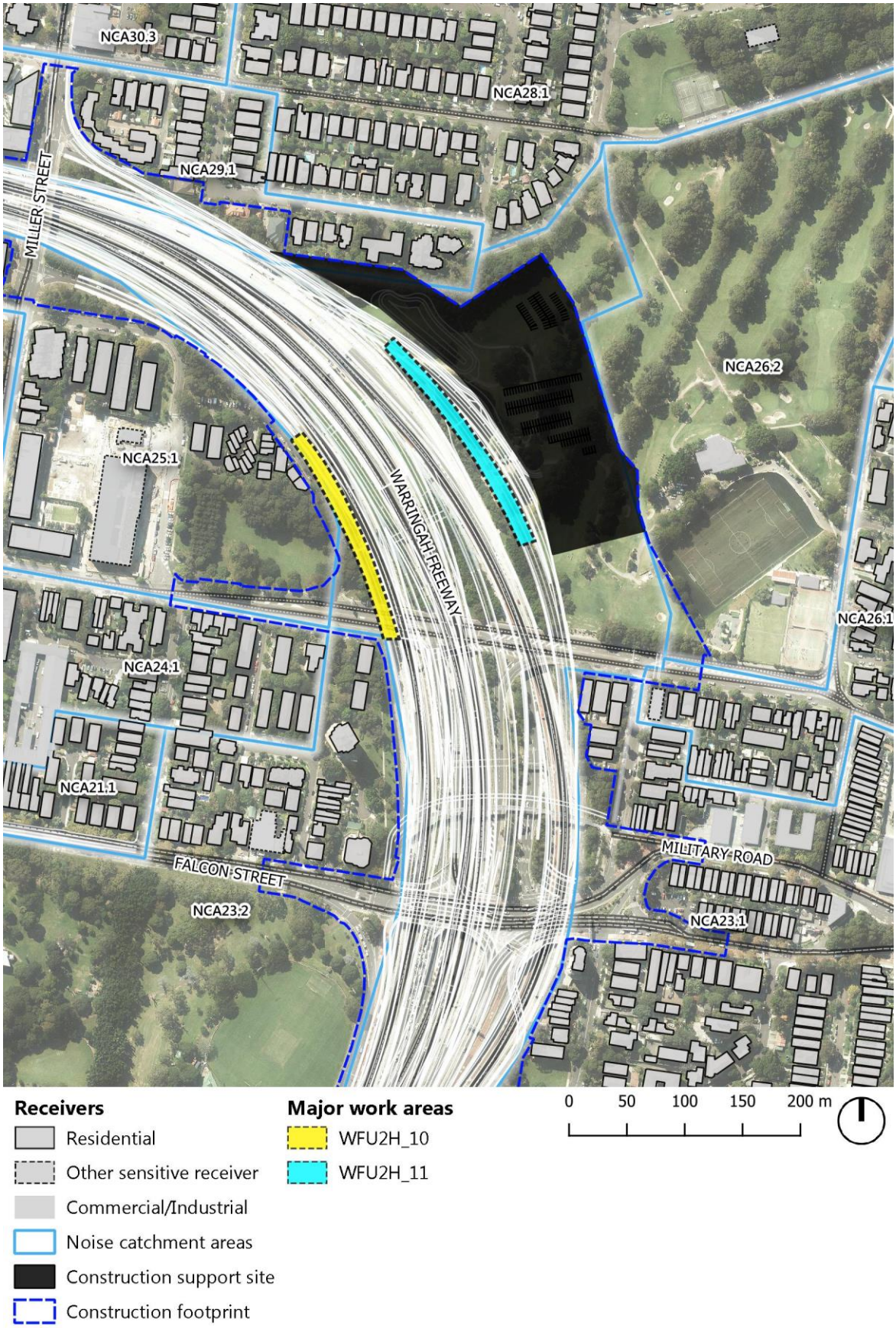


Figure 5-2 – Warringah Freeway surface road works area (WFU2H)



5.2.1.4 Construction hours and required out of hours work

Stages of the proposed works for WFU2H_10 would occur during night time road closures, as the works would require occupancy of the Warringah Freeway carriageways. Due to the importance of the road to the greater Sydney road network work would need to take place outside standard construction hours, as further detailed and justified in Section 5.1.6.1.

The portal construction works within the Cammeray Golf Course construction support site (BL1) area would not require work within the live traffic corridor, and so can be carried out during standard construction hours, except for tie in works.

The key OOHW required and justifications, are presented in Table 5-6.

Table 5-6 – Required out of hours work – Warringah Freeway surface road works

Location/Stage (Figure 5-1 and Figure 5-2)	Required OOHW	Percentage of program days OOHW is required	Justification
WFU2H_10	1. Oversized item delivery and installation 2. Concrete pours in/adjacent to road corridor 3. Paving/asphalting/ road works within the road corridor	10	1. ROL required to minimise impacts on road network performance, worker safety and road user safety. 2. Large load lifts over existing roads 3. Impact on road network performance/safety from oversized loads
WFU2H_11	Work would typically occur only during standard construction hours		

Notes: 1. Based on an estimated number of days of the overall stage duration that may require OOHW, rounded up to the nearest 10 per cent. Estimated period of OOHW would be refined during detailed construction planning stage.

In addition to the above key OOHW, utility and sewage infrastructure modifications would be required as part of the works and would be carried out during out of hours where a ROL is required to undertake the works. The temporary nature of works carried out under a ROL means that there are limited opportunities to install fixed noise mitigation (ie acoustic sheds, acoustic enclosures, large temporary barriers) as the road needs to be fully open the next day. Other feasible and reasonable noise mitigation and management measures would be reviewed and implemented to minimise noise impacts on nearby noise sensitive receivers.

The mitigation and management measures which would be put in place for surface road works are discussed in Section 6.4.

5.2.1.5 Concurrent construction projects

The nearest construction support sites associated with this project would be:

- The Cammeray Golf Course (BL1) construction support site, located directly adjacent to the northeast of the works

- The Flat Rock Drive construction support site (BL2), about 1.5 kilometres northwest of this site. Due to the distance of the Flat Rock Drive construction support site (BL2) from the Warringah Freeway road works and the level of noise emissions expected from the construction support site, cumulative noise impacts are unlikely.

The nearest construction work associated with another state significant project would be:

- Warringah Freeway Upgrade associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project, which includes works areas adjacent the project Warringah Freeway surface road works areas (WFU2H) along the Warringah Freeway.

5.2.2 Construction airborne noise

The methodology for assessing airborne noise impacts from surface road works is outlined in Section 4.2.3.

5.2.2.1 Construction assessment scenarios

The airborne noise assessment of the Warringah Freeway road works was separated into two work areas. Each work area was assessed for works both during and outside of standard construction hours. The location of the assessment works area is presented in Figure 5-1.

Presented in Table 5-7 are the assessed activities for each works area, which represents the reasonable most intensive noise activity required as part of the works. However, it should be noted that the type of plant and equipment used throughout the stage would vary depending upon the construction activities being carried out. Table 5-7 summaries the loudest noise generating works that are proposed for the works area.

The construction contractor, once appointed, would review and refine the project design and construction methodology during further design development and construction planning. The contractor should review noise impacts with a better understanding of the construction plant and equipment required for specific works, the locations they would likely operate and the potential for concurrent activities in order to make more accurate predictions of the nature and duration of impacts.

The equipment/plant listed in Annexure F represent the reasonable 'typical' and 'worst case' equipment/plant operating simultaneously in any 15 minute period (refer to Section 4.2.3 for further explanation of assessment scenarios). Where plant items are not operating simultaneously, or for reduced times in a 15 minute period, noise impacts could be lower than predicted.

Table 5-7 – Assessed construction activities – Warringah Freeway surface road works

Assessment scenario reference	Standard hours work	SWL level range, $L_{Aeq\ 15\ minute}$ dB(A)		Out-of-hours works	SWL level range $L_{Aeq\ 15\ minute}$ dB(A)	
		Typical	Worst case		Typical	Worst case
WFU2H_10	Demolition (rock hammering)	109	121	Paving/asphalting/road surface road works (including concrete sawing)	109	120
WFU2H_11	Piling	108	117	-[2]	-	-

Notes
1. The activity SWL includes the adjustments for quantity of equipment assumed operating, equipment usage factor, and penalties for annoying characteristics in accordance with the ICNG. Refer to Annexure F
2. No typical work is proposed outside standard construction hours.

5.2.2.2 Construction noise prediction summary

Table 5-9, Table 5-10 and Table 5-12 present the predicted noise levels from construction activities and compares them with the NMLs for the proposed works. Table 5-11 and Table 5-13 present the approximate number of receiver buildings that exceed the NMLs in each NCA and the number of receiver buildings that are potentially highly noise affected over the entire duration of the works stage.

All receiver building counts presented in this assessment are based upon the highest noise levels that would reasonably be expected to occur throughout a works stage and when the works are working closest to each receiver building, defined as the highest noise level envelope explained in Section 4.2.3.2.1. In practice during any individual period of construction works the actual number of receiver buildings that could experience the highest predicted noise levels would be less that these maximum receiver building counts.

Residential receivers

During standard construction hours no receiver buildings are predicted to be noise affected (>NML) by typical construction works. During worst case works, exceedances of the NML are predicted for NCAs 23.2, 24.1, 25.1, 28.1 which are located either side of the Warringah Freeway in North Sydney, Cammeray and Crows Nest:

- The highest predicted noise levels occur for receivers in NCA 25.1 which are directly west of the works areas. These impacts are when rock hammers are required when closest to NCA 25.1
- During the portal (northbound) construction works (WFU2H_10), the highest predicted noise level during worst case activities is approximately 80 dB(A) in NCAs 23.2 and 25.1, where six receiver buildings are identified as potentially being highly noise affected (ie >75 dB(A)). During the portal (southbound) construction works (WFU2H_11) the highest predicted noise level during worst case activities is 59 dB(A) in NCA 23.2, and so no receivers are predicted to be highly noise affected (ie >75 dB(A)).
- During standard hours, the highest noise impacts could be clearly audible, with exceedances of the NML of up to 11 dB(A). Up to 18 receiver buildings are predicted to exceed the NML over the entire works stage.

During OOHW, the key activities that have been assessed are paving and asphalting road works activities, including road saws, which would be required during the portal (northbound) construction (WFU2H_10) works, while works for the southbound portal are outside of the road corridor within the Cammeray construction support site, and so would typically not occur during the OOHW periods. During the night period:

- For the northbound portal construction (WFU2H_10) up to 148 receiver buildings are predicted to be noise affected outside standard construction hours during typical paving and asphalting road works activities works, and during periods of worst case paving and asphalting road works activities works up to 1917 receiver buildings are predicted to exceed the night NMLs
- In the worst case up to seven receiver buildings are predicted to experience noise levels that exceed the night NML by more than 25 dB(A), which is considered highly intrusive.

Non-residential receivers

Construction noise levels at non-residential receivers are generally predicted to meet the NMLs, except for the following key receivers:

- Marginal exceedances of 1 to 2 dB(A) are predicted at a childcare receiver (KU Cammeray Preschool) in NCA 28.1. This level of exceedance is considered minor
- One educational receiver (ANZAC Park Public School) with buildings located in NCA 25.1, where noise levels are predicted to exceed the NML by more than 7 dB(A) during worst case construction works. Construction noise during typical construction work would be lower than then NML
- One recreational receiver (ANZAC Park) in NCA 25.1 would exceed the NML by 5 dB(A) during worst case construction works. Predicted noise levels would comply during typical work.

Construction mitigation and management measures are provided in Section 6 to assist in reducing construction noise impacts to other sensitive receivers.

Sleep disturbance

The most likely source of potential sleep disturbance from the night construction works would be from truck air brakes, or metal on metal bangs from other equipment associated with the works. Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from OOHW.

Predicted noise levels show the sleep disturbance screening levels may be exceeded during the northbound portal construction work, if work occurs during the night period:

- During typical construction outside standard construction hours, air brakes are predicted to exceed the sleep disturbance screening level at up to 65 receiver buildings, including eight where the awakening reaction level is predicted to be exceeded. The affected receivers are mostly in NCAs 23.2, 24.1 and 25.1

- Maximum noise levels at up to 692 receiver buildings are predicted to exceed the sleep disturbance screening level during worst case works, where the predicted noise levels exceed the awakening reaction level at up 46 receiver buildings.

Where sources of high noise events (ie metal on metal bangs or air brake releases) are managed or eliminated, the potential for sleep disturbance can be mitigated. Construction mitigation and management measures are provided in Section 6 to assist in reducing OOHW construction noise impacts to receivers. Heavy vehicle movements that require excessive use of air brakes or activities requiring metal on metal bangs should be limited as much as practicable during the night period, in order to limit the potential for sleep disturbance.

5.2.2.2.1 Construction noise assessment outcomes

Due to the relatively high background noise levels during the daytime from Warringah Freeway road traffic noise in nearby suburbs, construction noise impacts during standard hours would be limited and minor. However, due to the proximity of the northbound portal works area (WFU2H_10) to live traffic and typical ROL requirements, a substantial portions of the works at that location would likely be required outside standard construction hours.

A large number of residential receiver buildings are predicted to be above the night NML during these worst case OOHW activities. Typical noise impacts are more limited to around the works area; however, even with the incorporation of feasible and reasonable noise treatments, exceedances are predicted.

Due to the nature of the surface road works, further acoustic mitigation, programming and alternative construction activity locations should be reviewed during detailed construction planning, to further reduce the residual impacts identified in this assessment. These measures are detailed in Section 6, with further surface road works measures included in Section 6.4.

5.2.2.3 Construction noise prediction tables

Table 5-8 provides a key to the cell shading and text formatting used to explain results in the following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-8 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes:
1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are expected to exceed NMLs. The range is of noise impacts throughout all receivers in the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented.

The predicted noise levels for residential receivers are presented in the following tables:

- Table 5-9: for residential receivers during standard hours
- Table 5-10: for residential receivers during works outside standard construction hours
- Table 5-12: for non-residential receivers.

The construction NMLs for all residential receivers nearby are presented in Annexure B.1, and for all other non-residential receivers see Section 3.4.1.

The number of receiver buildings predicted to exceed NMLs during each stage and time period are summarised Table 5-11 and Table 5-13. Predicted noise levels are intended to be conservative and represent reasonable typical and worst case impacts during the project.

The highest 'typical' noise levels that have been predicted for all major works areas and the representative scenarios across the works areas are presented as noise contour envelopes in Annexure H.2. These present the extent of typical predicted noise impacts during key OOHW periods to give an indication of the likely extent of noise levels from the Warringah Freeway road works. Maps presenting the predicted exceedance for a sample of scenarios from the major works areas with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different periods.

Table 5-9 – Predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – standard hours (residential receivers) – Warringah Freeway surface road works

Major works area/assessment reference				WFU2H_10		WFU2H_11	
Typical/worst case activity noise intensity				Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver				Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level		Predicted noise levels, $L_{Aeq\ (15\ minutes)}$			
		HNA	NML				
Wollstonecraft	22.2	75	62	< 35	44 / 46	< 35	40 / 42
North Sydney	21.1	75	63	36 / 45	48 / 57	37 / 42	46 / 51
	22.1	75	62	36 / 40	48 / 52	36 / 39	45 / 48
	23.2	75	71	39 / 68	51 / **80**	38 / 51	47 / 60
Neutral Bay	17.4	75	65	38 / 41	50 / 53	34 / 37	43 / 46
	23.1	75	71	27 / 50	39 / 62	33 / 52	42 / 61
Crows Nest	22.3	75	62	39 / 44	51 / 56	36 / 40	45 / 49
	24.1	75	66	41 / 57	53 / 69	39 / 49	48 / 58
	30.1	75	68	33 / 35	45 / 47	34 / 36	43 / 45
Cammeray	25.1	75	68	41 / 67	53 / **79**	34 / 53	43 / 62
	28.1	75	57	39 / 48	51 / 60	28 / 50	37 / 59
	29.1	75	74	38 / 51	50 / 63	49 / 57	58 / 66
	30.3	75	68	37 / 43	49 / 55	37 / 43	46 / 52
	31.2	75	66	33 / 36	45 / 48	34 / 38	43 / 47
Cremorne	26.1	75	68	35 / 46	47 / 58	36 / 49	45 / 58
	27.1	75	59	37 / 40	49 / 52	36 / 41	45 / 50
Naremburn	30.2	75	68	< 35	43 / 45	< 35	40 / 41
	31.1	75	66	< 35	44 / 46	< 35	40 / 42
	31.3	75	66	< 35	42 / 44	< 35	39 / 41
	37.1	75	55	< 35	40 / 41	< 35	38 / 39
Northbridge	38.1	75	62	< 35	43 / 44	< 35	37 / 39
	38.3	75	62	< 35	43 / 45	< 35	40 / 42
	39.1	75	47	< 35	37 / 38	< 35	< 35
	40.1	75	47	< 35	39 / 40	< 35	35 / 36

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
3. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-8
4. Table features are explained further in Section 4.2.3.2.

Table 5-10 – Predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – outside standard hours (residential receivers) – Warringah Freeway surface road works

Major works area/assessment reference						WFU2H_10		WFU2H_11[6]	
Typical/worst case activity noise intensity						Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver						Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level				Predicted noise levels, $L_{Aeq\ (15\ minutes)}$			
		HNA	Day (O)	Eve	Night				
Wollstonecraft	22.2	75	57	52	41	< 35	44 / 46	-	-
North Sydney	21.1	75	58	54	46	36 / 45	48 / 57	-	-
	22.1	75	57	52	41	36 / 40	48 / 52	-	-
	23.2	75	66	59	49	39 / 68	51 / **80**	-	-
Neutral Bay	17.4	75	60	59	50	38 / 41	50 / 53	-	-
	23.1	75	66	59	49	27 / 50	39 / 62	-	-
Crows Nest	22.3	75	57	52	41	39 / 44	51 / 56	-	-
	24.1	75	61	57	42	41 / 57	53 / 69	-	-
	30.1	75	63	61	43	33 / 35	45 / 47	-	-
Cammeray	25.1	75	63	60	48	41 / 67	53 / **79**	-	-
	28.1	75	52	50	42	39 / 48	51 / 60	-	-
	29.1	75	69	68	52	38 / 51	50 / 63	-	-
	30.3	75	63	61	43	37 / 43	49 / 55	-	-
	31.2	75	61	54	42	33 / 36	45 / 48	-	-
Cremorne	26.1	75	63	59	46	35 / 46	47 / 58	-	-
	27.1	75	54	53	44	37 / 40	49 / 52	-	-
Naremburn	30.2	75	63	61	43	< 35	43 / 45	-	-
	31.1	75	61	54	42	< 35	44 / 46	-	-
	31.3	75	61	54	42	< 35	42 / 44	-	-
	37.1	75	50	49	39	< 35	40 / 41	-	-
Northbridge	38.1	75	57	53	42	< 35	43 / 44	-	-
	38.3	75	57	53	42	< 35	43 / 45	-	-
	39.1	75	42	39	35	< 35	37 / 38	-	-
	40.1	75	42	42	38	< 35	39 / 40	-	-

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-8
5. Table features are explained further in Section 4.2.3.2
6. No typical work is proposed outside standard construction hours.

Table 5-11 – Number of residential receiver buildings over the noise management level – Warringah Freeway surface road works

Assessment reference	Typical/worst case activity noise intensity	Highly noise affected > 75 dB(A)		Day (standard hours)			Day (outside standard hours)				Evening				Night				Sleep disturbance	
		Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening level (L_{Amax})	Awakening (L_{Amax})
WFU2H_10	Typical	0	0	0	0	0	6	0	0	0	2	4	0	0	113	29	6	0	65	8
	Worst case	**6**	**6**	16	2	0	180	16	2	0	266	39	6	0	1146	710	54	7	692	46
WFU2H_11[4]	Typical	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Worst case	0	-	10	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes
1. 'Typical' and 'Worst case' case noise assessment scenarios are explained in Section 4.2.3.2.2, and demonstrated in Figure 4-8.
2. Refer to the "Required out of hours work" table in the section "Construction hours and durations" of this assessment section for an indication of the duration and how often these noise impacts are expected to occur.
3. An indicative program and timeline in provided at the beginning of this section to provide an indication of the duration of these construction works and the associated construction noise impacts.
4. No typical work is proposed outside standard construction hours

Table 5-12 – Predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – non-residential receivers – Warringah Freeway surface road works

Major works area/assessment reference			WFU2H_10		WFU2H_11	
Typical/worst case activity noise intensity			Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver			Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
OSR type	NCA	NML[6]	Predicted noise levels, $L_{Aeq\ (15\ minutes)}$			
Childcare	28.1	50	32 / 40	44 / 52	< 40	27 / 49
Educational	25.1	55	< 50	36 / 62	< 46	36 / 55
Recreational	25.1	60	< 53	38 / 65	< 44	34 / 53

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is < 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML. A full key is presented in Table 5-8
5. Table features are explained further in Section 4.2.3.2
6. Other sensitive receivers have a range of NMLs based upon the receiver classification as outlined in Section 3.4.1.2.The exceedances are based upon the respective receiver NML.

Table 5-13 – Number of non-residential receivers over the noise management level – Warringah Freeway surface road works

Assessment reference	Typical/worst case activity noise intensity	Commercial[1]			Childcare			Educational			Recreational[1]			Places of worship			Other sensitive receivers[1]		
		1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
WFU2H_10	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Worst case	0	0	0	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0
WFU2H_11	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table.

5.2.2.4 Cumulative construction noise impacts

There is potential for cumulative noise impacts on receivers near the Warringah Freeway surface road works from other construction works being carried out in the area at the same time. As further outlined in Section 4.2.4, the potential for cumulative construction noise impacts from other construction works associated with the project or other major construction projects in the area has been considered in assessing noise impacts.

Proposed staging of concurrent construction works associated with the project and other nearby major infrastructure that might result in cumulative construction impacts are presented in Table 5-14. The table shows that works associated with the different projects in this location have the potential to increase the duration over which affected receivers might experience elevated construction noise. Works associated with the different projects in this location have the potential to increase the duration over which affected receivers might experience elevated construction noise.

There is also the potential for cumulative impacts when works associated with the Gore Hill Freeway Connection surface road works are occurring in different areas concurrently.

Table 5-14 – Concurrent construction works near the Warringah Freeway surface road works

The project	2023	2024	2025	2026	2027	2028
Warringah Freeway surface road works			■	■		
Cammeray Golf Course construction support site (BL1/CGC)			■	■	■	
Other major projects						
Cammeray Golf Course construction support site as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project (WHT10 & WFU8/CGC)[1]	■	■	■			
Warringah Freeway Upgrade project (WFU) (Falcon Street to Miller Street construction works (WFU2H))[1,2]	■					

Notes
1. Construction support sites WHT10 & WFU8 that form part of the Western Harbour Tunnel and Warringah Freeway Upgrade projects, refer to Western Harbour and Warringah Freeway Upgrade environmental impact statement (Transport for NSW, 2020).
2. Warringah Freeway Upgrade project works are proposed to extend to the end of 2025, this program is for adjacent Warringah Freeway Upgrade works area only as per the Western Harbour and Warringah Freeway Upgrade environmental impact statement (Transport for NSW, 2020).

Table 5-15 and Table 5-16 present all the major works areas and nearby major construction projects and indicates if predicted cumulative noise levels the from projects during typical construction activities are likely to exceed the NML in each NCA. If construction is carried out in more than one major works area at the same time, and both are predicted to exceed the NML in the same NCA, then there is potential for an increase in construction noise levels in that NCA due to cumulative noise impacts.

Worst case noise activities have not been included in the cumulative noise assessment, as they are likely to be infrequent and sporadic. It is unlikely that they would frequently occur simultaneously in more than one works area. Worst case impacts have the potential to impact a larger number of NCAs than presented in Table 5-15 and Table 5-16.

For worst case works there is greater chance that the same NCAs may be impacted over consecutive nights, affecting respite for affected receivers. This is because the worst case activities are more noise intensive and affect a large range of receivers than for typical activities. Depending upon when they are to occur, both typical and worst case activities may require consideration when determining respite provisions.

Table 5-15 and Table 5-16 show that there is potential for cumulative impact from daytime construction works in NCA 28.1, from concurrent work within the Cammeray Golf Course construction support site (BL1). During OOHW, only NCAs 21.2 and 28.1 have overlapping impacts which would be considered during detailed construction planning.

Works would be scheduled to provide respite to noise affected (ie >NML) receivers as outlined and recommended in the CNVG (see Annexure G) and further detailed in Section 6.4.3.

Table 5-15 – Noise affected (ie >NML) NCAs for each major works area – typical activities (standard hours) – Warringah Freeway surface road works

Suburb	NCA	Day NML	Beaches Link and Gore Hill Freeway Connection			OMP[2]	
			WFU2H_10	WFU2H_11	BL1/CGC (Section 5.3)	WHT10 & WFU8/CGC[3]	WFU[3]
North Sydney	23.2	71					♦
Neutral Bay	23.1	71				♦	♦
Crows Nest	22.3	62					
	24.1	66				♦	♦
Cammeray	25.1	68				♦	♦
	28.1	57			♦	♦	♦
	29.1	74					
	31.2	66					
Cremorne	26.1	68				♦	♦
	27.1	59				♦	♦
Naremburn	31.1	66					
	31.3	66					

Notes 1. ♦ and (**blue**) shading indicates 'typical' construction activities are predicted to exceed the Daytime NML. Receivers in that NCA are considered 'noise affected'

2. OMP – Other major construction projects, refer to Table 5-14 for the project references.

3. Construction support sites WHT10 & WFU8 that form part of the Western Harbour Tunnel and Warringah Freeway Upgrade projects, information sourced from the Western Harbour Tunnel and Warringah Freeway Upgrade Technical working paper: Noise and vibration (Renzo Tonin and Associates, 2019)

Table 5-16 – Noise affected (ie >NML) NCAs for each major works area – typical activities (OOHW) – Warringah Freeway surface road works

Suburb	NCA	Night NML	Beaches Link and Gore Hill Freeway Connection			OMP[2]	
			WFU2H_10	WFU2H_11[3]	BL1/CGC (Section 5.3)	WHT10 & WFU8/CGC[3]	WFU[3]
North Sydney	23.2	49	♦				♦
Neutral Bay	23.1	49	♦			♦	♦
Crows Nest	22.3	41	♦				♦
	24.1	42	♦		♦	♦	♦
Cammeray	25.1	48	♦				♦
	28.1	42	♦			♦	♦
	29.1	52					♦
	31.2	42					♦
Cremorne	26.1	46				♦	♦
	27.1	44					♦
Naremburn	31.1	42					♦
	31.3	42					♦

Notes
1. ♦ and (**orange**) shading indicates 'typical' construction activities are predicted to exceed the Night NML. Receivers in that NCA are considered 'noise affected'
2. OMP – Other major construction projects, refer to Table 5-14 for the project references
3. No typical work is proposed outside standard construction hours.
4. Construction support sites WHT10 & WFU8 that form part of the Western Harbour Tunnel and Warringah Freeway Upgrade projects, information sources from the Western Harbour Tunnel and Warringah Freeway Upgrade Technical working paper: Noise and vibration (Renzo Tonin and Associates, 2019)

5.2.3 Construction related road traffic noise

5.2.3.1 Changes in road traffic noise impacts due to construction works

As traffic speeds would decrease from the current posted speeds of 80 kilometres per hour down to 60 kilometres per hour, or where required 40 kilometres per hour, road traffic noise levels would reduce during construction. Based on the distances from the existing carriageway and roads, even where a single carriageway is closed and all other traffic is redirected onto the other carriageway, the reduced speed would compensate for the consolidation of all traffic into the lanes closest to the receiver. As such, road traffic noise impacts would not increase as a result of traffic switching as presented in Table 5-17. Even if the affected vehicles do not completely observe the adjusted speed limit, it is unlikely that road traffic noise levels would increase due to traffic management associated with the project.

Table 5-17 – Changes in road traffic noise impacts due to construction works – Warringah Freeway surface road works

Existing situation	Reduced speed, and all traffic switched to closest carriageway	Reduced speed, and all traffic switched to closest carriageway	Reduced speed, and all traffic switched to far carriageway	Reduced speed, and all traffic switched to far carriageway
Assessed traffic speed	60 km/hr	40 km/hr	60 km/hr	40 km/hr
Reduction from existing, dB(A)	- 0.4	- 1.8	- 4.3	- 5.8

Notes:
1. Assume distance to closest carriageway is 25 metres and far side is 65 metres
2. Heavy vehicle percentage during the night period is eight per cent
3. Night is 10.00pm to 7.00am
4. Assessed to the receivers closest to the road upgrade
5. Existing posted speed = 80 kilometres per hour (km/hr).

5.2.3.2 Heavy vehicle operations associated with surface road works

A relatively small number of construction vehicles are proposed to travel to the Warringah Freeway road works, with most vehicles travelling directly to each area at the start of a shift. Vehicles would mostly travel to or between major works areas via the Warringah Freeway and major arterial roads, which already carry high traffic volumes with substantial numbers of heavy vehicles.

Generally, only light vehicle movements would be associated with the construction support sites. Approximately two to four trucks per hour would be associated with the Warringah Freeway road works during standard hours and OOHW. Warringah Freeway already carries more than 100,000 vehicles per day, with greater than eight per cent heavy vehicles.

Construction traffic associated with the Warringah Freeway surface road works is unlikely to increase road traffic noise levels by more than 2 dB(A), as an overall total traffic volume increase of at least 60 per cent would be required, or a substantial increase in heavy vehicles, to increase noise levels by 2 dB(A).

Mitigation and management measures detailed in Section 6.7 should be considered during further design development and construction planning and, where feasible and reasonable, adopted to minimise construction traffic noise impacts associated with the project.

5.2.4 Ground-borne construction noise

Ground-borne noise levels have the potential to be generated by vibration intensive works at the surface road works and associated support sites. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Section 4.3.2 outlines the potential ground-borne noise impacts from surface construction works such as these.

5.2.5 Construction vibration

Vibration generated from construction works would vary depending on the level and type of activity carried out at each site during each major works stage.

Vibration intensive activities such as rock hammering could be required as part of the Warringah Freeway surface road works. For a large rock hammer the minimum working distance is 22 metres for sound structures, 30 metres for unsound structures and 73 metres for adverse human response. These distances have been used to assess potential vibration impacts. A range of other vibration intensive plant may be used as part of the works. Typical minimum working distances for other vibration intensive plant items that may be used in the works are presented in Table 4-11 and the works area specific minimum working distances are presented in Annexure L.

The number of receiver buildings that are within the minimum working distances across the major works areas have been assessed and are presented in Table 5-18, with the locations presented in Annexure L. Potential vibration impacts to receivers would depend on vibration source levels, separation distances, intervening soil and rock strata, dominant frequencies of vibration and receiver structures. When construction works occur within the minimum working distance of nearby sensitive structures they should be assessed during further design development and construction planning, as recommended in Section 6.8.

Table 5-18 – Number of structures within nominated minimum working distance for vibration impacts – Warringah Freeway surface road works

Vibration intensive works location	NCA	Within minimum working distance		
		Cosmetic damage		Human response
		Sound structure	Unsound structure	
Warringah Freeway surface road works	24.1	-	-	2
	23.2	1	-	1
	25.1	6	-	19
	26.2	-	2[1]	-
	29.1	-	-	2

Notes: 1. A review of where any sensitive heritage items associated with the Cammeray Park is to be carried out to determine if further assessment for vibration impacts is required.

5.2.5.1 Heritage listed structures

The figures in Annexure L show the relative locations of heritage items nearby to all the assessed major works areas, along with the minimum working distances for vibration impacts.

The heritage items identified in Table 5-19 are within the minimum working distance for unsound structures.

Each identified heritage item should be assessed in detail during detailed construction planning to determine specific vibration mitigation and management measures, with consideration of the vibration intensive activities proposed at each site.

Two heritage items have been identified within the worst case minimum working distance for an unsound structure. A review of where any sensitive heritage items associated with the Cammeray Park should be carried out to determine if there are vibration sensitive items and so further assessment for vibration impacts is required.

Refer to the Technical working paper: Aboriginal cultural heritage assessment report (Appendix L of the environmental impact statement) and Technical working paper: Non-Aboriginal heritage (Appendix J of the environmental impact statement) for the assessment of impacts to heritage items.

Table 5-19 – Heritage receivers within minimum working distance for unsound structures – Warringah Freeway surface road works

Place/item name	Register	Type/classification[1]	Listing number	NCA
Warringah Freeway surface road works				
Cammeray Park (including golf course)	Local Environmental Plan	Item - Landscape	I0024	26.2
Northern Suburbs Ocean Outfall Sewer	Section 170 heritage and conservation register	-	4570286	26.2[2]

Notes: 1. Conservation areas have not been considered as they do not form a structure that would be impacted by vibration.
2. The Northern Suburbs Ocean Outfall Sewer is located not only in NCA26.2, but extends into NCA25.1 and beyond.

5.2.5.2 Vibration mitigation and management

Further analysis and assessment of potential vibration impacts should be carried out during the detailed construction planning phase, when likely plant and equipment, timing and location of works are confirmed.

Due to the varying nature of vibration intensive activities, cumulative vibration impacts are unlikely to result in increased vibration levels at sensitive receivers. However, all vibration generating activities should be considered during detailed construction planning and individual activities should not be considered only in isolation.

Vibration mitigation and management measures should be used to minimise any possible impacts on sensitive receivers. The measures recommended for this project are outlined in Section 6and would be included in a CNVMP.

5.3 Cammeray Golf Course construction support site (BL1)

This section assesses the potential construction noise and vibration impacts, and the reasonable and feasible treatment measures that would be considered to control impacts on noise and vibration sensitive receivers near the Cammeray Golf Course construction support site (BL1).

5.3.1 Construction support site overview

5.3.1.1 Construction support site description

Work at the site would occur in stages as presented in Table 5-20.

Table 5-20 – Cammeray Golf Course construction support site (BL1) – major stage overview

Stage	Representative activity	Major stage activities/description
Early works and site establishment	Installation of enviro controls and establishment of construction facilities	Adjust Western Harbour Tunnel construction support site environmental controls Adjust construction of vehicle access points Install site offices, store rooms and workshops
Construction of tunnel access decline at surface and acoustic shed	Acoustic shed and surface level access decline and ventilation tunnel construction works	Pile access decline walls and shed footings at surface level Surface level excavation of access decline and ventilation tunnels Acoustic shed construction
Civil works	Cut and cover and trough structures support	Support cut and cover portal construction and trough structures
Tunnel construction (access decline, ventilation and mainline and ramp tunnels)	Tunnelling	Tunnel spoil handling and haulage, tunnel support, tunnel lining and associated deliveries
Tunnel fitout and finishing	Tunnel fitout	Install electrical and mechanical infrastructure to the tunnel
Construction of motorway facilities	Construct motorway facilities building	Build operational motorway facilities building
Fitout of motorway facilities and ventilation outlet	Motorway facilities building fitout and ventilation outlet	Install electrical and mechanical infrastructure to the motorway facilities building and within the ventilation outlet Civil works constructed by the Western Harbour Tunnel project
Site rehabilitation	Site rehabilitation works and site demobilisation	Remove construction facilities Post construction condition surveys Remove construction environmental controls Remove construction support site related traffic signage

The construction support site for the project would be established within the footprint established for the Western Harbour Tunnel and Warringah Freeway Upgrade project. The site earthworks and general site established as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project. Refer to Western Harbour Tunnel and Warringah Freeway Upgrade Technical working paper: Noise and vibration (Renzo Tonin and Associates, 2019) for information on noise and vibration impacts from the site.

As part of the major activities presented above, the Cammeray Golf Course construction support site (BL1) would support up to three roadheaders constructing the mainline and ramp tunnels operating as follows:

- Two excavating mainline and ramp tunnels towards Naremburn
- One excavating cross passages.

The construction of the mainline and ramp tunnels are assessed in Section 5.16.

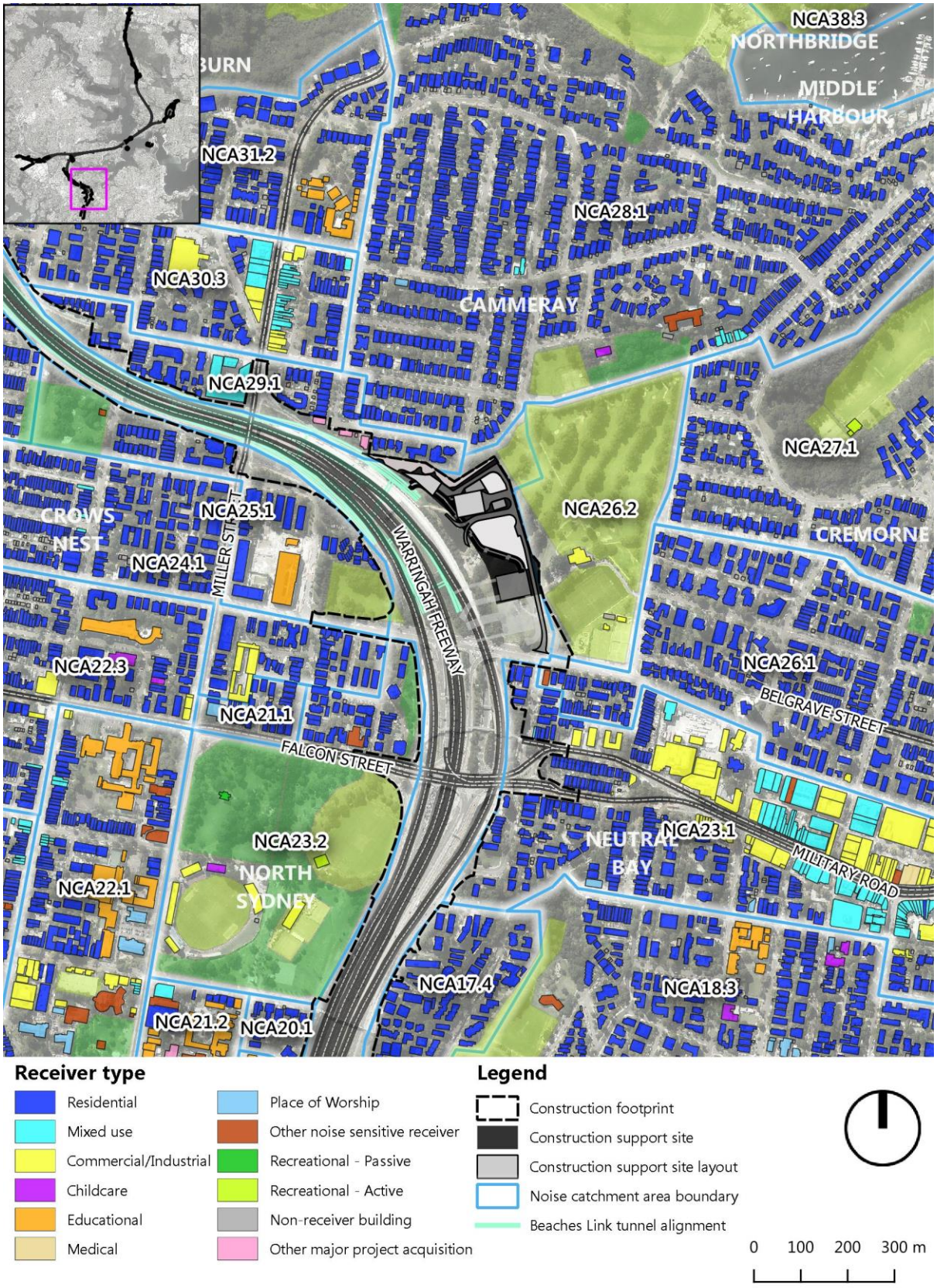
The construction support site would also be used by the Western Harbour Tunnel and Warringah Freeway Upgrade prior to the project; however, this assessment only relates to the site's use for the project.

5.3.1.2 Nearby noise and vibration sensitive receivers

The site is located at Ernest Street in Cammeray, adjacent to the Warringah Freeway, and is mostly surrounded by residential and recreational receivers.

The location of the site, nearby NCAs and receiver locations are shown in Figure 5-3.

Figure 5-3 – Location of the Cammeray Golf Course construction support site (BL1)



5.3.1.3 Construction works program

An approximate timeframe for the operation of the site is presented in Table 5-21, subject to project approval. This site is planned to operate from late 2024 until the end of 2027.

Table 5-21 – Cammeray Golf Course construction support site (BL1) – indicative program and timeline

Stage	Representative activity	Reference	Indicative construction timeframe															
			2024				2025				2026				2027			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Site establishment	1. Installation of enviro controls and establishment of construction facilities	CGC_01																
Access decline piling	2. Piling for access decline, acoustic shed and ventilation tunnels	CGC_02																
Access decline excavation	3. Access decline and ventilation tunnel excavation	CGC_03																
Acoustic shed construction	4. Acoustic shed construction	CGC_04																
Civil works	5. Cut and cover and trough structures support and fitout	CGC_05																
Tunnel construction (access decline, ventilation and mainline and ramp tunnels)	6. Tunnelling	CGC_06																
Tunnel fitout and finishing	7. Tunnel fitout	CGC_07																
Construction of motorway facilities	8. Construct motorway facilities building.	CGC_08																
Fitout of motorway facilities and ventilation outlet	9. Motorway facilities building and ventilation outlet	CGC_09																
Site rehabilitation	10. Site rehabilitation works and site demobilisation	CGC_10																

5.3.1.4 Construction duration and working hours

Table 5-22 presents each of the major stages and each of the assessed activities for the Cammeray Golf Course construction support site (BL1), along with the duration and proposed periods of works for each activity.

During the operation of the Cammeray Golf Course construction support site (BL1), work would typically take place during the ICNG standard construction hours, presented in Table 3-2 (Section 3).

Table 5-22 – Cammeray Golf Course construction support site (BL1) – construction hours

Stage		Representative activity	Reference	Assessed activities[1]	Work hours[2]			
					Day (Standard)	Day (OOHW)	Evening	Night
Site establishment	1.	Installation of enviro controls and establishment of construction facilities	CGC_01	Adjustment of enviro controls	♦			
				Establishment of construction facilities	♦			
Access decline piling	2.	Piling for access decline, shed and ventilation tunnels	CGC_02	Pile access decline walls and shed footings at surface level	♦			
Access decline excavation	3.	Access decline and ventilation tunnel excavation	CGC_03	Surface level excavation of access decline and ventilation tunnels	♦			
Acoustic shed construction	4.	Acoustic shed construction	CGC_04	Acoustic shed construction	♦			
Civil works	5.	Cut and cover and trough structures support and fitout	CGC_05	General construction activities[4]	♦	♦	♦	♦
				Deliveries to site	♦			
Tunnel construction (access decline, ventilation and mainline and ramp tunnels)	6.	Tunnelling	CGC_06	General site activities[4]	♦	♦	♦	♦
				Deliveries	♦			
				Tunnelling and support[4]	♦	♦	♦	♦
				Tunnel lining (concreting) deliveries[4]	♦	♦	♦	♦
				Spoil handling in an acoustic shed	♦	♦[3]	♦[3]	♦[3]
				Spoil haulage	♦			
Tunnel fitout and finishing	7.	Tunnel fitout	CGC_07	Deliveries[4]	♦	♦	♦	♦
				Laydown areas	♦			
Construction of motorway facilities	8.	Construct motorway facilities building.	CGC_08	Construct motorway facilities building	♦			
Fitout of motorway facilities and ventilation outlet	9.	Motorway facilities building fitout and ventilation outlet	CGC_09	Deliveries to site	♦			
Site rehabilitation	10.	Site rehabilitation works and site demobilisation	CGC_10	Decommissioning and rehabilitation of site	♦			

Notes:
1. Annexure E describes the modelled plant for each activity
2. Day (Standard) is 7.00am to 6.00pm Monday to Friday and 8.00am to 1.00pm Saturday
   Day Out of Hours Work is 1.00pm to 6.00pm Saturday and 8.00am to 6.00pm Sunday/Public holiday
   Evening is 6.00pm to 10.00pm Monday to Friday and 6.00pm to 10.00pm Saturday/Sunday/Public holiday
   Night is 10.00pm to 7.00am Monday to Friday and 10.00pm to 8.00am Saturday/ Sunday/Public holiday
3. Spoil haulage off the construction support site would occur during standard construction hours. OOHW spoil handling would occur inside acoustic shed
4. Activities typically within acoustic shed during OOHW periods.

5.3.1.5 Concurrent construction projects

The nearest construction support sites associated with this project would be the cut and cover portals immediately west of this site as part of the Warringah Freeway surface road works, and the Flat Rock Drive

construction support site (BL2), about 1.5 kilometres northwest of this site. Due to the distance of the Flat Rock Drive construction support site (BL2) from the Cammeray Golf Course construction support site (BL1) and the level of noise emissions expected from the construction support site, cumulative noise impacts are unlikely.

The nearest construction work associated with another state significant project would be:

- The Cammeray Golf Course construction support site (WHT10 & WFU8) for the Western Harbour Tunnel, which would be completing the final motorway facilities and ventilation outlet construction and tunnel fitout stages
- Warringah Freeway Upgrade associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project, which includes works areas north, west and south of the Cammeray Golf Course construction support site (BL1) along the Warringah Freeway.

5.3.1.6 Construction assessment scenarios

Airborne noise from the Cammeray Golf Course construction support site (BL1) was assessed against the work periods proposed in Table 5-22. The details of modelled construction plant items and corresponding sound power levels are presented in Annexure E.

The equipment/plant listed in Annexure E represent the reasonable worst case equipment/plant operating simultaneously in any 15 minute period (refer to Section 4 for further explanation of assessment scenarios).

5.3.1.7 Summary of assumed noise treatment and management measures

As part of the assessment process, feasible and reasonable noise treatment and management measures have been identified based on the preliminary site layout and the reasonable worst case plant/equipment operating, to assist in attenuating and managing noise emissions from construction activities.

Identified feasible and reasonable noise treatment measures have been included in the noise model and are presented in Table 5-23. The results presented in this assessment are based on these noise treatments and management measures being implemented. The locations of physical treatment measures are shown on Figure 5-4.

Refinements to the construction support site layouts, equipment, construction methods or construction hours during further design development and construction planning may require specific mitigation and management measures that are different from those outlined in this section. Final details for noise treatments and management measures will be confirmed during further design development and construction planning to determine what is feasible and reasonable, with consideration of cumulative construction impacts.

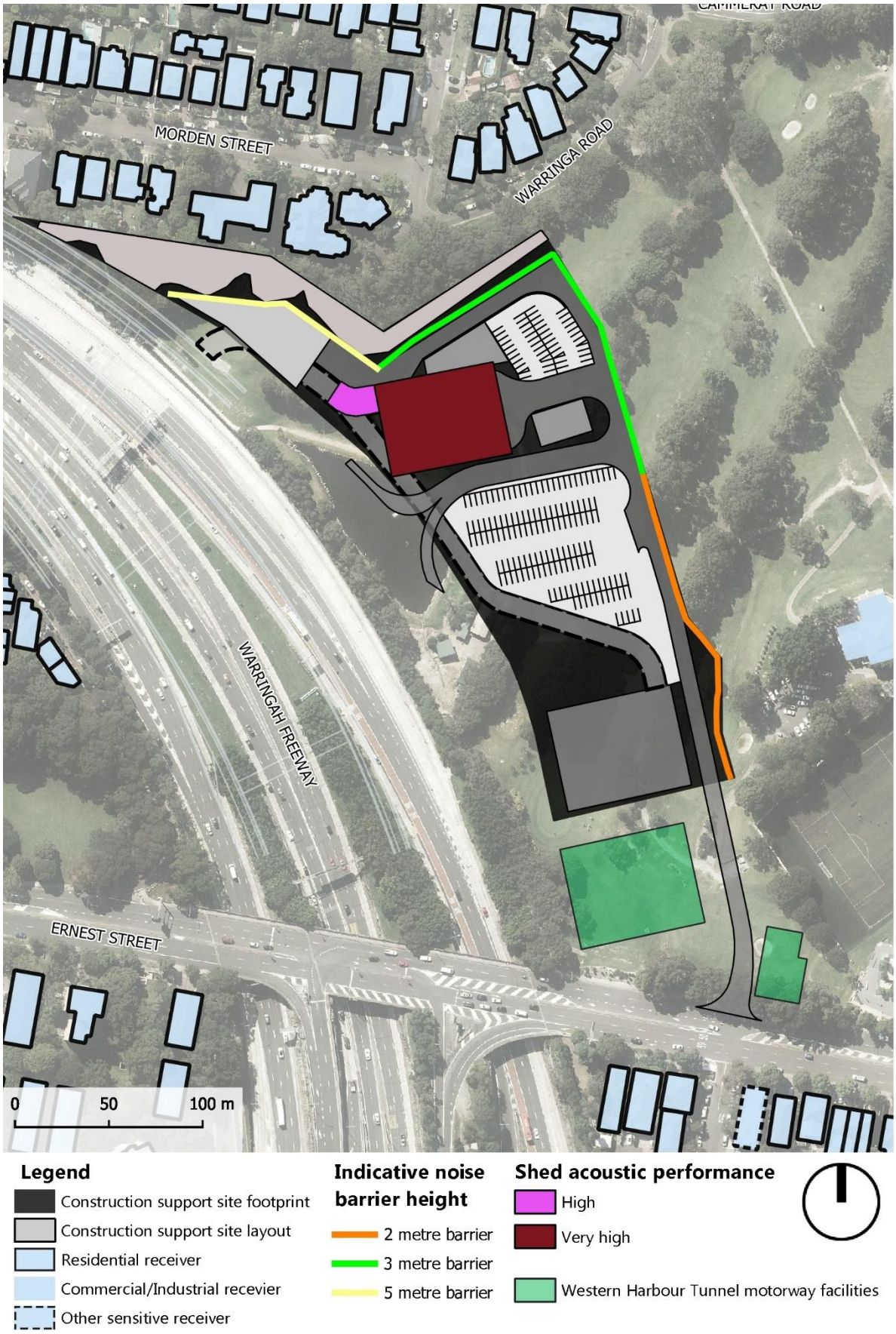
Table 5-23 – Assumed noise treatment and management measures – Cammeray Golf Course construction support sites (BL1)

Activity or plant/equipment	Management and noise treatment measures applied
Work outside standard hours	Work would only occur outside standard hours where it: • Meets the relevant NMLs, • Occurs in an acoustic enclosure, • Is required for safety reasons, or • Needs to occur outside standard hours to maintain the operational integrity of the road network. The majority of the following temporary noise barriers are only indicative at this stage of construction planning and would have been installed as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project Cammeray Golf Course construction support site (WHT10 & WFU8). Where feasible and reasonable, these barriers should be retained to mitigate noise impacts to nearby receivers. • Three to five metre high barriers along the northern boundary • Two to three metre high barriers to the east along the site boundary.
Heavy vehicle access outside standard hours	All heavy vehicles accessing the site outside standard hours would enter and exit from and to the Warringah Freeway and travel to the acoustic shed via the internal access roads.
Tunnelling, support and fitout: acoustic shed and covered access decline	An acoustic shed and covered access decline would be built to reduce noise from tunnelling, support and fitout works outside standard hours. Indicative performance requirements for shed elements are presented Table 5-24. Outside standard hours, noise generating activities associated with laydown, deliveries would occur within the acoustic shed. Additionally, other noise intensive works (ie. workshop related activities) will be conducted within the acoustic shed when outside standard construction hours.
Wastewater treatment plant	The wastewater treatment plant would achieve a total sound power level of 98 dB(A), which may require acoustic treatment or the use of an acoustic enclosure.
Substation	The substation is to achieve a total sound power level of 90 dB(A), which may require acoustic treatment or the use of an acoustic enclosure.
Ventilation plant	Ventilation system would be acoustically treated to achieve a maximum total sound power level of 98 dB(A) at the external opening. Five ventilation plants were included in the model. External openings are assumed to be located in the middle of the southern facade of the shed to reduce noise impacts.

Table 5-24 – Indicative acoustic shed construction and acoustic performance – Cammeray Golf Course construction support sites (BL1)

Shed / access decline element (Indicative example constructions are shown in Table 4-1)	Octave band frequency transmission loss, dB						
	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Acoustic shed (very high performance)							
Walls – Very High performance	25	31	40	49	61	69	75
Roof – High performance	20	27	36	45	51	56	62
Access decline cover (high performance)							
Walls – High performance	10	29	35	42	46	51	57
Roof – High performance	10	29	35	42	46	51	57

Figure 5-4 – Site layout with indicative acoustic treatment for the Cammeray Golf Course construction support site (BL1)



5.3.2 Construction airborne noise

The methodology used for assessing airborne noise impacts from construction support sites is outlined in Section 4.2.2.

5.3.2.1 Nearby receiver summary and objectives

Table 5-25 presents NMLs and the screening levels for the assessment of sleep disturbance for the nearest residential receivers surrounding the Cammeray Golf Course construction support site (BL1). Noise management levels for other (non-residential) noise sensitive receivers are presented in in Section 3.4.1. The locations of the NCAs surrounding the construction support site are shown in Figure 5-3.

Table 5-25 – Construction noise management levels and screening levels for residential receivers

NCA ID	Noise management levels (NML) $L_{Aeq(15\ minute)}$				Sleep disturbance screening levels
	Standard hours (RBL + 10dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL + 5dB)			L_{Amax} (RBL + 15dB)
	Day	Day	Evening	Night	Night
16.3	70	65	65	55	65
17.4	65	60	65	55	65
18.3	64	59	57	48	58
19.1	62	57	57	50	60
20.1	62	57	57	50	60
21.1	63	58	54	46	56
21.2	63	58	54	46	56
22.1	62	57	52	41	51
22.2	62	57	52	41	51
22.3	62	57	52	41	51
23.1	71	66	59	49	59
23.2	71	66	59	49	59
24.1	66	61	57	42	52
25.1	68	63	60	48	58
26.1	68	63	59	46	56
27.1	59	54	53	44	54
28.1	57	52	50	42	52
29.1	74	69	68	52	62
30.1	68	63	61	43	53
30.2	68	63	61	43	53

5.3.2.2 Predicted noise impacts

Table 5-26 provides a key to the cell shading and text formatting used to explain results in the following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-26 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes:
1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are expected to exceed NMLs. The range is of noise impacts throughout all receivers in the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented. It is noted that the noise predictions include adjustments for annoying activities, in accordance with the ICNG.

Noise contours for the loudest early works, site establishment, and longer term tunnelling stages are shown in Annexure H.1. Maps presenting the predicted exceedance for a sample of scenarios at the construction support site with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different assessment periods.

5.3.2.3 Residential

The predicted noise levels for residential receivers are presented in the Table 5-27 for standard hours and Table 5-28 for works outside standard construction hours.

The number of receiver buildings predicted to exceed NMLs during the proposed construction stage and time period are summarised in Table 5-29. Predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-27 – Predicted construction noise levels during standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Cammeray Golf Course construction support site (BL1)

NCA	Noise Management Level		Predicted noise levels at construction stage[1, 2]							
	HNA	NML	CGC_01	CGC_02	CGC_03	CGC_04	CGC_05 + 06	CGC_05 + 07+ 08	CGC_05 + 07+ 09	CGC_10
16.3	75	70	< 35	≤ 38	< 35	< 35	< 35	< 35	< 35	≤ 36
17.4	75	65	≤ 38	≤ 50	≤ 37	≤ 37	≤ 38	≤ 39	≤ 37	≤ 44
18.3	75	64	≤ 37	≤ 47	≤ 35	≤ 35	≤ 36	≤ 37	< 35	≤ 42
19.1	75	62	< 35	< 35	< 35	< 35	< 35	< 35	< 35	≤ 35
20.1	75	62	≤ 35	≤ 46	< 35	< 35	< 35	≤ 36	< 35	≤ 41
21.1	75	63	37 - 42	45 - 53	35 - 41	≤ 42	36 - 42	36 - 45	≤ 41	41 - 49
21.2	75	63	< 35	37 - 41	< 35	< 35	< 35	≤ 36	< 35	37 - 40
22.1	75	62	≤ 39	≤ 50	≤ 37	≤ 38	≤ 38	≤ 40	≤ 36	≤ 45
22.2	75	62	< 35	≤ 44	< 35	< 35	< 35	≤ 35	< 35	≤ 40
22.3	75	62	≤ 40	≤ 53	≤ 39	≤ 39	≤ 38	≤ 47	≤ 42	≤ 50
23.1	75	71	≤ 44	≤ 59	≤ 47	≤ 48	≤ 46	≤ 47	≤ 46	≤ 53
23.2	75	71	≤ 49	41 - 60	≤ 48	≤ 50	≤ 51	≤ 57	≤ 49	37 - 60
24.1	75	66	≤ 50	≤ 60	≤ 49	≤ 50	≤ 52	≤ 56	≤ 51	≤ 58
25.1	75	68	≤ 54	39 - 64	≤ 53	≤ 54	≤ 53	≤ 57	≤ 55	≤ 60
26.1	75	68	≤ 47	≤ 61	≤ 47	≤ 49	≤ 48	≤ 52	≤ 45	≤ 57
27.1	75	59	≤ 46	≤ 57	≤ 44	≤ 45	≤ 47	≤ 45	≤ 44	≤ 52
28.1	75	57	≤ 62	≤ 73	≤ 59	≤ 60	≤ 60	≤ 58	≤ 57	≤ 68
29.1	75	74	≤ 63	**≤ 76**	≤ 61	≤ 64	≤ 60	≤ 62	≤ 61	≤ 71

Notes: 1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))

2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-28 – Predicted construction noise levels outside standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Cammeray Golf Course construction support site (BL1)

NCA	Noise Management Level				Predicted noise levels at each construction stage[3]							
	HNA	Day (O)	Eve	Night	CGC_01[1]	CGC_02[1]	CGC_03[1]	CGC_04[1]	CGC_05 + 06	CGC_05 + 07+ 08	CGC_05 + 07+ 09	CGC_10[1]
16.3	75	65	65	55	-	-	-	-	< 35	< 35	< 35	-
17.4	75	60	59	50	-	-	-	-	< 35	< 35	< 35	-
18.3	75	59	57	48	-	-	-	-	< 35	< 35	< 35	-
19.1	75	57	57	50	-	-	-	-	< 35	< 35	< 35	-
20.1	75	57	57	50	-	-	-	-	< 35	< 35	< 35	-
21.1	75	58	54	46	-	-	-	-	< 35	< 35	< 35	-
21.2	75	58	54	46	-	-	-	-	< 35	< 35	< 35	-
22.1	75	57	52	41	-	-	-	-	< 35	< 35	< 35	-
22.2	75	57	52	41	-	-	-	-	< 35	< 35	< 35	-
22.3	75	57	52	41	-	-	-	-	< 35	< 35	< 35	-
23.1	75	66	59	49	-	-	-	-	≤ 41	≤ 41	≤ 41	-
23.2	75	66	59	49	-	-	-	-	≤ 44	≤ 43	≤ 44	-
24.1	75	61	57	42	-	-	-	-	≤ 44	≤ 43	≤ 43	-
25.1	75	63	60	48	-	-	-	-	≤ 47	≤ 47	≤ 47	-
26.1	75	63	59	46	-	-	-	-	≤ 41	≤ 41	≤ 40	-
27.1	75	54	53	44	-	-	-	-	≤ 36	≤ 36	≤ 36	-
28.1	75	52	50	42	-	-	-	-	≤ 46	≤ 45	≤ 45	-
29.1	75	69	68	52	-	-	-	-	≤ 46	≤ 45	≤ 45	-

Note:
1. No typical work is proposed outside standard construction hours
2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-26
3. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-29 – Number of residential receiver buildings over the noise management level (all NCAs) – residential receivers – Cammeray Golf Course construction support site (BL1)

Modelled representative activity	Assessment reference	Highly noise affected > 75 dB(A) L_{Aeq}		Day (standard hours) L_{Aeq}			Day (outside standard hours) L_{Aeq}				Evening L_{Aeq}				Night L_{Aeq}				Sleep disturbance LA_{max}	
		Standard hours	Outside standard hours	1 – 10 dB(A)	11 – 20 dB(A)	> 20 dB(A)	1 – 5 dB(A)	6 – 15 dB(A)	16 – 25 dB(A)	> 25 dB(A)	1 – 5 dB(A)	6 – 15 dB(A)	16 – 25 dB(A)	> 25 dB(A)	1 – 5 dB(A)	6 – 15 dB(A)	16 – 25 dB(A)	> 25 dB(A)	Screening	Awakening
Site establishment	CGC_01[1]	0	-	7	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Access decline piling	CGC_02[1]	**2**	-	149	8	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Access decline excavation	CGC_03[1]	0	-	3	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acoustic shed construction	CGC_04[1]	0	-	4	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cut and cover support and tunnel construction	CGC_05 + CGC_06	0	0	4	0	0	0	0	0	0	0	0	0	0	8	0	0	0	68	0
Cut and cover support, tunnel fitout and build motorway facilities	CGC_05 + CGC_07 + CGC_08	0	0	2	0	0	0	0	0	0	0	0	0	0	7	0	0	0	69	0
Cut and cover support, tunnel fitout and fitout motorway facilities	CGC_05 + CGC_07 + CGC_09	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	69	0
Site rehabilitation	CGC_10	0	-	10	3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: 1. No typical work is proposed outside standard construction hours

2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period in accordance with the key presented in Table 5-26

5.3.2.4 Residential – summary of airborne noise assessment

Standard construction hours

The highest predicted noise levels would occur during the access decline piling (CGC_02) works. Up to 157 receiver buildings in NCA 29.1 are expected to experience noise levels greater than the relevant NML due to works during scheduled. Additionally, up to two receiver buildings are expected to be highly noise affected (>75 dB(A)). This is largely caused by excavation works near the northern end of the site. During other stages when piling works are not occurring, noise impacts would be less, with up to seven residential receiver buildings predicted to be noise affected (ie > NML) by less than 10 dB(A) above the daytime NML during any other stage except for site rehabilitation (CGC_10), where 11 residential receiver buildings predicted to be noise affected (ie > NML) with impacts predicted to be up to 11 dB(A) above the daytime NML.

Furthermore, receiver buildings within NCA 28.1 are expected to be noise affected (ie >NML) throughout most of the construction stages for this site. However, construction noise is only expected to be above the daytime NML by up to 3 dB(A) during the majority of the works (ie CGC_03 to CGC_08).

Noise impacts during standard construction hours would be managed through the CNVMP developed during detailed construction planning.

Work outside standard construction hours

At the Cammeray Golf Course construction support site (BL1), the key activities requiring OOHW are during:

- Civil works + Tunnel construction (CGC_05+CGC_06)
- Civil works + Tunnel fitout and finishing (CGC_05+CGC_07).

Parts of the Beaches Link cut and cover portal structures and associated ramps works, assessed in Section 5.2, within the Warringah Freeway corridor would need to take place outside of standard construction hours, as detailed in Section 5.2.1.4. The associated support activities for these works that occur within the Cammeray Golf Course construction support site have been assessed as CGC_05.

Similarly, tunnel construction (CGC_06) and tunnel fitout and finishing works (CGC_07) would take place outside standard construction hours because of associated 24 hour tunnelling requirements, as presented in Table 5-22, with further justifications in Section 5.1.4.

Since both assessment activities CGC_08 and CGC_09 occur during standard hours only, then CGC_05 + CGC_07 + CGC_08 and CGC_05 + CGC_07 + CGC_09 can be simplified to just CGC_05 + CGC_07 outside standard construction hours. When these works occur during the night period, up to eight residential receivers located in NCA 24.1, 26.1 and 28.1 are predicted to be noise affected by 1-5 dB(A). This is largely due to truck movements as they enter and move along the internal roads within the site to the acoustic shed. In order to mitigate and manage these potential impacts, the configuration of the internal layout should be reviewed during further design development for the construction support site to:

- Minimise the duration and distances that heavy vehicles are required to move within the site

- Locate site buildings and structures, such as site offices, to provide additional shielding between the support site noise sources and the potentially noise affected receivers.

Sleep disturbance

At the Cammeray Golf Course construction support site (BL1), the activities with the potential for maximum noise levels (L_{Amax}) above the sleep disturbance criteria include Site support general activities and tunnelling (CGC_05 + CGC_06) and Site support general activities and tunnel fitout (CGC_05+CGC_07). During these stages, occasional metal on metal bangs may occur from general site activities in laydown areas, and maximum noise level events could occur from occasional truck movements into and out of the site from the Warringah Freeway. Up to 69 receiver buildings may be exposed to maximum noise levels above the sleep disturbance screening level (up to L_{Amax} 64 dB(A)); however, no receivers are expected to be exposed to maximum noise levels above the awakening reaction level.

Potential maximum noise events from high noise sources (ie metal on metal bangs or air brake releases) should be minimised by adopting quiet work practices to minimise or eliminate these noise sources.

5.3.2.5 Non-residential

The predicted noise levels for non-residential receivers are presented in Table 5-30. The number of receiver buildings predicted to exceed the NMLs are summarised in Table 5-31. The predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-30 – Predicted noise levels at other sensitive receiver locations– $L_{Aeq(15\ minute)}$, dB(A) – Cammeray Golf Course construction support site (BL1)

Receiver type	NCA	NML[3]	Predicted noise level at each construction stage[1, 2]							
			CGC_01	CGC_02	CGC_03	CGC_04	CGC_05 + 06	CGC_05 + 07+ 08	CGC_05 + 07+ 09	CGC_10
Commercial	23.1	70	≤ 43	≤ 54	≤ 42	≤ 43	≤ 43	≤ 44	≤ 40	≤ 50
	26.1	70	47 - 54	59 - 67	46 - 53	47 - 54	47 - 55	51 - 57	44 - 54	53 - 61
Childcare	23.2	50	≤ 36	≤ 47	≤ 35	≤ 36	≤ 37	≤ 39	≤ 37	≤ 41
	28.1	50	≤ 49	≤ 62	≤ 48	≤ 50	≤ 50	≤ 49	≤ 48	≤ 56
Educational	22.1	55	≤ 39	≤ 50	≤ 37	≤ 38	≤ 38	≤ 40	≤ 36	≤ 45
	25.1	55	40 - 46	51 - 57	39 - 45	39 - 47	39 - 42	43 - 51	42 - 47	48 - 54
	31.2	55	≤ 41	≤ 53	≤ 40	≤ 41	≤ 39	≤ 43	≤ 39	≤ 46
Other sensitive receiver[3]	28.1	60	≤ 47	≤ 59	≤ 45	≤ 46	≤ 47	≤ 47	≤ 45	≤ 53
Place of worship	28.1	55	≤ 47	≤ 57	≤ 45	≤ 46	≤ 46	≤ 47	≤ 45	≤ 52
Recreational[3]	18.3	60	≤ 50	≤ 64	≤ 51	≤ 52	≤ 52	≤ 56	≤ 51	≤ 58
	26.2	60	44 - 55	56 - 67	43 - 55	44 - 56	43 - 56	47 - 62	40 - 57	49 - 66
	28.1	60	≤ 50	≤ 61	≤ 48	≤ 50	≤ 51	≤ 50	≤ 49	≤ 56

Notes:
1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML
2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.
3. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs.

Table 5-31 – Number of other sensitive receivers over the noise management levels (all NCAs) – Cammeray Golf Course construction support site (BL1)

Modelled representative activity	Assessment reference	Commercial[1]			Childcare			Educational			Recreational[1]			Places of worship			Other sensitive receivers1		
		1 – 10 dB(A)	11 – 20 dB(A)	> 20 dB(A)	1 – 10 dB(A)	11 – 20 dB(A)	> 20 dB(A)	1 – 10 dB(A)	11 – 20 dB(A)	> 20 dB(A)	1 – 10 dB(A)	11 – 20 dB(A)	> 20 dB(A)	1 – 10 dB(A)	11 – 20 dB(A)	> 20 dB(A)	1 – 10 dB(A)	11 – 20 dB(A)	> 20 dB(A)
Site establishment	CGC_01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access decline piling	CGC_02	0	0	0	0	1	0	1	0	0	3	0	0	1	0	0	1	0	0
Access decline excavation	CGC_03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acoustic shed construction	CGC_04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cut and cover support and tunnel construction	CGC_05 + CGC_06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cut and cover support, tunnel fitout and build motorway facilities	CGC_05 + CGC_07 + CGC_08	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Cut and cover support, tunnel fitout and fitout motorway facilities	CGC_05 + CGC_07 + CGC_09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site rehabilitation	CGC_10	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Notes: 1. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table.

Based on the predicted construction noise levels, up to six non-residential sensitive receivers are noise affected (ie >NML) by up to 10 dB(A) during access decline piling. The identified receivers include:

- Childcare – one childcare centre (KU Cammeray Preschool) in NCA 28.1 is predicted to above the childcare screening level by 12 dB(A) during the access decline piling (CGC_02) and 6 dB(A) during site rehabilitation (CGC_10)
- Educational – one school building (ANZAC Park Public School) in NCA 25.1 predicted noise levels are up to 2 dB(A) above the education facility NML during the access decline piling (CGC_02)
- Recreational – Three recreational facilities including the Cammeray Golf Course, Cammeray Playing Field and the Green Park Tennis Courts are predicted to be noise affected. Only the Cammeray Golf Course is predicted to be noise affected by more than 2 dB(A) above the NML during any stage.

No other non-residential sensitive receivers are predicted to be noise affected.

5.3.2.6 Cumulative construction noise impacts

As outlined in Section 4.2.4, the potential for cumulative noise impacts from other major construction projects in the area around the Cammeray Golf Course construction support site (BL1) would be considered when assessing the site and determining feasible and reasonable treatment and management measures.

Proposed staging of concurrent construction works associated with the project and other nearby major infrastructure projects that are considered for potential cumulative construction impacts are presented in Table 5-32, based upon the information presented in the environmental impact statement documentation for the other projects.

Table 5-32 – Concurrent construction works near the Cammeray Golf Course construction support site (BL1)

The project	2023	2024	2025	2026	2027	2028
Cammeray Golf Course (BL1/CGC) construction support site						
Warringah Freeway surface road works						
Other major projects						
Cammeray Golf Course construction support site as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project (WHT10 & WFU8/CGC)[1]						
Warringah Freeway Upgrade project (WFU) [1,2]						

Notes
1. Construction support sites WHT10 & WFU8 that form part of the Western Harbour Tunnel and Warringah Freeway Upgrade project, refer to Western Harbour and Warringah Freeway Upgrade Environmental Impact Statement (Transport for NSW, 2020).
2. Warringah Freeway Upgrade project works are proposed to extend to the end of 2025. However, the program for the Falcon Street to Miller Street construction works (WFU2H) as presented in the Western Harbour and Warringah Freeway Upgrade environmental impact statement (Transport for NSW, 2020), which are located directly adjacent to the Cammeray Golf Course, is only proposed to occur until early 2023.

Proposed staging of concurrent work has been reviewed for the receivers closest to the work site. The loudest stages for both standard construction hours and out-of-hours works have been used to calculate potential cumulative noise impacts.

Work at the Cammeray Golf Course construction support site (BL1) would overlap with work for the Warringah Freeway surface road work for the Beaches Link portals. It would also overlap with works on other major projects, including the Western Harbour Tunnel project during the final motorway facilities and ventilation outlet construction, tunnel fitout stages at Cammeray Golf Course (WHT10 & WFU8) and the late stages of the Warringah Freeway Upgrade project (WFU) in particular to the Falcon Street to Miller Street component of the works.

For cumulative noise impacts, if noise from one site dominates noise levels at the receiver (ie > 5-10 dB(A) above noise from other sites), that site would typically control construction noise levels at the receiver. As such, it is not likely to increase the overall $L_{Aeq,\ 15\ minute}$ construction noise level at these receivers.

If noise levels from each site are similar at a receiver, a total construction noise increase of up to 3 dB(A) is expected. A representative NCA adjacent to the works has been assessed in Table 5-33.

Table 5-33 – Potential cumulative noise impacts from construction projects near Cammeray Golf Course construction support site (BL1)

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 28.1	Standard hours NML= 57 dB(A)	BL1/CGC	Civil works + Tunnelling	≤ 60	Negligible cumulative increase. This is because during standard hours the Cammeray Golf Course construction support site (BL1) would likely dominate during noise intensive works. This is due to the close proximity of receivers along Morden Street and Warringah Road, Cammeray to the Cammeray Golf Course construction support site (BL1) compared with the other works areas. Other construction impacts are more than 7 dB(A) below NML.
		WFU2H	Piling	50	
		WHT10 & WFU8/CGC[1] (	Permanent motorway facilities construction	≤ 46	
	OOHW NML D/E/N 52/50/42	BL1/CGC	Civil works + Tunnelling	≤ 46	Construction noise levels from other construction support sites could result in similar construction noise levels to the Cammeray Golf Course construction support site (BL1) at nearby receivers. This may result in cumulative increases in construction noise.
		WFU2H	Paving/asphalting /road works (including road saws)	48	
		WHT10 & WFU8/CGC[1]	-	-	Up to 2 dB(A) cumulative increase is predicted when works from both sites operate near the receiver.

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 24.1	Standard hours NML= 66 dB(A)	CGC	Civil works + Tunnelling	≤ 52	Construction noise levels from other construction support sites could result in similar construction noise levels at nearby receivers, resulting in cumulative increases. The noise levels due to the construction support site and the surface road works are below the NML. Cumulative construction noise levels would likely remain below the NML at nearby receivers.
		WFU2H	Demolition works	57	
		CGC (WHT)	Permanent motorway facilities construction	≤ 41	
	OOHW NML D/E/N 61/57/42	CGC	Civil works + Tunnelling	≤ 44	Construction noise levels from other construction support sites could result in similar construction noise levels to the Cammeray Golf Course construction support site (BL1) at nearby receivers. This may result in cumulative increases in construction noise. The Cammeray Golf Course construction support site (BL1) achieves the NML, however cumulative noise levels may be above the NML. Warringah Freeway surface road works, as part of the project, would likely dominate over noise generated by the Cammeray Golf Course construction support site (BL1) where works are near to receivers.
		WFU2H	Paving/asphalting /road works (including road saws)	57	
		CGC (WHT)	-	-	

Notes 1. Construction support sites WHT10 & WFU8 that form part of the Western Harbour Tunnel and Warringah Freeway Upgrade project, information sources from the Western Harbour Tunnel and Warringah Freeway Upgrade Technical working paper: Noise and vibration (Renzo Tonin and Associates, 2019).

At receivers not directly adjacent to the Cammeray Golf Course construction support site (BL1), there is potential for cumulative increases of construction noise from concurrent works with other construction work areas that make up the Warringah Freeway Upgrade. However, it is unlikely that cumulative construction noise would result in additional noise affected receivers.

Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5.

5.3.3 Construction related road traffic noise assessment

Access points to and from the Cammeray Golf Course construction support site (BL1) would be predominately constructed during Western Harbour Tunnel and Warringah Freeway Upgrade project, with some access modifications made by the project. All heavy vehicle haulage access to this construction site during tunnel construction and some civil works, would be directly to and from the Warringah Freeway. Access for light vehicle and some deliveries to this site is expected to be to and from Ernest Street.

Table 5-34 presents forecasted number of vehicles accessing the construction support site during the peak construction periods at this site. No more than six heavy vehicles would access the site per hour

during the daytime period (7.00am to 10.00pm) and one heavy vehicle per hour in the night time period (10.00pm to 7.00am). Very limited heavy vehicle movements would access this site via Ernest Street.

Table 5-34 – Number of construction vehicles accessing the Cammeray Golf Course construction support site (BL1)

Type of vehicle	Per day[1] over 15 hours[3,4]	Per night[2] over nine hours[3]
Heavy vehicle (deliveries, spoil haulage and concrete deliveries)	90	4
Light vehicle	91	54

Notes:
1. Day is 7.00am to 10.00pm
2. Night is 10.00pm to 7.00am
3. Numbers presented are individual vehicles, not vehicle movements.
4. Vehicle numbers have been distributed onto the local road network based upon the proposed access roads. Where a vehicle accesses the site by one road and leaves by another, one vehicle movement is counted along each road once. Where a vehicle accesses and leaves the site by the same road, two vehicle movements are counted on that road.

The existing traffic volumes on the Warringah Freeway are more than 100,000 vehicles per day, with greater than eight per cent heavy vehicles. Because of the relatively small number of construction vehicles associated with this site, the added traffic on Warringah Freeway is unlikely to noticeably increase L_{Aeq} road traffic noise levels at receivers along the freeway.

However, increased vehicle traffic on Ernest Street needs to be assessed. This assessment is based on the predicted non-project existing traffic volumes during the peak construction. Table 5-35 presents the predicted increase in road traffic noise from additional construction traffic.

Table 5-35 – Road traffic noise impacts from the Cammeray Golf Course construction support site (BL1)

Construction vehicle access road	Road type	Time of day	Predicted road traffic noise increase, dB(A)[1, 2]	Exceedance of the RNP criteria	Exceedance of sleep disturbance screening level (night only)
Ernest Street	Sub-arterial	Day $L_{Aeq(15hr)}$	<0.5	No	N/A
		Night $L_{Aeq(9hr)}$	<0.5	No	No

Notes:
1. Predicted road traffic noise levels are based upon the nearest residential receiver to the road. Receivers at further distances are expected to experience lower noise levels than those predicted

The predicted road traffic noise increase due to the Cammeray Golf Course construction support site (BL1) is less than 2 dB(A) during the day and night time periods on Ernest Street. Therefore, predicted noise levels for receivers along Ernest Street would comply with the RNP criteria identified in Section 3.4.2.

Maximum noise levels (L_{Amax}) from night period heavy vehicle movements are predicted to exceed both the sleep disturbance screening level and the adopted awakening reaction level. However, night time heavy vehicle movements from this site would be limited to four trucks per night, which is not a substantial number when compared to existing heavy vehicle movements on the Warringah Freeway. Nearby receivers are not likely to notice the increase in the number of maximum noise events caused by the additional truck movements generated by the site.

Mitigation and management measures detailed in Section 6.7 should be considered during further design development and construction planning and, where feasible and reasonable, adopted to minimise construction traffic noise impacts associated with the project.

5.3.4 Ground-borne construction noise

Ground-borne noise could result from the construction of the access decline and ventilation tunnels between the Cammeray Golf Course construction support site (BL1) and the mainline and ramp tunnel alignment. However, due to the distance of nearby occupied receiver buildings from the access decline and ventilation tunnels being greater than 40 metres, no receiver (occupied) are predicted to be affected by ground-borne noise above the strictest night time NML of 35 dB(A).

Ground-borne noise may be generated by vibration intensive works within the construction support site. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers. Section 4.3.2 outlines the potential impacts from ground-borne noise generated by surface construction works such as these and how any ground-borne noise generated from these works would be mitigated and managed.

Ground-borne noise impacts from the construction of the mainline and ramp tunnel are assessed through ground-borne vibration impacts presented in Section 5.16.1.

5.3.5 Construction vibration

The vibration generated from construction works would vary depending on the level and type of activity carried out. Most activities using vibration intensive plant items for the Cammeray Golf Course construction support site (BL1) are carried out during the site establishment stage for Western Harbour Tunnel. he only stage which may include vibration intensive works is during the access decline construction (CGC_02), where rock hammers and piling rigs may be needed for construction of the access decline, acoustic shed and ventilation tunnels.

Proposed vibration intensive plant items are identified in Annexure E. Minimum working distances for a range of construction plant items are presented in in Table 4-11. Estimated minimum working distances from the construction support site for both structural damage and adverse human response to vibration for the most vibration intensive activity proposed are presented in Annexure L.

Table 5-36 presents the identified building/structures within the minimum working distances for rock hammering within Cammeray Golf Course construction support site (BL1). Only one heritage item is within the cosmetic damage minimum working distances, with two receiver buildings within the minimum working distance for adverse human response.

Potential vibration generated to receivers depends on the vibration source levels, separation distance, intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. This assessment considers a worst case scenario that the proposed vibration intensive plant items could be used anywhere within the boundaries of the site. However, this is unlikely to occur and the location of

the vibration intensive equipment should be reviewed during detailed construction planning, as recommended in Section 6.8.

Table 5-36 – Number of structures within nominated minimum working distance for vibration impacts – Cammeray Golf Course construction support site (BL1)

NCA	Number of structures within minimum working distances		
	Cosmetic damage		Human response
	Sound structure	Unsound structure	
Surface level access decline construction and acoustic shed construction			
26.2	-	1[1]	2
Tunnelling (access decline and ventilation tunnel)			
26.2	-	-	-

Notes: 1. A review of where any sensitive heritage items associated with the Cammeray Park is to be carried out to determine if further assessment for vibration impacts is required

For the access decline and ventilation tunnel construction, due to the tunnel depth there are no structures that are identified within the minimum working distances presented in Section 4.4.1 for roadheader tunnelling for either cosmetic damage or human response screening levels. As such, vibration impacts above the screening levels from the tunnel access decline construction works are unlikely but would be reviewed during further design development and construction planning.

5.3.5.1 Heritage listed structures

One heritage item has been identified within the unsound structure minimum working distance. The item is shown in Annexure L and identified and described in Table 5-37.

Refer to the Technical working paper: Non-Aboriginal heritage (Appendix J of the environmental impact statement)for the assessment of impacts to heritage items.

Table 5-37 – Heritage receivers within the cosmetic damage minimum working distance

Place/item name	Register	Type/classification[1]	Listing number	NCA
Cammeray Park (including golf course)	Local Environmental Plan	Item - Landscape	I0024	26.2

Notes: 1. Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

Before starting work with the potential to impact on heritage items, all nearby heritage items should be confirmed, structural surveys carried out where required, and appropriately revised minimum working distances and vibration limits determined to prevent cosmetic damage to heritage items.

Vibration monitoring should be carried out to ensure vibration levels do not exceed appropriate limits.

5.3.5.2 Human response

Rock hammering would occur for limited duration only at this site associated with access decline construction at the surface level and acoustic shed construction; therefore, the risk of annoyance is considered low. However, as shown in Annexure L occupants of up to two properties may be exposed to vibration levels above the human response screening level (ie residents may feel vibration from rock hammering) as presented in Table 5-36.

The extent of mitigation and management required to limit potential impacts to receivers would be determined by not only the level of vibration, but also the duration that receivers are likely to be exposed to vibration above the human response screening level.

No receivers are expected to be exposed to vibration from tunnelling of the access decline and ventilation tunnel above the human response screening level. Mainline and ramp tunnel construction vibration impacts are presented in Section 5.16

After applying feasible and reasonable vibration mitigation measures, if vibration monitoring still identifies that measured vibration levels exceed the human response screening level, appropriate additional mitigation measures should be provided (see Section 6.10.3).

5.4 Gore Hill Freeway Connection surface road works

5.4.1 Construction works overview

5.4.1.1 Summary of construction works

The project would connect to the Gore Hill Freeway at Artarmon between the existing Lane Cove Tunnel portals and North Shore railway overbridge. The Gore Hill Freeway Connection surface road works would include the following:

- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore and Western line/T9 Northern line and the Pacific Highway
- Modifications to the Reserve Road and Hampden Road bridges
- Construction of Beaches Link ramps and cut and cover structures
- Widening of Reserve Road between the Gore Hill Freeway and Dickson Avenue
- Modification of the Dickson Avenue and Reserve Road intersection to allow for the Beaches Link off ramp
- Upgrades to existing roads around the Gore Hill Freeway to integrate the project with the surrounding road network
- Upgrade of the Dickson Avenue and Pacific Highway intersection
- New and upgraded pedestrian and cyclist infrastructure
- Other operational ancillary facilities, including surface drainage and utility works, signage and lighting, CCTV and other traffic management systems, environmental controls and landscape treatments.

The noise assessment has assessed six subzones, which is then broken down further into ten major works areas in addition to three minor construction support sites which have been identified for use during the construction works.

For the purposes of assessing construction activities in the area of Gore Hill Freeway, associated project components of Beaches Link that are in the vicinity of the Gore Hill Freeway Connection surface road works have been grouped and assessed as part of this assessment section.

The key features of the proposed Gore Hill Freeway Connection surface road works are provided in Table 5-38 with the locations of the relevant subzones detailed in Table 5-39 and major works areas shown in Figure 5-6 to Figure 5-9

Table 5-38 – Gore Hill Freeway Connection surface road works – key works summary

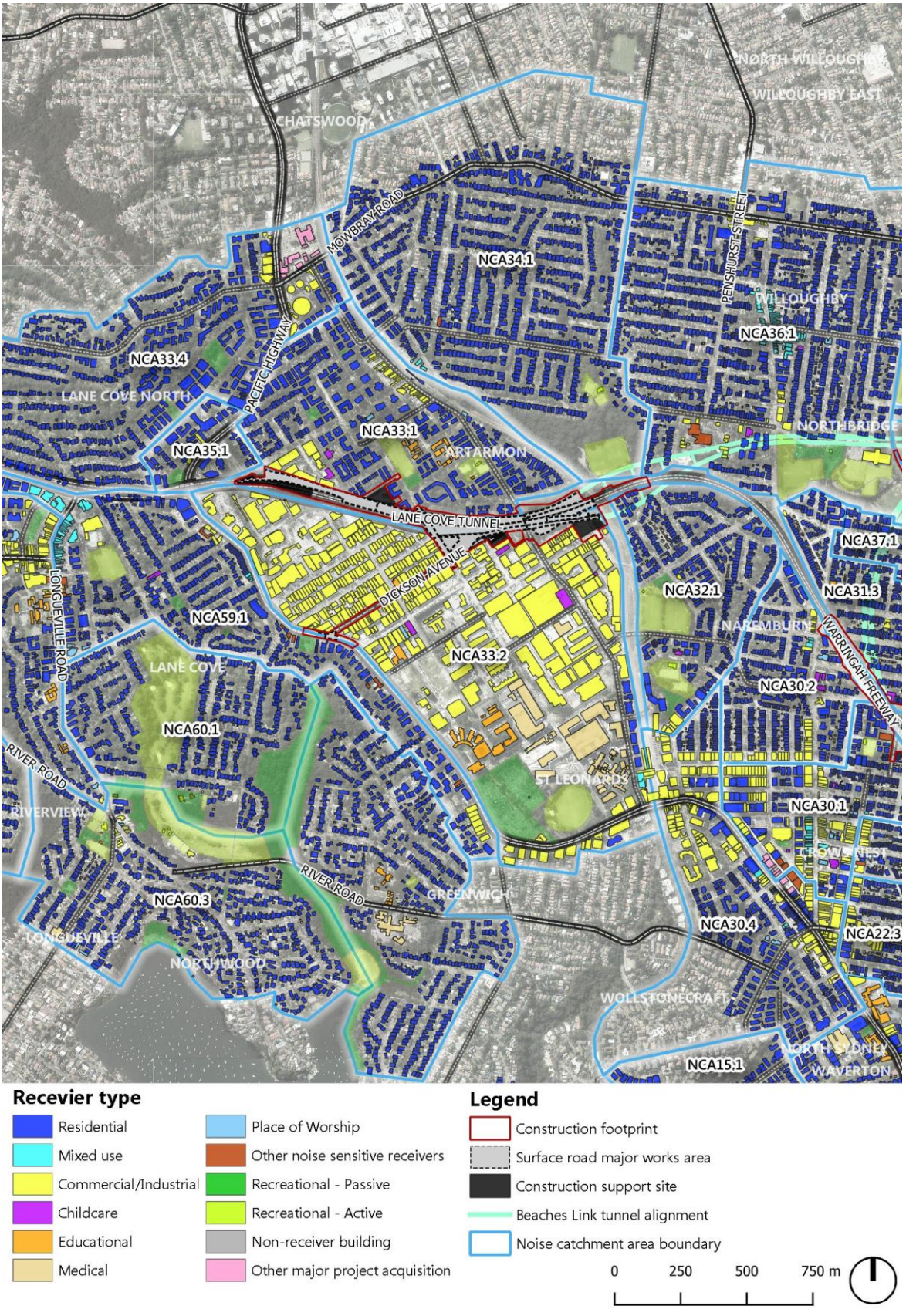
Key works element	Description	Relevant subzones See Table 5-39
Beaches Link connections		
Eastbound lanes, including eastbound on ramps to Beaches Link	One lane eastbound from Epping Road	4
	One lane eastbound from Reserve Road	
	Eastbound lanes	1
	Eastbound portal	4
Westbound lanes, including split westbound off ramps to Lane Cove Tunnel and Reserve Road	125 m cut and cover structure	5
	One lane westbound to Reserve Road	
	Westbound lanes	2
	Westbound southern portal	5
	Westbound northern portal	6
Local road and intersection changes		
Dickson Avenue and Reserve Road	Road modifications and cul-de-sac construction	5
Lambs Road between Punch Street and Cleg Street	Road modifications and cul-de-sac construction	5
Reserve Road intersections	Intersection modifications	3 and 5
Dickson Avenue and Pacific Highway	Intersection modifications and bus stop relocation	7
Bridge works		
Reserve Road bridge	Bridge modifications, including an increase from four to five lanes.	3
Hampden Road bridge	Strengthening works	1 and 2
Operational facility construction		
Operational facility construction	Construction of the motorway control centre at the Gore Hill Freeway	5
	Construction of the tunnel support facility on Waltham Street	5
Utilities, sewerage and infrastructure works		
Surface drainage and stormwater modification works	Channels, culverts throughout subzones	1 to 6
Shared pedestrian/bike paths	Between the North Shore Rail Line and Reserve Road, replacing and connecting to the existing path	6
Lighting, signage and road infrastructure	Throughout subzones	1 to 6
Utilities modification works	Throughout subzones	1 to 6
Landscaping	Throughout subzones	1 to 6

5.4.1.2 Nearby noise and vibration sensitive receivers

Figure 5-5 presents the site location, nearby noise sensitive receivers, and the nearby NCA boundaries.

The NCAs that are in proximity to the Gore Hill Freeway Connection surface road works are NCA 30.1 through to NCA 38.2 and NCA 59.1 to NCA 60.5. Refer to Annexure B.1 for more detailed information on the nearby noise sensitive receivers and the NCA boundaries.

Figure 5-5 – Gore Hill Freeway Connection major works areas, nearby noise sensitive receivers and noise catchment area (NCA) boundaries



5.4.1.3 Assessed construction works

The assessment of construction noise and vibration impacts associated with the Gore Hill Freeway Connection surface road works focused on the six major works subzones, and with large subzones broken down into ten separate assessment work areas for the purpose of assessing the construction noise and vibration impacts, which are presented in Figure 5-6 Figure 5-7, Figure 5-8 and Figure 5-9. Each stage was assessed against the works periods proposed in Section 3.3.

A summary of the works areas that have been assessed, as well as a description of the required construction works and the associated locations is presented in Table 5-39. In addition, three minor construction support sites have been identified for assessment due to their potential use during the construction works.

Table 5-39 - Gore Hill Freeway Connection surface road works assessment areas

Subzone	Works area reference	Works area/description	Location
Support sites	GHC0D	Minor construction support site	Dickson Avenue (BL4)
	GHC0B	Minor construction support site	Barton Road (BL5)
	GHC0C	Minor construction support site	Gore Hill Freeway median (BL6)
Subzone 1	GHC1_E	Gore Hill Freeway eastbound lanes including Epping Road and Pacific Highway entrance ramps	East (west of Hampden Road)
	GHC1_C		Central (between Reserve Road and Hampden Road)
	GHC1_W		West (west of Reserve Road)
Subzone 2	GHC2_E	Gore Hill Freeway westbound lanes including the Epping Road and Pacific Highway exit ramp	East (east of Hampden Road)
	GHC2_W		West (west of Hampden Road)
Subzone 3	GHC3	Modifications to Reserve Road bridge and ramps	All subzones
Subzone 4	GHC4	Beaches Link eastbound portal cut and cover tunnel and entrance ramp	All subzones
Subzone 5	GHC5_E	Beaches Link westbound southern portal cut and cover tunnel and exit-ramp to Reserve Road	East (east of Hampden Road)
	GHC5_W		West (west of Hampden Road)
	GHC5_MCC	Motorway Control Centre construction Tunnel support facility construction	Dickson Ave/Waltham Street, Artarmon
Subzone 6	GHC6	Beaches Link westbound northern portal cut and cover tunnel and exit-ramp to Gore Hill Freeway	All subzones
Subzone 7	GHC7_E	Dickson Avenue intersection modifications works	Intersection of Pacific Highway/Dickson Avenue
	GHC7_W	Dickson Avenue bus stop relocation	Intersection of Pacific Highway/Dickson Avenue

Figure 5-6 – Gore Hill Freeway Connection – Subzone 1 (GHC1W, GHC1C and GHC1E) and Subzone 2 (GHC2W and GHC2E)

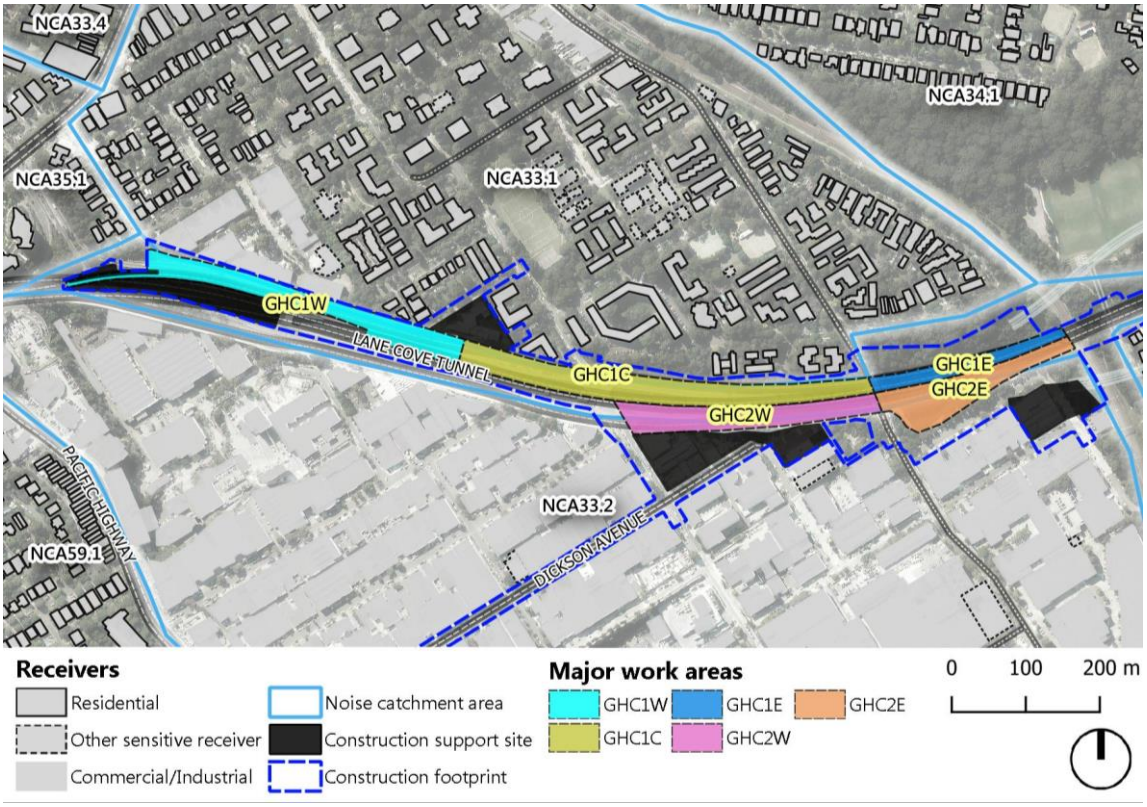


Figure 5-7 – Gore Hill Freeway Connection – Subzone 3, Subzone 4, Subzone 5 (GHC5W, GHC5E and GHC5_MCC) and Subzone 6

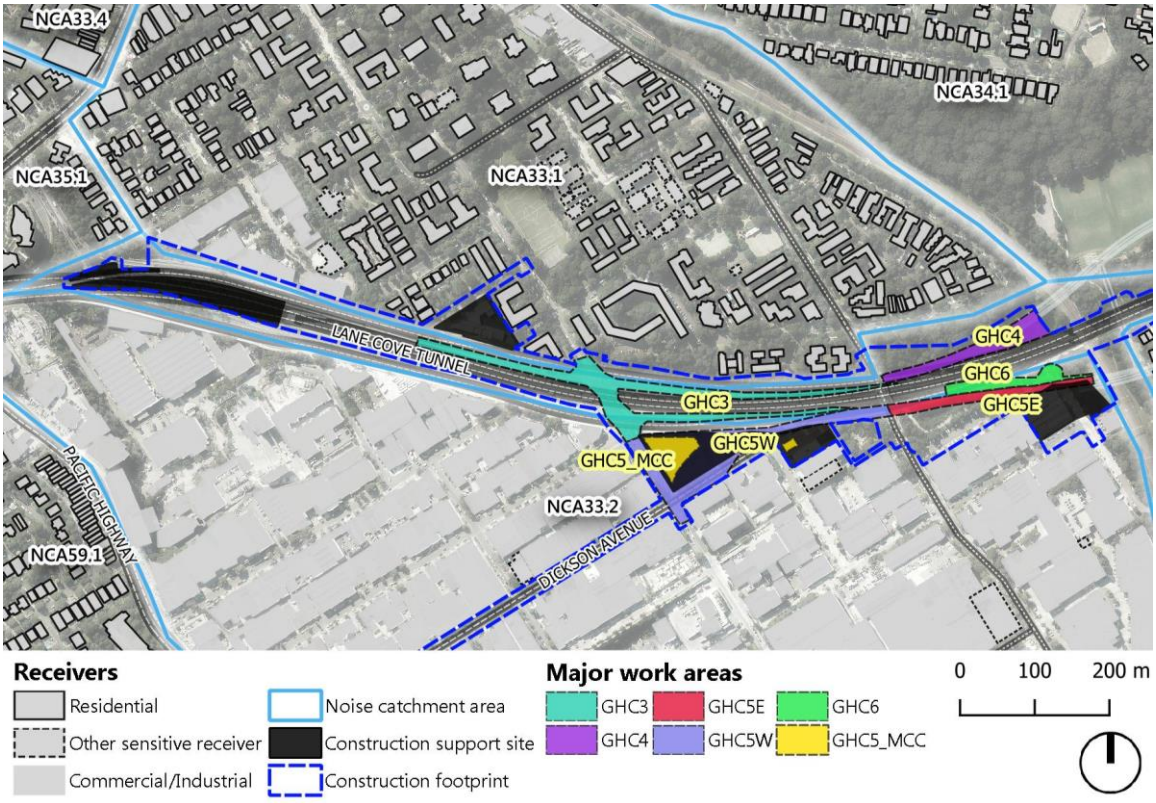
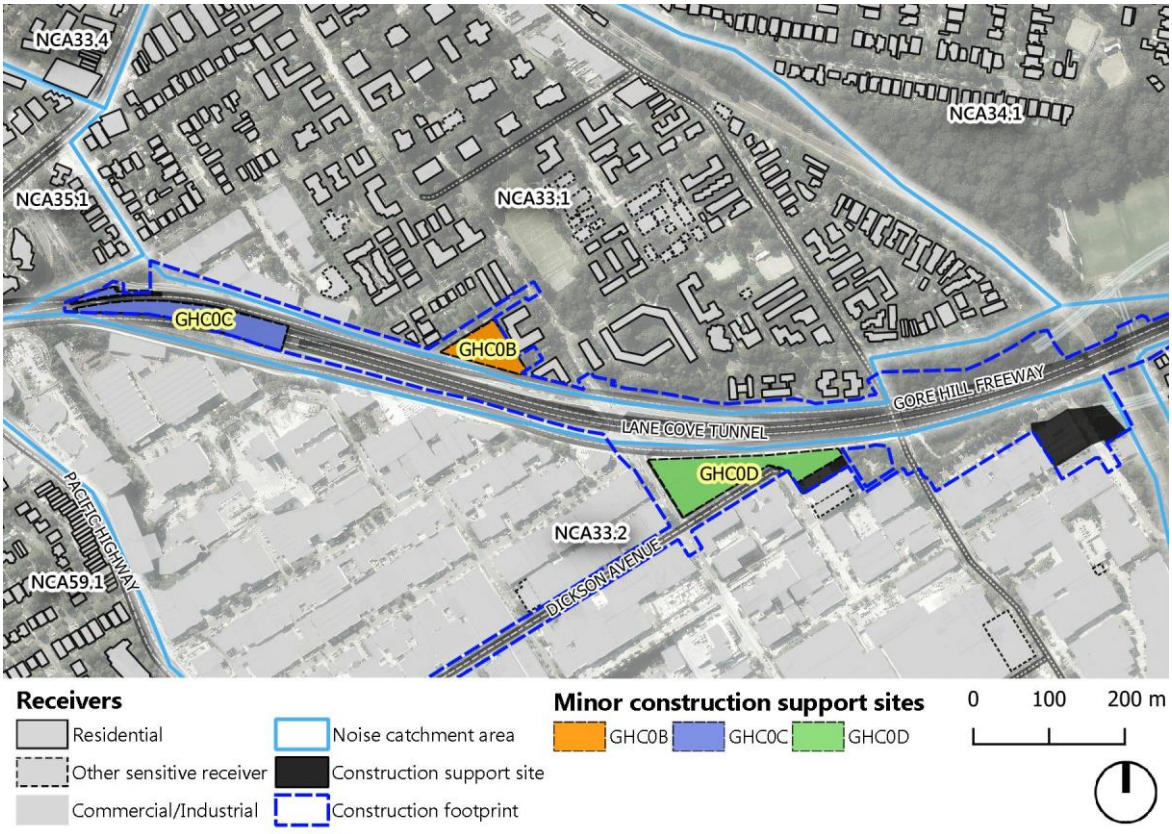


Figure 5-8 – Gore Hill Freeway Connection – Subzone 7 (GHC7_W and GHC7_E)



Figure 5-9 – Gore Hill Freeway Connection – minor construction support sites



The construction footprint for the Gore Hill Freeway Connection extends from Naremburn in the east into Artarmon in the west. There would also be minor construction activities such as local road works (eg pavement, linemarking, tie in works) and utility adjustment works required that would take place for relatively short periods (less than one month) within the construction footprint. This would include intersection modification works and line marking works along Dickson Avenue, Artarmon. These would occur during standard hours where practicable, however, work outside standard construction hours may be required due to road congestion and road safety issues. The noise and vibration impacts from these types of works have been assessed separately in Section 5.15.1.

5.4.1.4 Construction works program

The assumed timeframe for the Gore Hill Freeway Connection surface road works is presented in Table 5-40 and Table 5-41 subject to project approval. The works would take place from the middle of 2023 until the middle of 2027. Excluding the minor construction support sites, the activity with the longest duration at this construction area would be the construction of the westbound road lanes and associated ramps in Subzone 2.

Table 5-40 – Gore Hill Freeway Connection – indicative program and timeline

Project component	Indicative construction timeframe																			
	2022				2023				2024				2025				2026				2027			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Gore Hill Freeway Connection																								

Table 5-41 – Gore Hill Freeway Connection – indicative duration of construction work

Subzone	Works area reference (Figure 5-6 to Figure 5-9)	Indicative duration of works
Minor construction support sites	GHC0D	50 months
	GHC0B	
	GHC0C	
Subzone 1	GHC1_E	24 months
	GHC1_C	
	GHC1_W	
Subzone 2	GHC2_E	30 months
	GHC2_W	
Subzone 3	GHC3	24 months
Subzone 4	GHC4	27 months
Subzone 5	GHC5_E	30 months
	GHC5_W	
	GHC5_MCC	12 months
Subzone 6	GHC6	30 months
Subzone 7	GHC7_E	3 months
	GHC7_W	

5.4.1.5 Construction working hours and required out of hours work (OOHW)

Where feasible and reasonable, works would be scheduled to be carried out during the standard construction hours, outlined in Section 3.3. However, extensive works would be carried out during night time road closures, as the works would require occupancy of Gore Hill Freeway carriageways and key connecting roads. Further details and justifications are included in Section 5.1.6.1. The key OOHW required as part of the Gore Hill Freeway Connection, and justifications as to why, are presented in Table 5-42.

Table 5-42 – Required out of hours work – Gore Hill Freeway Connection

Location/Stage (Figure 5-6 to Figure 5-8)	Required OOHW	Percentage of program days OOHW is required	Justification
GHC1	Bridge and road modification works, works adjacent to live traffic corridor.	10	ROL required, impact on road network performance and worker safety
GHC2	Bridge and road modification works, works adjacent to live traffic corridor.	10	ROL required, impact on road network performance and worker safety
GHC3	Bridge and road modification works, deliver of oversized items. Works adjacent to live traffic corridor.	10	ROL required, impact on road network performance and worker safety, large load lifts over existing roads.
GHC4	Completion of tie-ins at the extents of the proposal, and completion of temporary diversions and traffic switches. Delivery of oversized items	10	ROL required, impact on road network performance and worker safety
GHC5_E / GHC5_W	Road modifications and cul-de-sac construction. Delivery of oversized items. Grubbing/clearing adjacent to live traffic.	10	ROL required, impact on road network performance and worker safety
GHC5_MCC	Works limited to standard construction hours		
GHC6	Delivery of oversized items. Grubbing/clearing adjacent to live traffic.	10	ROL required, impact on road network performance and worker safety
GHC7_E	Pavement/road modification works in major traffic corridor	30	1. ROL required, impact on road network performance and worker safety 2. Impacts on road network performance/safety due to closure
GHC7_W	Works limited to standard construction hours		

Notes: 1. Based on an estimated number of days of the overall stage duration that may require OOHW, rounded up to the nearest 10 per cent. Estimated period of OOHW would be refined during detailed construction planning stage.

In addition, works that may be required outside standard construction hours include:

- Utility modifications including sewage infrastructure (where the works is in proximity to live traffic)

- Modifications to existing bridges/construction of new bridges
- Delivery of precast units and other materials
- Road tie in works
- Traffic management, set up and traffic switches
- Erection of traffic signs (where the erection is in proximity to traffic)
- Pavement and temporary median works
- Asphalt works and line marking
- Use of construction support sites to support out of hours works.

The temporary nature of works carried out under a ROL means that there are limited opportunities to install fixed noise mitigation (ie acoustic sheds, acoustic enclosures, large temporary barriers) as the road needs to be fully open the next day.

Other feasible and reasonable noise mitigation and management measures would be reviewed and implemented to minimise noise impacts on nearby noise sensitive receivers. The mitigation and management measures which would be put in place for surface road works are discussed in Section 6.4.

5.4.1.6 Concurrent construction projects

The nearest construction work associated with this project would be:

- The Flat Rock Drive construction support site (BL2) supporting tunnelling for the Beaches Link component of the project, approximately one kilometre east of the works areas
- Warringah Freeway Upgrade (part of the Western Harbour Tunnel and Warringah Freeway Upgrade project), around one kilometre southeast of the works areas
- Punch Street construction support site (BL3) supporting tunnelling for the Beaches Link component of the project, adjacent to the southeast of the works areas (Subzone 5/6)

The nearest construction work associated with another state significant project would be:

- Warringah Freeway Upgrade associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project, with works areas extending from approximately one kilometre southeast of the works areas
- Construction work associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project, which would involve the construction of the motorway control centre on Waltham Street, Artarmon on the south side of the to the Gore Hill Freeway. This would also include associated trenching work from the motorway control centre site that would then extend along the Warringah Freeway to Cammeray.

A construction site at Artarmon for the Sydney Metro City & Southwest project, which involves the construction of a substation on the southern side of Gore Hill Freeway at 98-104 Reserve Road, Artarmon. These works are expected to be completed six months prior to works associated with Beaches Link.

5.4.2 Construction airborne noise

The methodology used to assess airborne noise impacts from surface road works in this section is outlined in Section 4.2.3.

5.4.2.1 Construction activities and noise sources

Presented in Table 5-43 is the range of potential types of construction activities along with the associated SWLs that may occur as part of the surface road works, and an indication if these are to occur in each major works area. Works that could occur during standard construction hours are indicated as 'D', works modelled during OOHW periods are indicated as 'O', and where the activity may occur during both period it is indicated as 'DO'.

For assessment purposes, only the most noise intensive activities have been modelled which are highlighted in Table 5-43 with **blue** shading where the activity has been modelled during standard construction hours, and **orange** shading where the activity has been modelling outside standard construction hours. However, the other activities may also occur as part of the construction works. As presented the noise impacts would vary as the construction activities vary.

A construction contractor, once appointed, would review and refine the project design and construction methodology during further design development and construction planning. The contractor should review noise impacts with a better understanding of the construction plant and equipment required for specific works, the locations they would likely operate, and the potential for concurrent activities in order to better predict the nature and duration of impacts.

Table 5-43 – Proposed construction activities and construction hours across the works areas and assessed works activities – Gore Hill Freeway Connection surface road works

Assessment scenario and major works area reference (Figure 5-6 to Figure 5-8)		Road works	Concrete barriers and traffic controls	Demolition (rock hammering)	Demolition (non-rock hammering)	Pavement/road modification works	Paving/asphalting/road surface road works (with concrete saw)	Resurfacing works	Road furniture installation/modify	Earthworks	Clearing and grubbing works	Bulk earthwork	Pile breaking	Piling - bored	Rock drilling	Rock trimming	Shotcrete	Structures	Concrete formwork/reinforcement	Concrete pours	Erection of structural steelwork	Erection/removal large items	Noise barrier installations	Services/utilities	Utilities modification works	Support activities	Deliveries	Deliveries (oversized)	Mobilisation/demobilise/site setup	Spoil handling	Support site activities
Worst case SWL[1]			105	121	112	120	120	118	114		116	119	122	117	117	121	112		113	116	117	111	118		120		104	111	110	106	105
Typical case SWL[1]			99	109	109	110	109	112	107		112	116	113	108	95	116	109		104	112	111	110	111		110		98	110	108	104	100
Subzone 1	GHC1W		DO			DO	DO	DO																	DO		D		D		
	GHC1C		DO			DO	DO	DO																	DO		D		D		
	GHC1E		DO			DO	DO	DO																	DO		D		D		
Subzone 2	GHC2W		DO			DO	DO	DO	DO																DO		D		D		
	GHC2WE		DO			DO	DO	DO	DO																DO		D		D		
Subzone 3	GHC3		DO			DO	DO	O																	DO		D		D		
Subzone 4	GHC4								DO		D	D	D	DO					D	D							D	DO	D	D	
	GHC5W		DO						DO			D													DO		D		D		
Subzone 5	GHC5E		DO			DO			DO			D													DO		D		D		
	GHC5 MCC																		D	D	D	D					D		D		
Subzone 6	GHC6		DO			DO	DO						D									O			DO		D		D		
Subzone 7	GHC7E		DO			O		DO	DO																		DO		DO		
	GHC7W		D			D			D																		D		D		
Minor construction support sites																															
Gore Hill Freeway median (BL6)	GHC0_C																										DO		D		DO
Barton Road (BL5)	GHC0_B				D																						D				DO
Dickson Avenue (BL4)	GHC0_D																										DO		D		DO

Notes:
1. The activity SWL includes the adjustments for quantity of equipment assumed operating, equipment usage factor, and penalties for annoying characteristics in accordance with the ICNG. Refer to Annexure F
2. ACTIVITY KEY - Standard construction hours = 'D', OOHW = 'O', Standard construction hours and OOHW = 'DO'
3. MODELLED SCENARIO KEY – Shaded **blue** = Standard construction hours, Shaded **orange** = OOHW.

5.4.2.2 Construction assessment scenarios

Presented in Table 5-44 are the assessed activities for each works area, which represents the most intensive noise activities expected to be required as part of the works. However, it should be noted that the type of plant and equipment used throughout the stage would vary depending upon the construction activities being carried out. Table 5-44 also presents the sound power levels for each activity.

More details of the modelled plant items and relevant sound power levels are presented in Annexure F. The equipment/plant listed in Annexure F represent the 'typical' and 'worst case' case equipment/plant operating simultaneously in any 15 minute period (refer to Section 4.2.3 for further explanation of assessment scenarios). Where plant items are not operating simultaneously or for reduced times in the 15 minute period, noise impacts could be lower than predicted.

Table 5-44 – Assessed construction activities – Gore Hill Freeway Connection surface road works

Assessment scenario reference	Standard hours works	SWL level range, $L_{Aeq\ 15\ minute}$ dB(A)		Out-of-hours works	SWL level range $L_{Aeq\ 15\ minute}$ dB(A)	
		Typical	Worst case		Typical	Worst case
GHC0C	Mobilisation/site setup	108	110	Support site general activities	100	105
GHC0B	Mobilisation/site setup	108	110	Support site general activities	100	105
GHC0D	Demolition (non-rock hammering)	109	112	Support site general activities	100	105
GHC1_E	Utilities modification works	110	120	Utilities modification works	110	120
GHC1_C	Utilities modification works	110	120	Utilities modification works	110	120
GHC1_W	Utilities modification works	110	120	Utilities modification works	110	120
GHC2_E	Utilities modification works	110	120	Utilities modification works	110	120
GHC2_W	Utilities modification works	110	120	Utilities modification works	110	120
GHC3	Utilities modification works	110	120	Utilities modification works	110	120
GHC4	Pile breaking	113	122	-	-	-
GHC5_E	Utilities modification works	110	120	Utilities modification works	110	120
GHC5_W	Utilities modification works	110	120	Utilities modification works	110	120
GHC5_MCC	Erection of structural steelwork	111	117	-	-	-
GHC6	Pile breaking	113	122	Utilities modification works	110	120
GHC7_E	Road furniture installation/modification	107	114	Pavement/road modification works	110	120
GHC7_W	Pavement/road modification works	110	120	-	-	-

Notes 1. The activity SWL includes the adjustments for quantity of equipment assumed operating, equipment usage factor, and penalties for annoying characteristics in accordance with the ICNG. Refer to Annexure F for a description of the assumed equipment/plant that are operating.

5.4.2.3 Construction noise prediction summary

5.4.2.3.1 Major works areas

Table 5-46 to Table 5-48 present the predicted noise levels from construction activities and compare them with the NMLs for standard construction hours. Table 5-50 to Table 5-52 compare predicted noise levels against NMLs outside standard construction hours.

Table 5-58 presents the approximate number of residential receiver buildings that exceed the NMLs in each NCA, and the number of receiver buildings that are potentially highly noise affected over the entire duration of the works stage.

All receiver building counts presented in this assessment are based upon the highest noise levels that would be expected to occur throughout a works stage and when the works are working closest to each receiver building, defined as the highest noise level envelope explained in Section 4.2.3.2.1. In practice during any individual period of construction works the actual number of receiver buildings that could experience the highest predicted noise levels would be less that these maximum receiver building counts.

Residential receivers

For Subzones 1 to 6 the predicted noise levels during standard construction hours are not predicted to exceed the daytime NMLs, except for NCAs 33.1, 34.1 and 35.1 which are adjacent to the works. For Subzone 7, exceedances of the daytime NMLs are predicted for NCAs 59.1, 60.1 and 60.2.

For Subzones 1 to 6, the assessed activity likely to generate the highest noise levels is utility modification works, which would occur at various locations. During standard construction hours, for Subzones 1 to 6 up to 31 receiver buildings are predicted to exceed the NMLs during the worst case works. In Subzone 7, due to the proximity of the nearby receivers, up to 100 receiver buildings are predicted to exceed the daytime NMLs during the worst case works. Up to eight receiver buildings are predicted to be highly noise affected (ie >75 dB(A)) from construction work during standard construction hours in any one subzone, the highest being for Subzone 1 (Central).

Generally, the daytime NMLs are predicted to be exceeded by less than 10 dB(A), which could mean that the construction works would be clearly audible. During the worst case activities, such as during the use of rock hammers or during concrete saw cutting, impacts are predicted to be 10 to 20 dB(A) above the daytime NML which may be perceived as moderately intrusive.

The highest predicted levels during standard construction hours are due to the use of excavators with rock hammers typically during utility modification works or pile breaking works, except for the motorway facilities where building construction works were modelled.

Residential receiver buildings are only predicted to be highly noise affected (ie >75 dB(A)) during worst case works, when they are carried out in close proximity to residential receivers adjacent to Subzone 1 (GHC1_W, GHC1_C, GHC1_E), Subzone 2(GHC2_W, GHC2_E), Subzone 3 (GHC3), and

Subzone 7 (GHC7_E, GHC7_W) (see Figure 5-6 to Figure 5-8 and Table 5-39 for locations). The only exception is for one receiver during typical works in GHC7_E. This would only occur when the works are close to the receiver during pavement/ modification works, and would be a result from use of a road saw for short periods during road possession works at night.

Outside standard construction hours, construction noise levels are predicted to result in up to 112 residential receiver buildings being noise affected from any one major works area during typical works. This is predicted to increase up to 1453 noise affected receiver buildings during worst case construction activities from any one major works area.

The key noise generating activities that would be required outside standard construction hours would be utility modification works, and the use of excavators with rock hammers or concrete saws as part of pavement/road modification works. For high noise impacts that are predicted outside of standard construction hours the following should be considered:

- When these noise intensive activities are not occurring, the number of potentially noise affected (ie >NML) receiver buildings are reduced to only 10 to 20 per cent of the worst case total.
- Predicted noise levels are based upon the potentially worst case works locations and due to the substantial acoustic shielding along the Gore Hill Freeway, on any individual night, noise levels might be substantially less than those predicted.
- It is important to note that the highest exceedances are during worst case activities such as concrete sawing or rock hammering, which normally occur sporadically and for short periods of time.

The number of receiver buildings that are presented in Table 5-58 assume the works are anywhere within the major works area, and the not the discrete locations that may occur on individual nights. Therefore, the total number presented is greater than the number that would be affected on any individual night.

Non-residential receivers

Table 5-54 and Table 5-55 present the predicted noise levels from construction activities for non-residential receivers. Construction noise levels at non-residential receivers are generally predicted to meet NMLs, except for the following key receivers:

- Up to six childcare centres located in NCAs 33.1 and 33.2, three of which are predicted to exceed the NML by more than 20 dB(A) during worst case works
- Up to a 5 dB(A) exceedance at two educational facilities (Artarmon Public School and Thrive Early Learning Centre, Artarmon) (multiple buildings are identified as potentially exceeding the NML within some facilities) in NCAs 33.1 and 33.2
- A marginal exceedance of 2 dB(A) at a place of worship (St. Basil's Anglican Church Artarmon) and a recreational area in NCA 33.1 during worst case works

- Exceedances of the NML by up to 5 dB(A) for a recreational park in NCA 33.1, and up to 17 dB(A) at recreational parks nearby to Subzone 7 (major works areas GHC7_E and GHC7_W)
- Up to 27 commercial and industrial receivers from all works areas, with up to 18 for works in any one major works area. The highest noise levels from works in Subzone 5 (west) exceeding the NML by up to 19 dB(A) and in Subzone 7 exceeding the NML by up to 24 dB(A) at adjacent commercial properties.

Construction mitigation and management measures are provided in Section 6 to assist in reducing construction noise impacts to other sensitive receivers. Specific detail for surface road works is provided in Section 6.4.

5.4.2.3.2 Minor construction support sites

Table 5-49, Table 5-53 and Table 5-57 present the predicted noise levels from construction activities at the minor construction support sites and compare them with the NMLs for standard construction hours, OOHW and non-residential receivers respectively.

Table 5-59 presents the approximate number of receiver buildings that are predicted to experience construction noise levels greater than the NMLs in each NCA. During the operation of the three construction support sites the key noise impacts on the nearby receivers are as follows:

Dickson Avenue construction support site (BL4)

- Compliance is predicted at all nearby residential receiver locations, except for during the night period, when construction noise at up to 33 residential buildings would exceed the NML. At 16 of those, located across the Gore Hill Freeway in Artarmon (NCA 33.1), the NMLs may be exceeded by more than 5 dB(A)

- The screening NML is predicted to be exceeded at a childcare centre (Butterflies Early Learning Childcare Centre) in NCA 33.2 by up to 17 dB(A). However, as the existing ambient noise level from Gore Hill Freeway at this location is similar to the predicted noise level, it is likely that internal spaces are sufficiently acoustically treated to protect internal spaces from construction noise

- The NML is predicted to be exceeded at an adjacent commercial receiver.

Noise from the site is not predicted to be above the highly noise affected (ie >75 dB(A)) level at any residential receiver buildings.

Barton Road construction support site (BL5)

- A noise barrier at least three metres high was assumed along the northeast boundary of the site. This would be reviewed as the construction support site design is refined. Feasible and reasonable mitigation measures would be implemented considering the construction support

site layouts, equipment, construction methods or construction hours which may require specific mitigation and management measures that are different from those outlined in this section

- Compliance is predicted at all nearby residential receiver locations, except for the adjacent residential receiver at 108 Reserve Road, Artarmon which is a multi-storey receiver that overlooks the site. During standard construction hours, the exceedance is predicted to be 2 dB(A), which is minor, but greater exceedances are predicted in other assessment periods
- Compliance is predicted at all non-residential receivers
- Where feasible and reasonable, it is recommended that use of the construction support site be limited to standard construction hours.

Gore Hill Freeway median construction support site (BL6)

- Compliance with the relevant NMLs is predicted at all nearby residential receiver locations during standard construction hours, daytime OOHW and evening periods
- Night time NMLs are predicted to be exceeded at eight residential receivers in Artarmon (NCA 33.1 and NCA 35.1) by up to 4 dB(A) during typical works, and up to 9 dB(A) in Artarmon (NCA 33.1, NCA 35.1 and NCA 59.1) during worst case activities
- The NML is predicted to be exceeded at two childcare centres (Willoughby/Lane Cove Family Day Care and Innovative Early Learning Artarmon)), both northwest of the site. However, as the existing ambient noise level in the area is 59 dB(A), similar to the predicted construction noise levels, it is likely that the internal spaces are sufficiently acoustically treated to protect internal spaces from construction noise.

These sites would operate in conjunction with Gore Hill Freeway Connection surface road works that would often impact the same receivers. As such, the mitigation and management measures implemented for surface road works would assist to manage noise impacts on these receiver locations, and further on site mitigation would typically not assist in reducing overall construction noise levels.

Gore Hill Freeway Connection minor construction support sites – Assessment outcomes discussion

In order to assess noise impacts from the minor construction support sites, typical construction activities for standard construction hours and outside standard construction hours have been assessed. The assessed activities represent the reasonable most noise intensive activities that would operate at each of the minor construction support sites. However, the type of plant and equipment used throughout the stage would vary depending upon the construction activities being carried out.

As there is potential for exceedance of the NMLs for all minor construction support sites, further noise mitigation and management measures would be developed during the detailed construction planning of the minor construction support sites. This includes developing the site layout with consideration of noise, including the positioning of the site offices and fixed structures to assist in mitigating noise impacts to nearby receivers. This would be beneficial for multi-storey residential receivers.

Where feasible and reasonable, careful use of close proximity temporary noise barriers near designated areas where noise generating activities would take place can assist in mitigating noise impacts at the nearby receivers.

Additional mitigation measures would be adopted during detailed construction planning considering cumulative and long term noise impacts on the affected receivers, taking into consideration the various major works areas that may be operating concurrently or consecutively and impacting the same receiver locations.

5.4.2.3.3 Sleep disturbance

The most likely source of potential sleep disturbance from night construction works would be from the use of pneumatic hammers or saws during services relocation or road pavement work, or from truck movements on site (particularly the application of air brakes).

Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from OOHW.

Table 5-58 show that there is potential for high noise events to exceed the sleep disturbance screening levels for all major works areas, where the support sites need to operate during the night period if sources are not managed. During works in any one major works area, maximum noise levels during typical construction works are predicted to be above the sleep disturbance screening level at up to 63 receiver buildings for any works major works area, which could increase to 454 receiver buildings during worst case construction activities. However, only a portion of these may be above the awakening level. Up to 19 receiver buildings across all NCAs have potential to exceed the awakening level during typical construction activities, which could increase to 46 receiver buildings during worst case construction activities for any one major works area.

The highest maximum noise levels are predicted during night utility modification works, which are predicted to exceed the awakening reaction level at some nearby residential receivers in Artarmon (NCA 33.1).

Where sources of high noise events (ie metal on metal bangs or air brake releases) are managed or eliminated, this potential for sleep disturbance can be mitigated. Construction mitigation and management measures are provided in Section 6 to assist in reducing OOHW construction noise impacts to receivers.

5.4.2.3.4 Construction noise assessment outcomes

The assessment indicates that a number of sensitive receivers are expected to experience construction noise levels above the NMLs during both standard construction hours and during works undertaken outside of standard construction hours with the implementation of some feasible and reasonable mitigation measures.

Due to the nature of the surface road works, further acoustic mitigation, programming and alternative construction activity locations should be reviewed during detailed construction planning, to further reduce the residual impacts identified in this assessment. These measures are detailed in Section 6, with further surface road works measures included in Section 6.4.

5.4.2.4 Construction noise prediction tables

Table 5-45 provides a key to the cell shading and text formatting used to explain results in following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-45 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes: 1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are expected to exceed NMLs. The range is of noise impacts throughout all receivers in the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented.

The predicted noise levels for nearby receiver locations are presented in the following tables:

- Table 5-46 to Table 5-49 are for residential receivers during works during standard construction hours
- Table 5-50 to Table 5-53 are for residential receivers during works outside standard construction hours
- Table 5-54 to Table 5-57 are for non-residential receivers.

It is important to note that all results presented in this section are conservative and represent the noise levels that occur over an entire stage/works area and not an individual activity/night. As such, the number of noise affected receivers (ie >NML) during individual works/activities or on an individual night would be less than presented, and receivers impacted would also vary between nights as the location and type of activity changes.

The construction NMLs for all residential receivers nearby are presented in Annexure B and for all other non-residential receivers see Section 3.4.1.2.

Predicted noise levels are intended to be conservative and represent reasonable typical and worst case impacts during the project.

The highest 'typical' noise levels that have been predicted for all works within each subzone are presented as noise contour envelopes in Annexure H.2. These present the extent of typical predicted noise impacts during OOHW periods (except for Subzone 4, which is a majority standard hours construction area) to give an indication of the likely extent of noise levels from the specific major works areas that make up the Gore Hill Freeway Connection surface road works. Maps presenting the predicted exceedance for a sample of scenarios from the major works areas with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

It is important to note that the noise contours represent the highest 'typical' noise levels that occur over an entire stage/works area and not an individual activity/night. As such, the number of noise affected receivers (ie >NML) during individual works/activities or on an individual night would be less than those presented, and receivers impacted would also vary between nights as the location and type of activity changes.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different periods.

Table 5-46 – Subzone 1 to 2 predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – standard hours (residential receivers) – Gore Hill Freeway Connection surface road works

Major works area/assessment reference				Subzone 1 (West) GHC1W		Subzone 1 (Central) GHC1C		Subzone 1 (East) GHC1E		Subzone 2 (West) GHC2W		Subzone 2 (East) GHC2E	
Typical/worst case activity noise intensity				Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver				Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level		Predicted noise levels, $L_{Aeq\ (15\ minutes)}$									
		HNA	NML										
Wollstonecraft	30.4	75	68	< 35	37 / 41	< 35	40 / 43	< 35	40 / 43	< 35	39 / 42	< 35	40 / 42
Crows Nest	30.1	75	68	< 35	38 / 42	< 35	40 / 43	< 35	42 / 44	< 35	40 / 43	< 35	41 / 44
Naremburn	30.2	75	68	< 35	38 / 42	< 35	41 / 44	33 / 35	43 / 45	< 35	41 / 44	33 / 35	43 / 45
	31.3	75	66	< 35	37 / 41	32 / 35	42 / 45	35 / 38	45 / 48	< 35	42 / 44	33 / 36	43 / 46
	32.1	75	69	≤ 35	39 / 45	38 / 45	48 / 55	44 / 55	54 / 65	39 / 45	49 / 55	48 / 57	58 / 67
	37.1	75	55	< 35	35 / 38	< 35	40 / 43	33 / 35	43 / 45	< 35	39 / 42	< 35	41 / 43
Artarmon	33.1	75	65	≤ 69	≤ **79**	49 / 75	59 / **85**	62 / 69	72 / **79**	56 / 67	66 / **77**	60 / 66	70 / **76**
	33.2	75	65	≤ 35	≤ 45	≤ 37	36 / 47	≤ 37	39 / 47	≤ 36	35 / 46	< 35	30 / 45
	34.1	75	54	≤ 35	33 / 45	32 / 40	42 / 50	36 / 43	46 / 53	34 / 40	44 / 50	40 / 46	50 / 56
Lane Cove	59.1	75	70	41 / 50	51 / 60	36 / 41	46 / 51	34 / 37	44 / 47	31 / 36	41 / 46	35 / 37	45 / 47
Lane Cove North	33.4	75	65	34 / 43	44 / 53	34 / 37	44 / 47	< 35	40 / 42	32 / 36	42 / 46	33 / 35	43 / 45
	35.1	75	77	31 / 62	41 / 72	40 / 44	50 / 54	< 35	41 / 43	34 / 38	44 / 48	33 / 36	43 / 46
Willoughby	36.1	75	60	< 35	36 / 41	35 / 40	45 / 50	43 / 50	53 / 60	37 / 42	47 / 52	44 / 50	54 / 60
Northbridge	38.1	75	62	< 35	< 35	< 35	41 / 43	33 / 35	43 / 45	< 35	41 / 43	33 / 35	43 / 45
	38.2	75	62	< 35	< 35	< 35	38 / 40	< 35	41 / 42	< 35	38 / 40	< 35	41 / 43

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-45
5. Table features are explained further in Section 4.2.3.2.

Table 5-47 – Subzone 3 to 6 predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – standard hours (residential receivers) – Gore Hill Freeway Connection surface road works

Major works area/assessment reference				Subzone 3 GHC3		Subzone 4 GHC4		Subzone 5 (West) GHC5W		Subzone 5 (East) GHC5E		Subzone 5 (MCC) GHC5 MCC		Subzone 6 GHC6	
Typical/worst case activity noise intensity				Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver				Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level		Predicted noise levels, $L_{Aeq\ (15\ minutes)}$											
		HNA	NML												
Wollstonecraft	30.4	75	68	< 35	38 / 43	34 / 37	43 / 46	< 35	39 / 42	< 35	38 / 41	34 / 36	43 / 45	34 / 36	43 / 45
Crows Nest	30.1	75	68	< 35	40 / 44	34 / 36	43 / 45	< 35	40 / 43	< 35	39 / 41	35 / 36	44 / 45	35 / 36	44 / 45
Naremburn	30.2	75	68	31 / 36	41 / 46	36 / 39	45 / 48	< 35	41 / 44	33 / 36	43 / 46	37 / 39	46 / 48	37 / 39	46 / 48
	31.3	75	66	< 35	40 / 44	37 / 40	46 / 49	32 / 35	42 / 45	33 / 36	43 / 46	37 / 39	46 / 48	37 / 39	46 / 48
	32.1	75	69	33 / 42	43 / 52	43 / 53	52 / 62	40 / 45	50 / 55	39 / 48	49 / 58	44 / 51	53 / 60	44 / 51	53 / 60
	37.1	75	55	< 35	39 / 43	34 / 36	43 / 45	< 35	40 / 42	< 35	41 / 43	35 / 36	44 / 45	35 / 36	44 / 45
Artarmon	33.1	75	65	47 / 74	57 / **84**	57 / 66	66 / 75	57 / 65	67 / 75	≤ 59	39 / 69	46 / 62	55 / 71	46 / 62	55 / 71
	33.2	75	65	≤ 38	≤ 48	32 / 38	41 / 47	≤ 36	≤ 46	≤ 35	≤ 43	≤ 38	38 / 47	≤ 38	38 / 47
	34.1	75	54	≤ 37	34 / 47	40 / 46	49 / 55	35 / 41	45 / 51	38 / 44	48 / 54	43 / 48	52 / 57	43 / 48	52 / 57
Lane Cove	59.1	75	70	31 / 41	41 / 51	37 / 40	46 / 49	34 / 39	44 / 49	34 / 37	44 / 47	38 / 40	47 / 49	38 / 40	47 / 49
Lane Cove North	33.4	75	65	33 / 39	43 / 49	< 35	41 / 42	34 / 37	44 / 47	< 35	42 / 44	35 / 37	44 / 46	35 / 37	44 / 46
	35.1	75	77	37 / 45	47 / 55	35 / 36	44 / 45	35 / 39	45 / 49	< 35	42 / 44	36 / 37	45 / 46	36 / 37	45 / 46
Willoughby	36.1	75	60	31 / 38	41 / 48	40 / 46	49 / 55	37 / 41	47 / 51	40 / 47	50 / 57	46 / 51	55 / 60	46 / 51	55 / 60
Northbridge	38.1	75	62	< 35	39 / 42	36 / 37	45 / 46	< 35	41 / 43	< 35	40 / 42	35 / 36	44 / 45	35 / 36	44 / 45
	38.2	75	62	< 35	37 / 40	33 / 35	42 / 44	< 35	39 / 40	< 35	38 / 40	< 35	41 / 42	< 35	41 / 42

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-45
5. Table features are explained further in Section 4.2.3.2.

Table 5-48 – Subzone 7 predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – standard hours (residential receivers) – Gore Hill Freeway Connection surface road works

Major works area/assessment reference				Subzone 7 GHC7E		Subzone 7 GHC7W	
Typical/worst case activity noise intensity				Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver				Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level		Predicted noise levels, $L_{Aeq\ (15\ minutes)}$			
		HNA	NML				
Lane Cove/Greenwich	59.1	75	70	69 / 74	**76 / 81**	71	**81**
Lane Cove	60.1	75	49	36	43	48	58
Greenwich	60.2	75	49	42 / 43	49 / 50	47	57
Longueville/Northwood	60.3	75	49	< 35	38	38	48
Lane Cove	60.4	75	49	< 35	38	35	45
Riverview	60.5	75	49	< 35	< 35	< 35	43

Notes:

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
3. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-45
4. Table features are explained further in Section 4.2.3.2.

Table 5-49 – Minor construction support sites predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – standard hours (residential receivers) – Gore Hill Freeway Connection surface road works

Major works area/assessment reference				Gore Hill Freeway construction support site (BL6) GHC0C		Barton Road construction support site (BL5) GHC0B		Dickson Avenue Support construction support site (BL4) GHC0D	
Typical/worst case activity noise intensity				Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver				Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level		Predicted noise levels, $L_{Aeq\ (15\ minutes)}$					
		HNA	NML						
Artarmon	33.1	75	65	≤ 57	≤ 59	≤ 65	≤ 67	≤ 62	≤ 65
	33.2	75	65	≤ 35	≤ 37	≤ 37	≤ 39	≤ 36	≤ 39
Lane Cove/Greenwich	59.1	75	70	≤ 51	≤ 53	≤ 40	≤ 42	≤ 37	≤ 40
Lane Cove North	33.4	75	65	≤ 44	≤ 46	≤ 39	≤ 41	≤ 36	≤ 39
	35.1	75	77	≤ 61	≤ 63	≤ 42	≤ 44	≤ 38	≤ 41

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-45
5. Table features are explained further in Section 4.2.3.2.

Table 5-50 – Subzone 1 to 2 predicted $L_{Aeq\ 15\ minute}$ construction noise levels dB(A) – outside standard hours (residential receivers) – Gore Hill Freeway Connection surface road works

Major works area/assessment reference						Subzone 1 (West) GHC1W		Subzone 1 (Central) GHC1C		Subzone 1 (East) GHC1E		Subzone 2 (West) GHC2W		Subzone 2 (East) GHC2E	
Typical/worst case activity noise intensity						Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver						Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level				Predicted noise levels, $L_{Aeq\ (15\ minutes)}$									
		HNA	Day (O)	Eve	Night										
Wollstonecraft	30.4	75	63	61	43	< 35	37 / 41	< 35	40 / 43	< 35	40 / 43	< 35	39 / 42	< 35	40 / 42
Crows Nest	30.1	75	63	61	43	< 35	38 / 42	< 35	40 / 43	< 35	42 / 44	< 35	40 / 43	< 35	41 / 44
Naremburn	30.2	75	63	61	43	< 35	38 / 42	< 35	41 / 44	33 / 35	43 / 45	< 35	41 / 44	33 / 35	43 / 45
	31.3	75	61	54	42	< 35	37 / 41	32 / 35	42 / 45	35 / 38	45 / 48	< 35	42 / 44	33 / 36	43 / 46
	32.1	75	64	60	45	29 / 35	39 / 45	38 / 45	48 / 55	44 / 55	54 / 65	39 / 45	49 / 55	48 / 57	58 / 67
	37.1	75	50	49	39	< 35	35 / 38	< 35	40 / 43	33 / 35	43 / 45	< 35	39 / 42	< 35	41 / 43
Artarmon	33.1	75	60	58	45	≤ 69	≤ **79**	49 / 75	59 / **85**	62 / 69	72 / **79**	56 / 67	66 / **77**	60 / 66	70 / **76**
	33.2	75	60	58	45	≤ 35	≤ 45	≤ 37	36 / 47	≤ 37	39 / 47	≤ 36	35 / 46	< 35	30 / 45
	34.1	75	49	49	42	≤ 35	33 / 45	32 / 40	42 / 50	36 / 43	46 / 53	34 / 40	44 / 50	40 / 46	50 / 56
Lane Cove	59.1	75	65	60	45	41 / 50	51 / 60	36 / 41	46 / 51	34 / 37	44 / 47	31 / 36	41 / 46	35 / 37	45 / 47
Lane Cove North	33.4	75	60	58	45	34 / 43	44 / 53	34 / 37	44 / 47	< 35	40 / 42	32 / 36	42 / 46	33 / 35	43 / 45
	35.1	75	72	68	51	31 / 62	41 / 72	40 / 44	50 / 54	< 35	41 / 43	34 / 38	44 / 48	33 / 36	43 / 46
Willoughby	36.1	75	55	53	43	< 35	36 / 41	35 / 40	45 / 50	43 / 50	53 / 60	37 / 42	47 / 52	44 / 50	54 / 60
Northbridge	38.1	75	57	53	42	< 35	< 35	< 35	41 / 43	33 / 35	43 / 45	< 35	41 / 43	33 / 35	43 / 45
	38.2	75	57	53	42	< 35	< 35	< 35	38 / 40	< 35	41 / 42	< 35	38 / 40	< 35	41 / 43

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-45
5. Table features are explained further in Section 4.2.3.2.

Table 5-51 – Subzone 3 to 6 predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – outside standard hours (residential receivers) – Gore Hill Freeway Connection surface road works

Major works area/assessment reference						Subzone 3 GHC3		Subzone 4 GHC4[6]		Subzone 5 (West) GHC5W		Subzone 5 (East) GHC5E		Subzone 5 (MCC) GHC5 MCC[6]		Subzone 6 GHC6	
Typical/worst case activity noise intensity						Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver						Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level				Predicted noise levels, $L_{Aeq\ (15\ minutes)}$											
		HNA	Day(O)	Eve	Night												
Wollstonecraft	30.4	75	63	61	43	< 35	38 / 43	-	-	< 35	40 / 43	< 35	35 / 38	-	-	33 / 35	42 / 44
Crows Nest	30.1	75	63	61	43	< 35	40 / 44	-	-	32 / 35	41 / 44	< 35	40 / 42	-	-	34 / 35	43 / 44
Naremburn	30.2	75	63	61	43	31 / 36	41 / 46	-	-	33 / 36	42 / 45	35 / 38	44 / 47	-	-	36 / 38	45 / 47
	31.3	75	61	54	42	< 35	40 / 44	-	-	34 / 37	43 / 46	35 / 38	44 / 47	-	-	36 / 38	45 / 47
	32.1	75	64	60	45	33 / 42	43 / 52	-	-	42 / 47	51 / 56	41 / 50	50 / 59	-	-	43 / 50	52 / 59
	37.1	75	50	49	39	< 35	39 / 43	-	-	< 35	41 / 43	33 / 35	42 / 44	-	-	34 / 35	43 / 44
Artarmon	33.1	75	60	58	45	47 / 74	57 / **84**	-	-	59 / 67	68 / **76**	31 / 61	40 / 70	-	-	45 / 61	54 / 70
	33.2	75	60	58	45	≤ 38	≤ 48	-	-	≤ 38	≤ 47	≤ 35	≤ 44	-	-	≤ 37	37 / 46
	34.1	75	49	49	42	≤ 37	34 / 47	-	-	37 / 43	46 / 52	40 / 46	49 / 55	-	-	42 / 47	51 / 56
Lane Cove[7]	59.1	75	65	60	45	31 / 41	41 / 51	-	-	36 / 41	45 / 50	36 / 39	45 / 48	-	-	37 / 39	46 / 48
Lane Cove North	33.4	75	60	58	45	33 / 39	43 / 49	-	-	36 / 39	45 / 48	33 / 35	42 / 44	-	-	34 / 35	43 / 44
	35.1	75	72	68	51	37 / 45	47 / 55	-	-	< 35	≤ 51	< 35	≤ 51	-	-	< 35	≤ 51
Willoughby	36.1	75	55	53	43	31 / 38	41 / 48	-	-	39 / 43	48 / 52	42 / 49	51 / 58	-	-	45 / 50	54 / 59
Northbridge	38.1	75	57	53	42	< 35	39 / 42	-	-	33 / 35	42 / 44	< 35	41 / 43	-	-	34 / 35	43 / 44
	38.2	75	57	53	42	< 35	37 / 40	-	-	< 35	40 / 41	< 35	39 / 41	-	-	< 35	40 / 41

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-45
5. Table features are explained further in Section 4.2.3.2
6. No typical work is proposed outside standard construction hours
7. Lane Cove and Greenwich.

Table 5-52 – Subzone 7 predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – outside standard hours (residential receivers) – Gore Hill Freeway Connection surface road works

Major works area/assessment reference						Subzone 7 GHC7E		Subzone 7 GHC7W[6]	
Typical/worst case activity noise intensity						Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver						Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level				Predicted noise levels, $L_{Aeq\ (15\ minutes)}$			
		HNA	Day (O)	Eve	Night				
Lane Cove/Greenwich	59.1	75	65	60	45	72 / **77**	**82** / **87**	-	-
Lane Cove	60.1	75	44	42	36	≤ 39	≤ 49	-	-
Greenwich	60.2	75	44	42	36	45 / 46	55 / 56	-	-
Longueville/Northwood	60.3	75	44	42	36	< 35	≤ 44	-	-
Lane Cove	60.4	75	44	42	36	< 35	≤ 44	-	-
Riverview	60.5	75	44	42	36	< 35	≤ 40	-	-

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-45
5. Table features are explained further in Section 4.2.3.2
6. No typical work is proposed outside standard construction hours.

Table 5-53 – Minor construction support sites predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – outside standard hours (residential receivers) – Gore Hill Freeway Connection surface road works

Major works area/assessment reference						Gore Hill Freeway construction support site (BL6) GHC0C		Barton Road construction support site (BL5) GHC0B		Dickson Avenue construction support site (BL4) GHC0D	
Typical/worst case activity noise intensity						Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver						Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level				Predicted noise levels, $L_{Aeq\ (15\ minutes)}$					
		HNA	Day (O)	Eve	Night						
Artarmon	33.1	75	60	58	45	≤ 49	≤ 54	≤ 57	≤ 62	≤ 53	≤ 58
	33.2	75	60	58	45	< 35	< 35	< 35	< 35	< 35	< 35
Lane Cove/Greenwich	59.1	75	65	60	45	≤ 43	≤ 48	< 35	≤ 37	< 35	< 35
Lane Cove North	33.4	75	60	58	45	≤ 36	≤ 41	< 35	≤ 36	< 35	< 35
	35.1	75	72	68	51	≤ 53	≤ 58	< 35	≤ 39	< 35	< 35

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-45
5. Table features are explained further in Section 4.2.3.2.

Table 5-54 – Subzone 1 to 2 predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – non-residential receivers – Gore Hill Freeway Connection surface road works

Major works area/assessment reference			Subzone 1 (West) GHC1W		Subzone 1 (Central) GHC1C		Subzone 1 (East) GHC1E		Subzone 2 (West) GHC2W		Subzone 2 (East) GHC2E	
Typical/worst case activity noise intensity			Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver			Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Receiver type	NCA	NML[6]	Predicted noise levels, $L_{Aeq\ (15\ minutes)}$									
Commercial	33.1	75	31 / 83	41 / 93	34 / 60	44 / 70	< 35	36 / 43	32 / 43	42 / 53	≤ 35	38 / 44
	33.2	75	45 / 66	55 / 76	56 / 67	66 / 77	54 / 62	64 / 72	58 / 70	68 / 80	53 / 68	63 / 78
Childcare	33.1	50	≤ 64	≤ 74	≤ 41	25 / 51	≤ 35	33 / 41	≤ 38	37 / 48	< 35	36 / 42
	33.2	50	≤ 40	≤ 50	49 / 59	59 / 69	51 / 58	61 / 68	49 / 61	59 / 71	45 / 60	55 / 70
	36.1	50	< 35	31 / 37	< 35	39 / 44	32 / 38	42 / 48	31 / 35	41 / 45	32 / 38	42 / 48
Educational	33.1	55	≤ 39	≤ 49	≤ 48	32 / 58	34 / 41	44 / 51	38 / 49	48 / 59	37 / 43	47 / 53
	33.2	55	≤ 42	31 / 52	36 / 46	46 / 56	34 / 42	44 / 52	33 / 44	43 / 54	≤ 41	36 / 51
Other sensitive receiver[6]	33.1	60	< 35	≤ 44	≤ 45	≤ 55	33 / 41	43 / 51	39 / 50	49 / 60	37 / 43	47 / 53
	33.2	55	≤ 36	≤ 46	≤ 38	38 / 48	30 / 38	40 / 48	≤ 39	37 / 49	≤ 38	33 / 48
Place of worship	33.1	55	≤ 38	≤ 48	≤ 38	≤ 48	< 35	36 / 43	≤ 37	36 / 47	≤ 35	39 / 45
Recreational	33.1	65	≤ 47	≤ 57	≤ 49	33 / 59	34 / 42	44 / 52	37 / 49	47 / 59	37 / 43	47 / 53

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML. A full key is presented in Table 5-45
5. Table features are explained further in Section 4.2.3.2
6. Other sensitive receivers have a range of NMLs based upon the receiver classification as outlined in Section 3.4.1.2. The exceedances are based upon the respective receiver NML.

Table 5-55 – Subzone 3 to 6 predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – non-residential receivers – Gore Hill Freeway Connection surface road works

Major works area/assessment reference			Subzone 3 GHC3		Subzone 4 GHC4		Subzone 5 (West) GHC5W		Subzone 5 (East) GHC5E		Subzone 5 (MCC) GHC5 MCC		Subzone 6 GHC6	
Typical/worst case activity noise intensity			Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver			Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Receiver type	NCA	NML[6]	Predicted noise levels, $L_{Aeq\ (15\ minutes)}$											
Commercial	33.1	75	≤ 56	39 / 66	< 35	35 / 44	34 / 42	44 / 52	< 35	≤ 43	≤ 48	≤ 54	≤ 37	30 / 46
	33.2	75	51 / 77	61 / 87	57 / 63	66 / 72	52 / 84	62 / 94	43 / 72	53 / 82	51 / 76	57 / 82	62 / 72	71 / 81
Childcare	33.1	50	≤ 42	≤ 52	< 35	33 / 43	33 / 41	43 / 51	< 35	≤ 41	≤ 46	≤ 52	≤ 36	≤ 45
	33.2	50	≤ 55	39 / 65	54 / 61	63 / 70	30 / 62	40 / 72	≤ 53	34 / 63	41 / 65	47 / 71	44 / 53	53 / 62
	36.1	50	< 35	36 / 44	34 / 39	43 / 48	32 / 36	42 / 46	≤ 36	39 / 46	39 / 42	45 / 48	35 / 41	44 / 50
Educational	33.1	55	≤ 50	32 / 60	34 / 43	43 / 52	42 / 50	52 / 60	≤ 43	≤ 53	≤ 52	≤ 58	≤ 45	38 / 54
	33.2	55	≤ 49	32 / 59	39 / 45	48 / 54	≤ 54	32 / 64	≤ 39	≤ 49	32 / 56	38 / 62	33 / 43	42 / 52
Other sensitive receiver[6]	33.1	60	≤ 47	30 / 57	31 / 40	40 / 49	43 / 51	53 / 61	≤ 41	≤ 51	≤ 55	≤ 61	≤ 45	38 / 54
	33.2	55	≤ 42	≤ 52	34 / 41	43 / 50	≤ 40	≤ 50	≤ 37	≤ 47	≤ 46	≤ 52	30 / 40	39 / 49
Place of worship	33.1	55	≤ 47	30 / 57	≤ 35	35 / 44	34 / 42	44 / 52	≤ 35	≤ 45	≤ 46	≤ 52	≤ 37	30 / 46
Recreational	33.1	65	≤ 55	37 / 65	35 / 42	44 / 51	≤ 38	≤ 48	< 35	≤ 45	≤ 46	≤ 52	30 / 40	39 / 49

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML. A full key is presented in Table 5-45
5. Table features are explained further in Section 4.2.3.2
6. Other sensitive receivers have a range of NMLs based upon the receiver classification as outlined in Section 3.4.1.2. The exceedances are based upon the respective receiver NML.

Table 5-56 – Subzone 7 predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – non-residential receivers – Gore Hill Freeway Connection surface road works

Major works area/assessment reference			Subzone 7 GHC7E		Subzone 7 GHC7W	
Typical/worst case activity noise intensity			Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver			Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Receiver type	NCA	NML[6]	Predicted noise levels, $L_{Aeq\ (15\ minutes)}$			
Commercial	33.2	70	74 / 79	81 / 86	83 / 84	93 / 94
Other sensitive receiver[6]	59.1	70	42 / 47	49 / 54	61	71
Recreational	59.1	60	45 / 50	52 / 57	66 / 67	76 / 77

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML. A full key is presented in Table 5-45
5. Table features are explained further in Section 4.2.3.2
6. Other sensitive receivers have a range of NMLs based upon the receiver classification as outlined in Section 3.4.1.2. The exceedances are based upon the respective receiver NML.

Table 5-57 – Minor construction support sites predicted $L_{Aeq\ 15\ minute}$ construction noise levels, dB(A) – non-residential receivers – Gore Hill Freeway Connection surface road works

Major works area/assessment reference			Gore Hill Freeway median construction support site (BL6) (GHC0C)		Barton Road construction support site (BL5) (GHC0B)		Dickson Avenue construction support site (BL4) (GHC0D)	
Typical/worst case activity noise intensity			Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver			Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Receiver type	NCA	NML[6]	Predicted noise levels, $L_{Aeq\ (15\ minutes)}$					
Commercial	33.1	75	51 / 68	53 / 70	≤ 42	≤ 44	31 / 42	34 / 45
	33.2	70	62 / 65	64 / 67	51 / 54	53 / 56	69 / 86	72 / 89
Childcare	33.1	50	39 / 56	41 / 58	≤ 44	≤ 46	30 / 40	33 / 43
	33.2	50	35 / 38	37 / 40	39 / 42	41 / 44	47 / 64	50 / 67
Educational	33.1	55	≤ 42	≤ 44	≤ 48	≤ 50	40 / 51	43 / 54
	33.2	55	40 / 43	42 / 45	43 / 46	45 / 48	34 / 50	37 / 53

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML. A full key is presented in Table 5-45
5. Table features are explained further in Section 4.2.3.2
6. Other sensitive receivers have a range of NMLs based upon the receiver classification as outlined in Section 3.4.1.2. The exceedances are based upon the respective receiver NML.

Table 5-58 – Number of residential receiver buildings over the noise management level (major works areas) (All NCAs) – Gore Hill Freeway Connection surface road works

Works area	Assessment reference	Typical/worst case activity noise intensity	Highly noise affected > 75 dB(A)		Day (standard hours)			Day (outside standard hours)				Evening				Night				Sleep disturbance	
			Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening level (L_{Amax})	Awakening (L_{Amax})
Subzone 1 (West)	GHC1W	Typical	0	0	3	0	0	2	3	0	0	4	3	0	0	48	18	5	0	30	10
		Worst case	**3**	**3**	7	3	0	10	7	3	0	25	8	3	0	192	147	18	5	158	36
Subzone 1 (Central)	GHC1C	Typical	0	0	8	0	0	5	8	0	0	6	9	1	0	23	19	9	4	27	19
		Worst case	**8**	**8**	12	8	0	13	12	8	0	24	10	9	1	343	100	19	13	126	37
Subzone 1 (East)	GHC1E	Typical	0	0	1	0	0	0	1	0	0	4	1	0	0	43	33	1	0	40	5
		Worst case	**1**	**1**	15	1	0	74	15	1	0	88	20	1	0	883	280	33	1	397	37
Subzone 2 (West)	GHC2W	Typical	0	0	2	0	0	6	2	0	0	3	6	0	0	18	24	8	0	28	9
		Worst case	**2**	**2**	13	2	0	19	13	2	0	17	16	6	0	460	118	24	8	141	32
Subzone 2 (East)	GHC2E	Typical	0	0	1	0	0	0	1	0	0	1	1	0	0	66	45	1	0	63	2
		Worst case	**1**	**1**	19	1	0	124	19	1	0	128	34	1	0	1059	348	45	1	454	46
Subzone 3	GHC3	Typical	0	0	7	0	0	6	7	0	0	7	9	1	0	36	15	10	3	21	17
		Worst case	**7**	**7**	13	7	0	8	13	7	0	17	11	9	1	619	81	15	13	105	33
Subzone 4[1]	GHC4	Typical	0	-	1	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	-	20	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Subzone 5 (West)	GHC5W	Typical	0	0	0	0	0	6	0	0	0	6	1	0	0	27	26	6	0	31	7
		Worst case	0	0	14	0	0	23	14	0	0	19	23	1	0	892	158	26	6	243	35
Subzone 5 (East)	GHC5E	Typical	0	0	0	0	0	0	0	0	0	1	0	0	0	50	24	0	0	34	1
		Worst case	0	0	12	0	0	85	12	0	0	98	15	0	0	817	240	24	0	336	29
Subzone 5 (MCC)[1]	GHC MCC	Typical	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	-	10	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Subzone 6	GHC6	Typical	0	0	0	0	0	0	0	0	0	1	0	0	0	66	23	0	0	37	1
		Worst case	0	0	31	0	0	106	14	0	0	115	18	0	0	978	293	23	0	384	28
Subzone 7 (East)	GHC7E	Typical	0	**1**	1	0	0	5	1	0	0	8	1	1	0	60	15	2	1	8	4
		Worst case	**1**	**2**	2	1	0	117	20	1	0	224	47	1	1	677	364	15	3	86	9
Subzone 7 (West)[1]	GHC7W	Typical	0	-	2	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	**3**	**-**	98	2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:
1. No typical work is proposed outside standard construction hours
2. 'Typical' and 'Worst case' case noise assessment scenarios are explained in Section 4.2.3.2.2, and demonstrated in Figure 4-8
3. Refer to the "Required out of hours work" table in the section "Construction hours and durations" of this assessment section for an indication of the duration and how often these noise impacts are expected to occur
4. An indicative program and timeline in provided at the beginning of this section to provide an indication of the duration of these construction works and the associated construction noise impacts.

Table 5-59 – Number of residential receiver buildings over the noise management level (minor construction support sites) (All NCAs) – Gore Hill Freeway Connection surface road works

Works area	Assessment reference	Typical/worst case activity noise intensity	Highly noise affected > 75 dB(A)		Day (standard hours)			Day (outside standard hours)				Evening				Night				Sleep disturbance	
			Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening level (L_{Amax})	Awakening (L_{Amax})
Gore Hill Freeway median construction support site (BL6)	GHC0C	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	63	7
		Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	37	8	0	0	117	12
Barton Road construction support site (BL5)	GHC0B	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	9	5	0	0	30	9
		Worst case	0	0	1	0	0	1	0	0	0	3	0	0	0	13	13	1	0	40	14
Dickson Avenue construction support site (BL4)	GHC0D	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	9	7	0	0	28	9
		Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	17	16	0	0	43	16

Notes
1. 'Typical' and 'Worst case' case noise assessment scenarios are explained in Section 4.2.3.2.2, and demonstrated in Figure 4-8
2. Refer to the "Required out of hours work" table in the section "Construction hours and durations" of this assessment section for an indication of the duration and how often these noise impacts are expected to occur
3. An indicative program and timeline in provided at the beginning of this section to provide an indication of the duration of these construction works and the associated construction noise impacts.

Table 5-60 – Number of non-residential receivers over the noise management level (major works areas) (All NCAs) – Gore Hill Freeway Connection surface road works

Works area	Assessment reference	Typical/worst case activity noise intensity	Commercial[2]			Childcare			Educational[6]			Recreational[2]			Places of worship			Other sensitive receivers[2]		
			1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
Subzone 1 (West)	GHC1W	Typical	3	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	2	3	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Subzone 1 (Central)	GHC1C	Typical	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	2	0	0	4	1	0	3	0	0	0	0	0	0	0	0	0	0	0
Subzone 1 (East)	GHC1E	Typical	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	4	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Subzone 2 (West)	GHC2W	Typical	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	3	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0
Subzone 2 (East)	GHC2E	Typical	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	14	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Subzone 3	GHC3	Typical	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	5	1	0	3	1	0	7	0	0	1	0	0	1	0	0	0	0	0
Subzone 4[1]	GHC4	Typical	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	11	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Subzone 5 (West)	GHC5W	Typical	7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	6	7	0	1	0	1	6	0	0	0	0	0	0	0	0	1	0	0
Subzone 5 (East)	GHC5E	Typical	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	13	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Subzone 5 (MCC)[1]	GHC5 MCC	Typical	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
		Worst case	6	0	0	2	0	1	6	0	0	1	0	0	0	0	0	1	0	0
Subzone 6	GHC6	Typical	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	17	1	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Subzone 7 (East)	GHC7W	Typical	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subzone 7 (West)[1]	GHC7E	Typical	2	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Worst case	1	2	2	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0

Notes:
1. No typical work is proposed outside standard construction hour
2. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table
3. 'Typical' and 'Worst case' case noise assessment scenarios are explained in Section 4.2.3.2.2, and demonstrated in Figure 4-8
4. Refer to the "Required out of hours work" table in the section "Construction hours and durations" of this assessment section for an indication of the duration and how often these noise impacts are expected to occur
5. An indicative program and timeline in provided at the beginning of this section to provide an indication of the duration of these construction works and the associated construction noise impacts
6. Some receivers (ie education facilities) are made up of multiple buildings. All receiver buildings are counted in this table, even if they are part of a single organisation.

Table 5-61 – Number of non-residential receivers over the noise management level (minor construction support sites) (All NCAs) – Gore Hill Freeway Connection surface road works

Works area	Assessment reference	Typical/worst case activity noise intensity	Commercial[1]			Childcare			Educational			Recreational[1]			Places of worship			Other sensitive receivers[1]		
			1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
Gore Hill Freeway construction support site (BL6)	GHC0C	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Barton Road construction support site (BL5)	GHC0B	Typical	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dickson Avenue construction support site (BL4)	GHC0D	Typical	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes:
1. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table
2. 'Typical' and 'Worst case' case noise assessment scenarios are explained in Section 4.2.3.2.2, and demonstrated in Figure 4-8
3. Refer to the "Required out of hours work" table in the section "Construction hours and durations" of this assessment section for an indication of the duration and how often these noise impacts are expected to occur
4. An indicative program and timeline in provided at the beginning of this section to provide an indication of the duration of these construction works and the associated construction noise impacts.

5.4.2.5 Cumulative construction noise impacts

There is potential for cumulative noise impacts on receiver locations in proximity to the Gore Hill Freeway Connection from other construction works that are being carried out in the same area at the same time. As further outlined in Section 4.2.4, the potential for cumulative or consecutive construction noise impacts from other construction works associated with the project or other major construction projects in the area has been considered in assessing noise impacts.

For the Gore Hill Freeway Connection surface road works, the proposed staging of concurrent construction works associated with the project and other nearby major infrastructure projects that are considered for cumulative construction impacts are presented in Table 5-62, while there is also the potential for cumulative impacts as specific work areas may operate concurrently with the Gore Hill Freeway Connection surface road works.

Table 5-62 – Concurrent construction works near the Gore Hill Freeway Connection surface road works areas

The project	2021	2022	2023	2024	2025	2026	2027
Gore Hill Freeway Connection surface road works (GHC)							
Flat Rock Drive (BL2/FRD) construction support site							
Punch Street (BL3/PUN) construction support site							
Other major projects							
Warringah Freeway Upgrade (WFU) as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project[1]							
Waltham Street construction support site (WHT11/WFU3K), part of the Western Harbour Tunnel and Warringah Freeway Upgrade project[1]							
Artarmon Substation, Sydney Metro City & Southwest (SM)[2]							

Notes: 1. Waltham Street construction support site (WHT11) forms part of the Western Harbour Tunnel project, refer to Western Harbour Tunnel and Warringah Freeway Upgrade Environmental Impact Statement (Transport for NSW, 2020).

2. Artarmon Substation forms part of the Sydney Metro (City & Southwest) project, refer to Victoria Cross Station and Artarmon Substation Modification Report.

Table 5-63 and Table 5-64 present all the major work areas and nearby major construction projects and indicates if predicted noise levels during typical construction activities exceed the NML in each NCA. When construction is carried out in more than one major work area at the same time, and both are predicted to exceed the NML in the same NCA, there is potential for an increase in construction noise levels in that NCA due to cumulative noise impacts.

Worst case noise activities have not been included in the cumulative noise assessment, as they are likely to be infrequent and sporadic. Worst case impacts have the potential to impact a larger number of NCAs than presented in Table 5-63 and Table 5-64. For worst case works there is greater chance that the same NCAs may be impacted over consecutive nights and so could result in consecutive impacts. This is because the worst case activities are more noise intensive and affect a large range of receivers than for typical activities. Depending upon when they are to occur, both typical and worst case activities may require consideration when determining respite provisions.

During standard construction hours, there is potential for cumulative construction noise levels over the NML between different major works areas/subzones of the GHC. With the exception of NCA 33.1 in Artarmon, cumulative construction noise levels over the NML are unlikely for other major project construction works outside of the GHC. While outside standard construction hours:

- During the night period, the major NCAs where there is potential for cumulative construction noise levels over the NML for the various Gore Hill Freeway Connection subzones are NCAs 32.1, 33.1, 59.1, 33.4, 34.1, 35.1 and 36.1 shown in Figure 5-5
- During the night period, there is potential for cumulative construction noise levels over the NML from the Gore Hill Freeway Connection construction works and other major projects in NCAs 32.1, 33.1 and 36.1.

As such, the staging, coordination and management of potential cumulative noise levels for these NCAs would be considered during detailed construction planning where feasible and reasonable. Construction works would be scheduled to provide respite to noise affected (ie >NML) receivers, as outlined and recommended in the CNVG (see Annexure G) and further detailed in Section 6.4.3. Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5. Refer to Section 5.6 for details of the Punch Street construction support site (BL3), and Section 5.5 for the Flat Rock Drive construction support site (BL2).

Table 5-63 – Noise affected (ie >NML) NCAs for each major works area – typical activities (standard hours) - Gore Hill Freeway Connection surface road works

Suburb	NCA	Daytime NML	GHC1W	GHC1C	GHC1E	GHC2W	GHC2E	GHC3	GHC4	GHC5W	GHC5E	GHC5 MCC	GHC6	GHC7E	GHC7W	FRD	PUN	WFU[1,4]	WFU3K[1,4]	SM[2,4]
Naremburn	31.1	66														●				
	31.3	66														●		●		
	32.1	69															●			
	37.1	55	●	●	●		●			●							●			●
Artarmon	33.1	65															●		●	●
	33.2	65																		
	34.1	54															●			
Lane Cove	60.1	49																		
Lane Cove North	33.4	65														●	●			
	35.1	77														●				
Lane Cove[5]	59.1	70														●				
Willoughby	36.1	60																		
Greenwich	60.2	49												●						
Northbridge	38.1	62																		
	38.2	62																		

Notes:
1. Warringah Freeway Upgrade - Refer to Western Harbour Tunnel and Warringah Freeway Upgrade Environmental Impact Statement (Transport for NSW, 2020)
2. Sydney Metro City & Southwest - Refer to Victoria Cross Station and Artarmon Substation Modification Report
3. ● and (**blue**) shading indicates 'typical' construction activities are predicted to exceed the Daytime NML receivers in that NCA are considered 'noise affected'
4. Other major construction projects, refer to Table 5-62 for the project references.
5. NCA 38.1 includes Lane Cove and Greenwich

Table 5-64 – Noise affected (ie >NML) NCAs for each major works area – typical activities (OOHW) - Gore Hill Freeway Connection surface road works

Suburb	NCA	Night NML	GHC1W	GHC1C	GHC1E	GHC2W	GHC2E	GHC3	GHC4	GHC5W	GHC5E	GHC5 MCC	GHC6	GHC7E	GHC7W	FRD	PUN	WFU[1,4]	WFU3K[1,4]	SM[2,4]
Naremburn	31.1	42														●		●		
	31.3	42														●		●		
	32.1	45			●	●	●			●	●		●					●		
	37.1	39														●		●		
Artarmon	33.1	45	●	●	●	●	●	●		●	●		●				●	●		●
	33.2	45																●		●
	34.1	42			●		●			●	●		●							
Lane Cove	60.1	36												●						
Lane Cove North	33.4	45	●	●																
	35.1	51	●	●																
Lane Cove[5]	59.1	45	●	●										●						
Willoughby	36.1	43			●	●	●				●		●			●		●		
Greenwich	60.2	36												●						
Northbridge	38.1	42														●		●		
	38.2	42																●		

Notes:
1. Warringah Freeway Upgrade - Refer to Western Harbour Tunnel and Warringah Freeway Upgrade Environmental Impact Statement (Transport for NSW, 2020)
2. Sydney Metro City & Southwest - Refer to Victoria Cross Station and Artarmon Substation Modification Report
3. ● and (**orange**) shading indicates 'typical' construction activities are predicted to exceed the Night NML receivers in that NCA are considered 'noise affected'
4. Other major construction projects, refer to Table 5-62 for the project references.
5. NCA 38.1 includes Lane Cove and Greenwich

5.4.3 Construction related road traffic noise

5.4.3.1 Changes in road traffic noise impacts due to construction works

A number of traffic switching arrangements would be used during construction of the project. As traffic speeds would decrease from the currently posted speeds of 80 kilometres per hour down to either 60 kilometres per hour, or where required 40 kilometres per hour when works take place next to live traffic, road traffic noise levels would also reduce.

As part of traffic switching staging, individual lanes on carriageways would be closed; however, there would still be westbound and eastbound traffic on both sides of the Gore Hill Freeway. Any changes in distance from the operating traffic lanes to the nearest residential facades in NCA 33.1 are likely to be relatively small. As such, the negligible distance change combined with the change in speed is likely to decrease road traffic noise impacts at these receivers.

5.4.3.2 Heavy vehicle operations associated with surface road works.

Vehicles would mostly travel between subzones via the Warringah Freeway, Gore Hill Freeway and to and from the site via these same roads in addition to Epping Road and the Pacific Highway. Heavy

vehicle deliveries, and OOHW movements would also predominately come from/via the Punch Street construction support site (BL3). This construction support site is located within an industrial zone, with the nearest residential receivers on the opposite side of the Gore Hill Freeway, around 150 metres away, and a direct access route from the construction support site to the Gore Hill Freeway would be constructed for the project. Construction vehicles associated with the Dickson Avenue/Pacific Highway intersection works (GHC7 W/E) would operate via the Pacific Highway when these works take place.

The existing traffic volumes on the Warringah Freeway are in excess of 100,000 vehicles per day, with greater than eight per cent heavy vehicles. The Pacific Highway is in excess of 50,000 vehicles per day. The predicted increase in road traffic noise levels from the associated construction vehicles as part of the project works operating in this manner are likely to have a minimal impact on the road traffic noise levels at nearby residential receivers, and any increase is likely to be within 2 dB(A) of existing road traffic noise levels.

During further design development and construction planning, in order to ensure that traffic noise impacts are minimised, the construction traffic associated with the project should include the mitigation and management measures detailed in Section 6.7 where feasible and reasonable.

5.4.3.3 Minor construction support sites

Construction support sites for the project would need to operate outside standard hours. All major work areas would be supported by one of the minor construction support sites nearby to the surface road works area or be supported by the Punch Street construction support site (BL3).

Table 5-65 presents the proposed vehicle movements for all construction support sites and the corresponding predicted road traffic noise assessment for Gore Hill Freeway Connection surface road works minor construction support sites. Based on the proposed construction vehicle movements, no site is predicted to increase overall road traffic noise levels by more than 2 dB(A) at the nearest affected residential receivers. Minor construction support sites that have heavy vehicle movements during the night period have the potential to exceed the sleep disturbance screening levels and awakening reaction levels from air brake releases or metal on metal bangs associated with the loads being carried if these are not mitigated and managed.

During further design development and construction planning, in order to ensure that traffic noise impacts are minimised, the construction traffic associated with the project should include the mitigation and management measures detailed in Section 6.7 where feasible and reasonable.

Road traffic noise impacts from the Punch Street construction support site (BL3) are covered in the individual site assessment in Section 5.6.

Table 5-65 – Gore Hill Freeway Connection surface road works – minor construction support sites – road traffic noise assessment

Minor construction support site	Construction vehicle access road	Road type	Time of day	Base RNP criteria, dB(A)	Proposed construction vehicle movements		Proposed construction vehicle movements (average maximum 1 hour)		Predicted construction road traffic noise level, dB(A)[1,5]	Estimated existing traffic level, dB(A)[2]	Predicted total road traffic noise level, dB(A)	Increase in road traffic noise, dB(A)	Increase greater than 2 dB(A)	Exceedance of sleep disturbance screening level[4]
					Light[3]	Heavy[3]	Light[3]	Heavy[3]						
Dickson Avenue (BL4)	Reserve Road/ Dickson Ave	Arterial	Day	60 $L_{Aeq(15hr)}$	266	13	-	-	44.2	70.7	61.4	0.0	No	-
			Night	55 $L_{Aeq(9hr)}$	89	4	-	-	41.5	65.8	57.4	0.0	No	Yes
Barton Road (BL5)	Reserve Road	Arterial	Day	60 $L_{Aeq(15hr)}$	107	10	-	-	48.3	70.7	61.6	0.0	No	-
			Night	55 $L_{Aeq(9hr)}$	38	0	-	-	44.1	65.8	57.6	0.0	No	No
	Barton Road/ Butchers Lane	Local	Day	55 $L_{Aeq(1hr)}$	-[3]	-[3]	27	2	53.3	63.3	62.4	0.4	No	-
			Night	50 $L_{Aeq(1hr)}$	-[3]	-[3]	22	0	51.2	55.0	59.0	1.5	No	No
Gore Hill Freeway median (BL6)	Gore Hill Freeway	Arterial	Day	60 $L_{Aeq(15hr)}$	42	10	-	-	39.2	66.7	73.8	0.0	No	-
			Night	55 $L_{Aeq(9hr)}$	22	2	-	-	36.1	62.0	68.9	0.0	No	Yes

Notes:
1. Predicted traffic noise levels have been calculated based upon noise measurements of similar construction delivery vehicles. Heavy vehicles are based upon a medium-rigid delivery truck. Light vehicles are based upon typical private cars
2. As the road traffic noise at these residential receivers at these residential receivers in controlled by the Gore Hill Freeway, existing traffic noise levels have been estimated using the operational noise modelling to determine the existing traffic noise levels at the receivers along the construction vehicle access road and determine the receiver which would be the worst affected. Existing traffic noise levels have been determined for the appropriate 15hr/9hr or worst 1 hour assessment periods where applicable
3. A '-' is included where these counts are no applicable for the assessment of this access road type
4. Not applicable during daytime, and assessed to the nearest residential receiver location
5. Based upon the distance from the facade to kerb of the potentially worst affected residential/sensitive receiver adjacent to the access road.

5.4.4 Ground-borne construction noise

Ground-borne noise levels have the potential to be generated by vibration intensive works at the surface road works and associated construction support sites. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Section 4.3.2 outlines the potential impacts from ground-borne noise generated by surface construction works such as these.

5.4.5 Construction vibration

Across the Gore Hill Freeway Connection surface road works it is assumed that vibration intensive activities such as the use of rock hammers could be required as part of the surface road works. Accordingly, minimum working distances of 22 metres for sound structures, 30 metres for unsound structures and 73 metres for adverse human response have been used to assess potential vibration impacts.

Vibration generated from construction works would vary depending on the level and type of activity carried out at each site during each stage. The minimum working distances for a range of plant presented in Table 4-11 and the works area specific minimum working distances are presented in Annexure L.

The number of receiver buildings within the minimum working distances is presented in Table 5-66. Potential vibration impacts to receivers would depend on vibration source levels, the separation distance, the intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. When construction works occur within the minimum working distance of nearby sensitive structures they should be assessed during further design development and construction planning, as recommended in Section 6.8.

Table 5-66 – Number of structures within nominated minimum working distance for vibration impacts – Gore Hill Freeway Connection surface road works

Vibration intensive works location	NCA	Number of receivers within minimum working distance		
		Cosmetic damage		Human response
		Sound structure	Unsound structure	
GHC1	33.1	15	-	38
	33.2	-	-	32
	35.1	1	-	14
GHC2	33.1	-	-	8
	33.2	1	-	38
GHC3	33.1	4	-	19
	33.2	4	-	25
GHC4	33.1	-	-	4
GHC5	33.1	-	-	3
	33.2	9	-	43

Vibration intensive works location	NCA	Number of receivers within minimum working distance		
		Cosmetic damage		Human response
		Sound structure	Unsound structure	
GHC6	33.2	2	-	17
GHC7	33.2	6	-	18
	59.1	3	-	11

Cosmetic damage

Up to 16 non-heritage receiver buildings have been identified within the minimum working distance for light framed sound structures for the whole of the Gore Hill Freeway Connection surface road works, the highest identified during works in GHC1.

This estimate is conservative and so during detailed construction planning when the vibration generating plant and the locations that would be used are known then the number of structures that are within minimum working distances would be reviewed.

Where items remain within minimum working distances, the risk of structural damage would be mitigated by measures including condition surveys, on site vibration testing and monitoring, as outlined in Section 6.

Human response

Up to 84 sensitive receivers are identified within the minimum working distance for adverse human response from the Gore Hill Freeway Connection surface road works, the highest number is identified during works in GHC1. For these receivers there is the potential to perceive vibration impacts during activities where vibration intensive plant such as large rock hammers are used at the closest point to any receiver.

This is a conservative screening assessment, and where less vibration intensive plant are used, vibration is attenuated or there is a discontinuity in the ground between the plant and receiver, the chance of perceived vibrations reduces.

5.4.5.1 Heritage listed structures

One area within the minimum working distances is a potential aboriginal archaeological deposit. It is within the footprint of Subzone 4 (GHC4) and adjacent to Subzone 1 (East) (GHC1_E). It is within the minimum working distance for unsound structures, assuming that vibration intensive plant such as a large rock hammer would be used.

As details for local area works associated with the Gore Hill Freeway Connection surface road works would be finalised during detailed construction planning, works outside of the assessed major works areas may be required and so could take place closer to heritage items.

Where heritage items are identified within minimum working distances, vibration impacts would be appropriately mitigated and managed as required and outlined in Section 6.

Refer to the Technical working paper: Aboriginal cultural heritage assessment report (Appendix L of the environmental impact statement) and Technical working paper: Non-Aboriginal heritage (Appendix J of the environmental impact statement)for the assessment of impacts to heritage items.

5.4.5.2 Vibration mitigation and management

Further analysis and assessment of potential vibration impacts should be carried out during the detailed construction planning phase, when likely plant and equipment, timing and location of works are confirmed.

Due to the varying nature of vibration intensive activities, cumulative vibration impacts are unlikely to result in increased vibration levels at sensitive receivers. However, all vibration generating activities should be considered during detailed construction planning, and individual activities would not be considered only in isolation.

Vibration mitigation and management measures should be used to minimise any possible impacts. The measures recommended for this project are outlined in Section 6 and should be included in a CNVMP.

5.5 Flat Rock Drive construction support site (BL2)

This section assesses the potential construction noise and vibration impacts, and the reasonable and feasible mitigation measures that would be considered to control impacts on noise and vibration sensitive receivers near the Flat Rock Drive construction support site (BL2).

5.5.1 Construction support site overview

5.5.1.1 Construction support site description

Work at the site would occur in stages as presented in Table 5-67.

Table 5-67 – Flat Rock Drive construction support site (BL2) – major stage overview

Stage	Representative activity	Major stage activities/description
Site establishment	1. Early works	Public utility adjustments and relocations
		Supply of utilities to construction facilities
	2. Establish site	Install environmental controls, clearing and grubbing
		Establish construction facilities (site offices and workshops)
		Intersection modifications (on site)
Road works	3. Road widening	Widening approximately 200 meters of existing Flat Rock Drive to allow dedicated turn lanes into and from the construction site
Acoustic shed and surface level access decline construction	4. Piling for access decline and acoustic shed	Piling for access decline and acoustic shed foundations
	5. Surface level access decline construction	Surface level excavation of the access decline
	6. Acoustic shed construction	Erect acoustic shed elements
Tunnel construction (access decline and mainline and ramp tunnels)	7. Tunnelling	Tunnel spoil handling and haulage, tunnel support, tunnel lining and associated deliveries
Tunnel fitout	8. Tunnel fitout	Install mechanical and utilities services to the tunnel
Tunnel commission and site rehabilitation	9. Site rehabilitation	Commission tunnel, decommission site and site rehabilitation

As part of the major activities presented above, the Flat Rock Drive construction support site (BL2) would support up to seven roadheaders constructing the mainline and ramp tunnels operating as follows:

- Two digging mainline and ramp tunnels south towards the Warringah Freeway at Cammeray
- Four digging north towards the Middle Harbour crossing at Northbridge
- One digging cross passages.

The construction of the mainline and ramp tunnels are assessed in Section 5.16.

5.5.1.2 Construction works program

An approximate timeframe for the operation of the site is presented in Table 5-68, subject to project approval. This construction support site is planned to operate from the start of 2023 until the end of 2027. The longest duration activity at this construction support site would be tunnelling.

Table 5-68 – Flat Rock Drive construction support site (BL2) – indicative program and timeline

Stage	Representative activity	Reference	Indicative construction timeframe																	
			2022				2023				2024				2025				2026				2027			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Site establishment	1. Early works	FRD_01																								
	2. Establish site	FRD_02																								
Road works	3. Road widening	FRD_03																								
Acoustic shed and surface level access decline construction	4. Piling for access decline and acoustic shed	FRD_04																								
	5. Surface level access decline construction	FRD_05																								
	6. Acoustic shed construction	FRD_06																								
Tunnel construction (access decline and mainline and ramp tunnels)	7. Tunnelling	FRD_07																								
Tunnel fitout	8. Tunnel fitout	FRD_08																								
Tunnel commission and site rehabilitation	9. Site rehabilitation	FRD_09																								

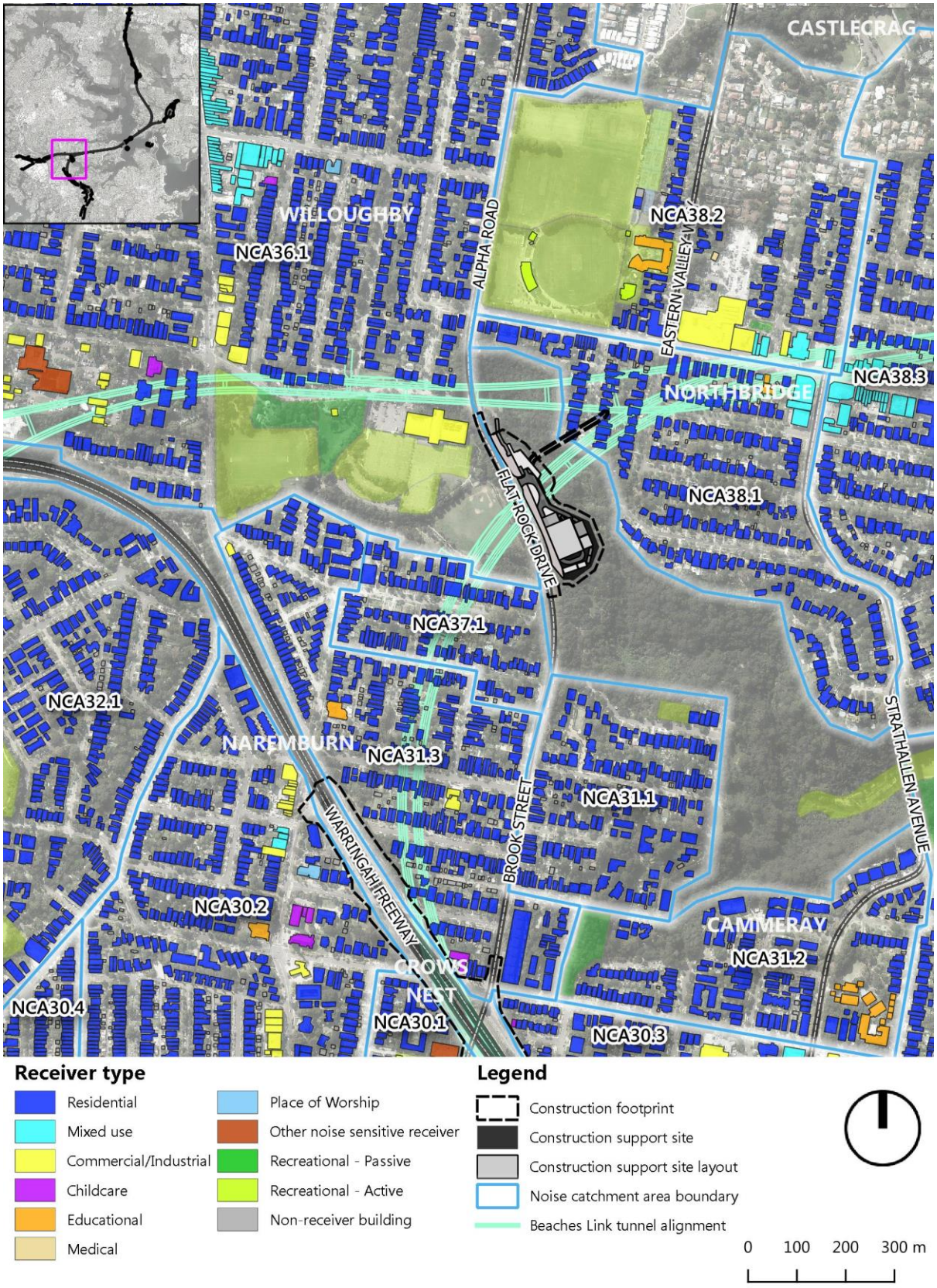
5.5.1.3 Nearby noise and vibration sensitive receivers

The construction support site is located on Flat Rock Drive at Northbridge. It is mostly surrounded by residential and active recreational receivers.

Residential receivers are mainly located to the east and west of the site. Active recreation areas (baseball field, and basketball and netball courts) are located to the west of the site, while commercial receivers associated with recreation areas are to the west of the site.

The location of the site, nearby NCAs and receiver locations are shown in Figure 5-10.

Figure 5-10 – Location of the Flat Rock Drive construction support site (BL2)



5.5.1.4 Construction duration and working hours

Table 5-69 presents each of the major stages and each of the assessed activities for the Flat Rock Drive construction support site (BL2), along with the duration and proposed periods of works for each activity. During the construction and operation of the Flat Rock Drive construction support site (BL2), work would typically take place during the standard construction hours, presented in Table 3-2 (Section 3). However, some works would take place outside standard hours, as presented in Table 5-69.

Table 5-69 – Flat Rock Drive construction support site (BL2) – construction hours

Stage	Representative activity	Reference	Assessed activities[1]	Work hours[2]			
				Day (Standard)	Day (OOHW)	Evening	Night
Site establishment	1. Early works	FRD_01	Utility works	♦			
	2. Establish site	FRD_02	Install environmental controls	♦			
			Clearing and grubbing	♦			
			Establish construction facilities (site offices and workshops)	♦			
			Intersection modification (on site)	♦			
Road works	3. Road widening	FRD_03	Road widening, intersection construction work and traffic controls	♦	♦	♦	♦
Acoustic shed and surface level access decline construction	4. Piling for access decline and acoustic shed	FRD_04	Piling for access decline and acoustic shed	♦			
	5. Surface level access decline construction	FRD_05	Surface level access decline excavation and construction	♦			
	6. Acoustic shed construction	FRD_06	Acoustic shed construction	♦			
Tunnel construction (access decline and mainline and ramp tunnels)	7. Tunnelling	FRD_07	General site activities[4]	♦	♦	♦	♦
			Deliveries	♦			
			Tunnelling and support[4]	♦	♦	♦	♦
			Tunnel lining (concreting) deliveries[4]	♦	♦	♦	♦
			Spoil handling in an acoustic shed	♦	♦[3]	♦[3]	♦[3]
			Spoil haulage	♦			
Tunnel fitout	8. Tunnel fitout	FRD_08	Deliveries[4]	♦	♦	♦	♦
			Laydown areas	♦			
Tunnel commission and site rehabilitation	9. Site rehabilitation	FRD_09	Decommission site and site rehabilitation	♦			

Notes:
1. Annexure E describes the modelled plant for each activity
2. Day Standard is 7.00am to 6.00pm Monday to Friday and 8.00am to 1.00pm Saturday
   Day Out-of-Hours Work is 1.00pm to 6.00pm Saturday and 8.00am to 6.00pm Sunday/Public holiday
   Evening is 6.00pm to 10.00pm Monday to Friday and 6.00pm to 10.00pm Saturday/Sunday/Public holiday
   Night is 10.00pm to 7.00am Monday to Friday and 10.00pm to 8.00am Saturday/ Sunday/Public holiday
3. Spoil haulage off the construction support site would occur during standard construction hours. OOHW spoil handling would occur inside acoustic shed
4. Activities typically within acoustic shed during OOHW periods.

5.5.1.5 Concurrent construction projects

The nearest construction work associated with this project would be the Gore Hill Freeway Connection surface road works, about one kilometre west of this site.

The nearest construction support site associated with another major infrastructure project would be the Warringah Freeway Upgrade, about one kilometre south of this site and part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

5.5.1.6 Construction assessment scenarios

The airborne noise assessment of the Flat Rock Drive construction support site (BL2) was separated into seven stages. Each stage was assessed against the work periods proposed in Table 5-69. The details of modelled construction plant items and corresponding sound power levels are presented in Annexure E.

The equipment/plant listed in Annexure E represent the reasonable worst case equipment/plant operating simultaneously in any 15 minute period (refer to Section 4.2.2 for further explanation of assessment scenarios).

Multiple activities would at times occur concurrently within the one construction support site and were captured in the assessment as shown in Table 5-69.

5.5.1.7 Summary of assumed noise treatment and management measures

As part of the assessment process, feasible and reasonable noise treatment measures and management methods have been identified based on the preliminary site layout and the reasonable worst case plant/equipment operating, to assist in attenuating and managing noise emissions from the construction activities.

Identified feasible and reasonable noise treatment measures have been included in the noise model and are presented in Table 5-70, with the assumed acoustic performance presented in Table 5-71. The results presented in this assessment are based on those noise treatments and management measures being implemented. The locations of physical noise treatment measures are shown in Figure 5-11.

Further design development and construction planning refinements to the construction support site layouts, equipment, construction methods or construction hours may require specific mitigation and management measures that are different from those outlined in this section. Final details for noise treatments and management measures will be confirmed during further design development and construction planning to determine what is feasible and reasonable, with consideration of cumulative construction impacts.

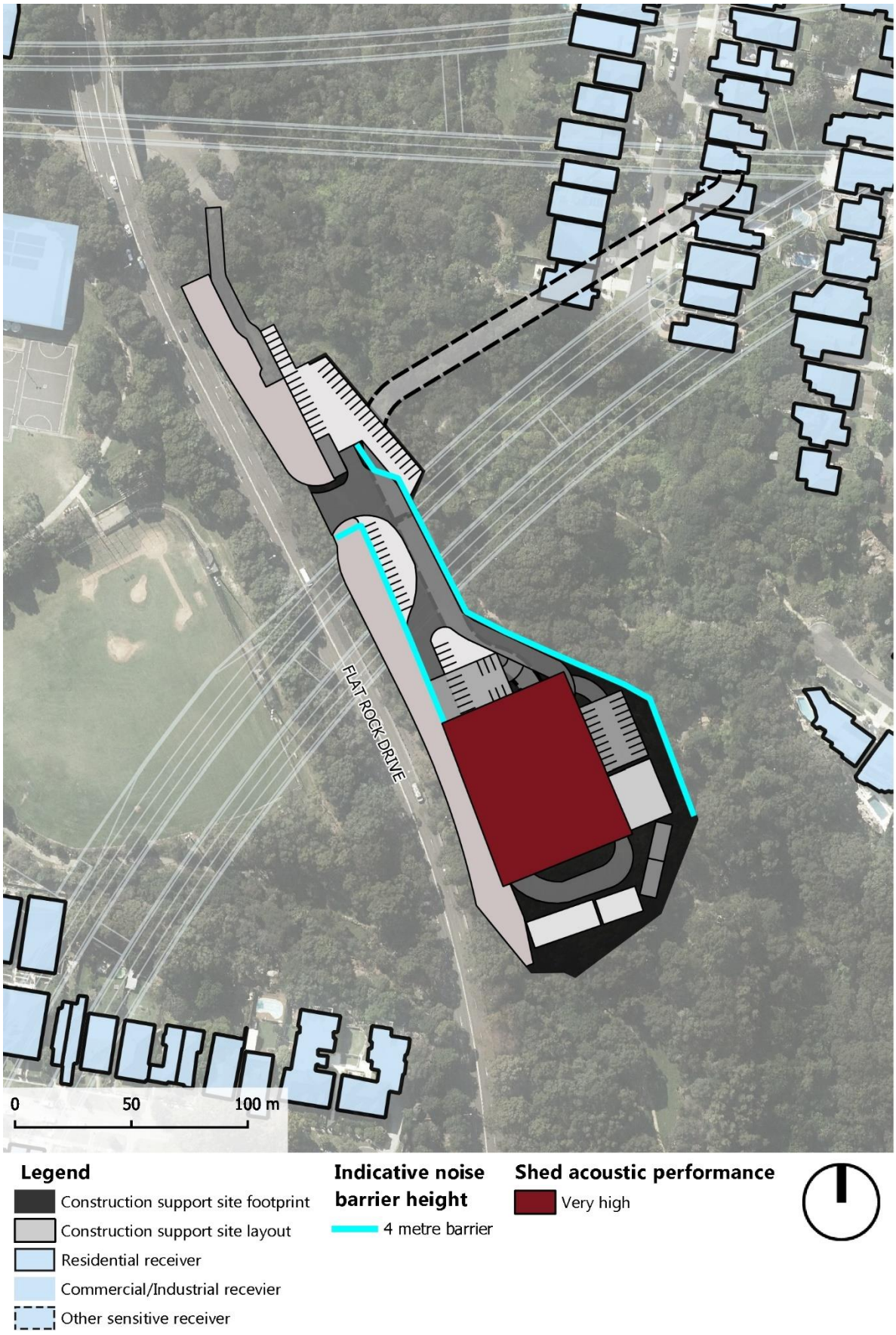
Table 5-70 – Assumed noise treatment and management measures – Flat Rock Drive construction support site (BL2)

Activity or plant/equipment	Description of management and mitigation measures
Work outside standard hours	The following indicative noise barriers would be installed around the site to manage noise emissions, as shown in Figure 5-11: • Four metre high noise barrier would be constructed along a section of the eastern boundary of the construction support site • Four metre high site hoarding would be installed along a section of the western boundary of the construction support site. All night time delivery vehicles would enter and leave the site by the site internal access road. Furthermore, night time delivery vehicle movements would be directly adjacent to the noise barrier when travelling to and from the acoustic shed to maximise the acoustic shielding provided by the noise barrier. Heavy vehicle movements would be limited to one heavy vehicle movement (either travelling to or exiting the acoustic shed) per 15 minute period. Work would only occur outside standard hours where it: • meets the relevant NMLs • occurs in an acoustic enclosure • is required for safety reasons needs to occur outside standard hours to maintain the operational integrity of the road network.
Tunnelling, support and fitout: acoustic shed	An acoustic shed would be built to reduce noise from tunnelling, support, spoil handling and fitout work outside standard hours. Indicative performance requirements for shed elements are presented in Table 5-71. Outside standard hours, noise generating activities associated with laydown and deliveries would occur within the acoustic shed. Additionally, other noise generating works (ie. workshop related activities) will be conducted within the acoustic shed when outside standard construction hours.
Ventilation plant	Ventilation plant would be acoustically treated to achieve a maximum combined sound power level of 85 dB(A). Seven ventilation plant were included in the model. Plant is assumed to be located along the north western facade of the shed to reduce noise impacts.
Wastewater treatment plant	The wastewater treatment plant would achieve a total sound power level of 85 dB(A), which may require acoustic treatment or the use of an acoustic enclosure.
Substation	The substation is to achieve a total sound power level of 75 dB(A), which may require acoustic treatment or the use of an acoustic enclosure.
Road works	Temporary noise screens/mobile noise screens would be used for high noise generating road works activities such as concrete sawing or rock hammering.
Workshop and elevated offices	Where feasible and reasonable, site buildings, such as workshops and site offices, would be located and/or constructed in a way that maximises blocking line of sight from the workshop activities and general noise generating areas (ie laydown or acoustic shed openings) to the receivers located south west of the site.

Table 5-71 – Indicative acoustic shed construction and acoustic performance – Flat Rock Drive construction support site (BL2)

Shed element (Indicative example constructions are shown in Table 4-1)	Octave band frequency transmission loss, dB						
	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Acoustic shed (very high performance)							
Walls – Very high performance	25	31	40	49	61	69	75
Roof – Very high performance	23	31	40	49	56	58	63

Figure 5-11 – Site layout with indicative acoustic treatment measures for the Flat Rock Drive construction support site (BL2)



5.5.2 Construction airborne noise

The methodology used for assessing airborne noise impacts from construction support sites is outlined in Section 4.2.2.

5.5.2.1 Nearby receiver summary and objectives

Table 5-72 presents NMLs and the screening levels for the assessment of sleep disturbance for the nearest residential receivers surrounding the Flat Rock Drive construction support site (BL2). Noise management levels for other (non-residential) noise sensitive receivers are presented in in Section 3.4.1. The locations of the NCAs surrounding the construction support site are shown in Figure 5-10.

Table 5-72 – Construction noise management levels and screening levels for residential receivers

NCA ID	Noise management levels (NML) $L_{Aeq(15\ minute)}$				Sleep disturbance screening levels
	Standard hours (RBL + 10dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL + 5dB)			L_{Amax} (RBL + 15dB)
	Day	Day	Evening	Night	Night
24.1	66	61	57	42	52
28.1	57	52	50	42	52
30.1	68	63	61	43	53
30.2	68	63	61	43	53
30.3	68	63	61	43	53
30.4	68	63	61	43	53
31.1	66	61	54	42	52
31.2	66	61	54	42	52
31.3	66	61	54	42	52
32.1	69	64	60	45	55
34.1	54	49	49	42	52
36.1	60	55	53	43	53
37.1	55	50	49	39	49
38.1	62	57	53	42	52
38.2	62	57	53	42	52
38.3	62	57	53	42	52

5.5.2.2 Predicted noise impacts

Table 5-73 provides a key to the cell shading and text formatting used to explain results in the following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-73 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes: 1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present for each NCA the range of the highest predicted noise levels for all noise affected residential, commercial and other noise sensitive receivers (ie receivers where noise levels are above the NMLs). If the lower noise level of the range is below the NML, only the upper noise level is presented. It is noted that the noise predictions include adjustments for annoying activities, in accordance with the ICNG.

Noise contours for the loudest early works, site establishment, and longer term tunnelling stages are shown in Annexure H.1. Maps presenting the predicted exceedance for a sample of scenarios at the construction support site with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different assessment periods.

5.5.2.3 Residential

The predicted noise levels for residential receivers are presented in the following tables:

- Table 5-74: for standard construction hours
- Table 5-75: for works outside standard construction hours.

The number of receiver buildings predicted to exceed NMLs during each stage and time period are summarised in Table 5-76. Predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-74 – Predicted construction noise levels during standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Flat Rock Drive construction support site (BL2)

NCA	Noise management level		Predicted noise level at each construction stage [1, 2]								
	HNA	NML	FRD_01	FRD_02	FRD_03	FRD_04	FRD_05	FRD_06	FRD_07	FRD_08	FRD_09
24.1	75	66	≤ 46	≤ 43	≤ 45	< 35	≤ 38	< 35	< 35	< 35	≤ 35
28.1	75	57	≤ 55	≤ 51	≤ 50	≤ 44	≤ 49	≤ 41	≤ 35	< 35	≤ 44
30.1	75	68	≤ 48	≤ 44	≤ 47	≤ 37	≤ 41	< 35	< 35	< 35	≤ 37
30.2	75	68	≤ 50	≤ 47	≤ 52	≤ 38	≤ 42	< 35	< 35	< 35	≤ 39
30.3	75	68	35 - 53	≤ 49	≤ 51	≤ 40	≤ 47	≤ 37	< 35	< 35	≤ 42
30.4	75	68	≤ 44	≤ 39	≤ 45	< 35	< 35	< 35	< 35	< 35	< 35
31.1	75	66	36 - 66	≤ 66	≤ 64	≤ 55	≤ 63	≤ 52	≤ 45	≤ 44	≤ 57
31.2	75	66	36 - 56	≤ 52	≤ 53	≤ 44	≤ 50	≤ 41	≤ 36	≤ 35	≤ 45
31.3	75	66	36 - 64	≤ 63	≤ 64	≤ 53	≤ 59	≤ 51	≤ 44	≤ 40	≤ 53
32.1	75	69	≤ 52	≤ 49	≤ 54	≤ 39	≤ 43	≤ 36	< 35	< 35	≤ 41
33.1	75	65	≤ 46	≤ 41	≤ 45	< 35	< 35	< 35	< 35	< 35	< 35
36.1	75	60	≤ **76**	≤ 65	≤ 65	≤ 49	≤ 55	≤ 47	≤ 46	≤ 38	≤ 56
37.1	75	55	54 - 74	49 - **76**	50 - **80**	38 - 65	41 - 70	≤ 63	≤ 54	≤ 50	42 - 67
38.1	75	62	44 - 75	40 - **76**	42 - 72	≤ 65	≤ 71	≤ 61	≤ 59	≤ 58	≤ 67
38.2	75	62	37 - 54	≤ 50	≤ 52	≤ 41	≤ 43	≤ 36	< 35	< 35	≤ 43
38.3	75	62	≤ 54	≤ 51	≤ 50	≤ 43	≤ 45	≤ 38	< 35	< 35	≤ 44

Notes:
1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is < 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))
2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-75 – Predicted construction noise levels outside standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Flat Rock Drive construction support site (BL2)

NCA	Noise Management Level				Predicted noise levels at each construction stage[3]								
	HNA	Day (O)	Eve	Night	FRD_01[1]	FRD_02[1]	FRD_03	FRD_04[1]	FRD_05[1]	FRD_06[1]	FRD_07	FRD_08	FRD_09[1]
24.1	75	61	57	42	-	-	< 35	-	-	-	< 35	< 35	-
28.1	75	52	50	42	-	-	≤ 43	-	-	-	< 35	< 35	-
30.1	75	63	61	43	-	-	≤ 36	-	-	-	< 35	< 35	-
30.2	75	63	61	43	-	-	≤ 41	-	-	-	< 35	< 35	-
30.3	75	63	61	43	-	-	≤ 42	-	-	-	< 35	< 35	-
30.4	75	63	61	43	-	-	< 35	-	-	-	< 35	< 35	-
31.1	75	61	54	42	-	-	≤ 59	-	-	-	< 35	< 35	-
31.2	75	61	54	42	-	-	≤ 44	-	-	-	< 35	< 35	-
31.3	75	61	54	42	-	-	≤ 56	-	-	-	< 35	< 35	-
32.1	75	64	60	45	-	-	≤ 43	-	-	-	< 35	< 35	-
33.1	75	60	58	45	-	-	< 35	-	-	-	< 35	< 35	-
36.1	75	55	53	43	-	-	≤ 59	-	-	-	< 35	< 35	-
37.1	75	50	49	39	-	-	42 - **80**	-	-	-	≤ 38	< 35	-
38.1	75	57	53	42	-	-	≤ 64	-	-	-	≤ 42	≤ 37	-
38.2	75	57	53	42	-	-	≤ 44	-	-	-	< 35	< 35	-
38.3	75	57	53	42	-	-	≤ 45	-	-	-	< 35	< 35	-

Notes:
1. No typical work is proposed outside standard construction hours
2. Construction noise level cells are shaded based on the 'Near' level: Green is < 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML. Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))
3. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-76 – Number of receiver buildings over the noise management level (all NCAs) – residential receivers – Flat Rock Drive construction support site (BL2)

Modelled representative activity	Assessment reference	Highly noise affected > 75 dB(A) L_{Aeq}		Day (standard hours) L_{Aeq}			Day (outside standard hours) L_{Aeq}				Evening L_{Aeq}				Night L_{Aeq}				Sleep disturbance L_{Amax}	
		Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening	Awakening
Early works	FRD_01[1]	1	-	143	31	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Establish site	FRD_02[1]	2	-	108	25	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Road widening	FRD_03	1	1	118	27	1	98	33	3	1	103	69	4	1	305	309	79	5	555	26
Piling for access decline and shed	FRD_04[1]	0	-	23	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surface level access decline construction	FRD_05[1]	0	-	57	8	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acoustic shed construction	FRD_06[1]	0	-	15	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunnelling	FRD_07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143	0
Tunnel fitout	FRD_08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143	0
Site rehabilitation	FRD_09[1]	0	-	28	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes: 1. No typical work is proposed outside standard construction hours

2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period in accordance with the key presented in Table 5-73

5.5.2.4 Residential – summary of airborne noise assessment

Standard construction hours

The highest predicted levels would occur during early works (FRD_01), site establishment (FRD_02), road works (FRD_03) and access decline excavation and construction (FRD_05) works:

- Up to 174 receiver buildings in NCAs 36.1, 37.1 and 38.1 are predicted to be noise affected (ie >NML) during early works (FRD_01). This would be caused by utility relocations using a vacuum truck and excavator with rock hammer. Up to one receiver in NCA 36.1 is expected to be highly noise affected (ie >75 dB(A)) during the early works stage
- Up to 134 receiver buildings in NCAs 36.1, 37.1 and 38.1 are predicted to be noise affected (ie >NML) during site establishment (FRD_02) works. The highest number of noise affected receivers during standard hours are from vegetation clearing and onsite intersection modification works. Up to one receiver in each of NCA 37.1 and NCA 38.1 (two receivers in total) is expected to be highly noise affected during the site establishment stage
- Up to 146 receiver buildings in NCAs 37.1 and 38.1 are predicted to be noise affected (ie >NML) during road widening works (FRD_03). This would be caused by road widening and offsite intersection modification works using road saw and an excavator with a rock hammer. Moreover, up to one receiver in NCA 38.1 is expected to be highly noise affected during the road widening works
- Up to 65 receiver buildings in NCAs 37.1 and 38.1 are predicted to be noise affected (ie >NML) during access decline excavation and construction (FRD_05) works. This would be caused by excavation works using an excavator with a rock hammer.

During other stages noise impacts would be less, with up to 67 noise affected receiver buildings. No receivers during these stages are expected to be highly noise affected (ie >75 dB(A)).

Work outside standard construction hours

Due to road operation, worker safety, and 24 hour tunnelling requirements, some works are likely to be completed outside standard construction hours as presented in Table 5-87.

The bulk of the road widening works (FRD_03) would take place during standard construction hours, outside of peak traffic periods. However, some of the road widening, such as setting up traffic management and road tie-in works, would be required to take place outside standard construction hours.

At the Flat Rock Drive construction support site (BL2), the key stages requiring OOHW are during:

- Road widening (FRD_03)
- Tunnelling (FRD_07)
- Tunnel fitout FRD_08.

During road widening works at night (FRD_03) up to 305 residential receiver buildings are predicted to be noise affected (ie >NML) by 1-5 dB(A), 309 residential receiver buildings are predicted to be noise affected by 6-15 dB(A), 79 residential receiver buildings by more than 15 dB(A) and five residential receiver buildings are predicted to be noise affected by more than 25 dB(A). This is from intersection modification and road works, which are relatively short-term works. The high noise impacts occur when noise intensive activities such as using road saws occur. The works would likely be carried out under a road occupancy licence, which would likely require that works take place outside standard hours to minimise disruption to the road network and protect the safety of road users and workers.

During longer term tunnelling and tunnel fitout night works (FRD_07 and FRD_08) no residential receivers are predicted to be noise affected, during OOHW.

The predicted noise levels are based on all plant operating concurrently during each assessed activity. However, in practice not all plant would typically operate all the time, meaning that for a substantial part of the time actual noise levels would be less than the predicted noise levels.

Sleep disturbance

At the Flat Rock Drive construction support site (BL2), the key OOHW stages that potentially include activities with maximum noise levels (L_{Amax}) are:

- Road widening (FRD_03)
- Tunnelling (FRD_07)
- Tunnel fitout (FRD_08).

Night time road widening (FRD_03) works would be short-term works under a road occupancy licence, required to minimise disruption to the road network and protect the safety of workers and road users. During this work, up to 555 receiver buildings are predicted to potentially be exposed to maximum noise levels above the sleep disturbance screening level (up to L_{Amax} 74 dB(A)). Of those, 26 receiver buildings could potentially experience noise levels above the awakening reaction level.

During night time tunnelling (FRD_07) works, concrete delivery trucks occasionally accessing the site could result in high instantaneous noise impacts during arrival or departure, this is similar for delivery trucks associated with night time tunnel fitout (FRD_08) works. In both cases, up to 143 receiver buildings are predicted to potentially be exposed to maximum noise levels above the sleep disturbance screening level (up to L_{Amax} 65 dB(A)); however, no receiver is predicted to be exposed to maximum noise levels above the awakening reaction level.

Only up to five concrete trucks are expected outside standard construction hours to provide shotcrete for ground support work during tunnelling (FRD_07) works. While predicted $L_{Amax)}$ noise levels are greater than the screening levels, substantial sleep disturbance impacts are not likely to occur from up to five heavy vehicles a night since the number of night heavy vehicle movements generated by the site is not substantial compared to existing traffic numbers on Flat Rock Drive. This would be similar for night time tunnel fitout (FRD_08) deliveries.

5.5.2.5 Non-residential

The predicted noise levels for non-residential receivers are presented in Table 5-77. The number of receiver buildings predicted to exceed the noise management levels are summarised in Table 5-78. The predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-77 – Predicted noise levels at other sensitive receiver locations – $L_{Aeq(15\ minute)}$, dB(A) – Flat Rock Drive construction support site (BL2)

Receiver type	NCA	NML	Predicted noise levels at each construction stage[1, 2]								
			FRD_01	FRD_02	FRD_03	FRD_04	FRD_05	FRD_06	FRD_07	FRD_08	FRD_09
Commercial	36.1	70	38 - 85	≤ 72	≤ 74	≤ 54	≤ 59	≤ 54	≤ 52	≤ 40	≤ 61
Childcare	30.2	50	44 - 50	40 - 46	44 - 51	≤ 37	≤ 42	< 35	< 35	< 35	≤ 38
	32.1	50	38 - 41	≤ 36	≤ 40	< 35	< 35	< 35	< 35	< 35	< 35
	33.2	50	≤ 40	≤ 35	≤ 40	< 35	< 35	< 35	< 35	< 35	< 35
	36.1	50	51 - 57	46 - 52	46 - 54	38 - 43	42 - 45	≤ 41	< 35	< 35	39 - 45
Educational	30.1	55	≤ 45	≤ 41	≤ 45	< 35	≤ 35	< 35	< 35	< 35	< 35
	30.2	55	≤ 46	≤ 41	≤ 45	< 35	≤ 35	< 35	< 35	< 35	< 35
	31.2	55	38 - 53	≤ 50	≤ 52	≤ 41	≤ 47	≤ 37	< 35	< 35	≤ 42
	31.3	55	38 - 46	≤ 42	≤ 46	< 35	≤ 36	< 35	< 35	< 35	< 35
	38.1	55	45 - 48	40 - 44	43 - 47	≤ 37	≤ 38	< 35	< 35	< 35	≤ 36
Other sensitive receiver	32.1	60	≤ 48	≤ 44	≤ 47	≤ 36	≤ 39	< 35	< 35	< 35	≤ 37
Place of worship	28.1	55	≤ 47	≤ 43	≤ 46	≤ 35	≤ 39	< 35	< 35	< 35	≤ 36
	30.1	55	40 - 45	36 - 42	37 - 45	< 35	≤ 37	< 35	< 35	< 35	< 35
	30.2	55	49 - 50	45 - 46	50 - 52	≤ 37	39 - 41	< 35	< 35	< 35	38 - 39
	36.1	55	≤ 54	≤ 49	≤ 54	≤ 40	≤ 44	≤ 37	< 35	< 35	≤ 42
	38.1	55	45 - 48	41 - 43	44 - 45	≤ 37	35 - 38	< 35	< 35	< 35	≤ 36
Recreational	31.1	60	≤ 62	≤ 61	≤ 57	≤ 52	≤ 59	≤ 47	≤ 44	≤ 43	≤ 52
	36.1	65	55 - 72	53 - 70	57 - 76	43 - 58	48 - 61	40 - 57	36 - 51	≤ 40	45 - 61
	38.2	60	46 - 58	41 - 56	43 - 61	≤ 44	≤ 48	≤ 41	≤ 38	< 35	≤ 49

Notes: 1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is < 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML

2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-78 – Number of other sensitive receivers over the noise management levels (all NCAs) – Flat Rock Drive construction support site (BL2)

Modelled representative activity	Assessment reference	Commercial1			Childcare			Educational			Places of worship			Other sensitive receivers[1]			Recreational[1]		
		1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
Early works	FRD_01	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Establish site	FRD_02	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Road widening	FRD_03	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3	1	0
Piling for access decline and shed	FRD_04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface level access decline construction	FRD_05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acoustic shed construction	FRD_06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tunnelling	FRD_07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tunnel fitout	FRD_08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site rehabilitation	FRD_09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table.

With the feasible and reasonable noise treatment and management measures are applied, up to one commercial receiver in NCA 36.1 is predicted to be noise affected (ie >NML) by up to 10 dB(A) during road works (FRD_02) and acoustic shed and surface level tunnel access construction (FRD_03); and by up to 20 dB(A) during site establishment works (FRD_01).

Up to two childcare receivers (Tree of Life Early Learning School - Willoughby and Koala Cottage) within NCA 36.1 and one (CatholicCare Naremburn Family Centre) in NCA 30.2 are predicted to be noise affected (ie >NML). However, only the childcare centre at 2 Artarmon Road, Willoughby (Tree of Life Early Learning School – Willoughby) has predicted levels up to 7 dB(A) above the NML during site establishment (FRD_01), road works (FRD_02) and acoustic shed and surface level tunnel access construction (FRD_03) while all other locations are only predicted to be 1 dB(A) above the NML.

Within NCA 31.1, NCA 36.1 and NCA 38.2 there are up to five recreational receivers that are predicted to be noise affected (ie >NML) by up to 10 dB(A) by works in site establishment (FRD_01), road works (FRD_02) and acoustic shed and surface level tunnel access construction (FRD_03) and one recreational receiver is predicted to be noise affected (ie >NML) by up to 20 dB(A) by acoustic shed and surface level tunnel access construction (FRD_03).

5.5.2.6 Cumulative construction noise impacts

As outlined in Section 4.2.4, the potential for cumulative noise impacts from other nearby major construction projects would be considered when assessing the site and determining feasible and reasonable mitigation and management measures.

Proposed staging of concurrent construction works associated with the project and other nearby major infrastructure projects that are considered for cumulative construction impacts are presented in Table 5-79, based upon information presented in the environmental impact statement documentation for the other projects. As the timing of the Warringah Freeway Upgrade project overlaps with the Beaches Link and Gore Hill Freeway Connection project, there is the potential that sensitive receivers may experience noise from both projects over extended durations.

Table 5-79 – Concurrent construction works near the Flat Rock Drive construction support site (BL2)

Project	2021	2022	2023	2024	2025	2026	2027
Flat Rock Drive (BL2/FRD) construction support site			■	■	■	■	■
Gore Hill Freeway Connection surface road works (GHC)			■	■	■	■	■
Other major projects							
Warringah Freeway Upgrade (WFU)[1]	■	■	■	■	■		

Notes: 1. Refer to Western Harbour Tunnel and Warringah Freeway Upgrade Environmental Impact Statement (Transport for NSW, 2020).

Proposed staging of concurrent work has been reviewed for the closest receivers to the site. The loudest stages for both standard construction hours and out of hours works have been used to calculate potential cumulative noise impacts.

If noise from one site dominates noise levels at the receiver (ie > 5-10 dB(A) above noise from other sites), that site would typically control construction noise levels at the receiver. As such, it is not likely to increase the overall $L_{Aeq,\ 15\ minute}$ construction noise level at these receivers.

If noise levels from each site are similar at a receiver, a total construction noise increase of up to 3 dB(A) is expected. Two representative NCAs adjacent to the works have been assessed in Table 5-80.

Table 5-80 – Potential cumulative noise impacts from construction projects near the Flat Rock Drive construction support site (BL2)

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 36.1	Standard hours NML= 60 dB(A	BL2/FRD	Surface level access decline construction	55	Flat Rock Drive construction support site (BL2) would generally dominate over other construction works at nearby receivers.
		GHC	Utilities modification works	46	In the case that all projects are noise intensive concurrently, there is potential for cumulative increases. The noise levels due to the construction support site and the surface road works are below the NML.
		WFU[1]	Utilities modification works	49	Cumulative construction noise levels would likely remain below the NML at nearby receivers.
	OOHW NML D/E/N 55/53/43	BL2/FRD	Tunnelling	35	There is potential for construction noise levels from the Gore Hill Freeway connection surface road works to dominate at some receivers during noise intensive works with noise levels above the NML. During other periods, when concurrent works occur, there is potential for cumulative increases.
		GHC	Utilities modification works	49	
		WFU[1]	Demolition works	49	Warringah Freeway Upgrade (as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project) construction noise could also impact receivers in the same noise catchment.
NCA 37.1	Standard hours NML= 55 dB(A)	BL2/FRD	Surface level access decline construction	70	During surface level access decline construction works the Flat Rock Drive construction support site (BL2) would likely dominate construction noise levels at nearby receivers. Negligible cumulative increases from other projects is likely, also noting that other project construction impacts are below NML.
		GHC	Utilities modification works	46	
		WFU[1]	Utilities relocation	49	
	OOHW NML D/E/N 50/49/39	BL2/FRD	Tunnelling	38	There is potential for construction noise levels from the Gore Hill Freeway connection surface road works to dominate at some receivers during noise intensive works with noise levels above the NML. During other periods, when concurrent works occur, there is potential for cumulative increases.
		GHC	Utilities relocation	49	
		WFU[1]	Demolition works	49	Warringah Freeway Upgrade (as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project) construction noise could also impact receivers in the same noise catchment.

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 38.1	Standard hours NML= 62 dB(A)	BL2/FRD	Surface level access decline construction	71	During surface level access decline construction works the Flat Rock Drive construction support site (BL2) would likely dominate construction noise levels at nearby receivers. Negligible cumulative increases from other projects is likely, also noting that other project construction impacts are below NML
		GHC	Cut and cover	50	
		WFU[1]	Demolition	50	
	OOHW NML D/E/N 57/53/42	BL2/FRD	Tunnelling	42	There is potential for construction noise levels from the Gore Hill Freeway connection surface road works to dominate at some receivers during noise intensive works with noise levels above the NML. During other periods, when concurrent works occur, there is potential for cumulative increases. Warringah Freeway Upgrade (as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project) construction noise could also impact receivers in the same noise catchment.
		GHC	Utilities relocation	50	
		WFU[1]	Utilities relocation	50	

Notes 1. Refer to Western Harbour Tunnel and Warringah Freeway Upgrade Environmental Impact Statement (Transport for NSW, 2020).

At receivers not directly adjacent to the Flat Rock Drive construction support site (BL2), there is potential for cumulative increases of construction noise from concurrent works with the Gore Hill Freeway Connection surface road works and Warringah Freeway Upgrade.

At some receiver locations, when an individual site does not dominate construction noise levels at the receiver (ie it does not contribute more than 5 dB(A) more noise than other sites), cumulative construction noise levels could be up to 3 dB(A) higher than the noise levels predicted for any one activity.

Any increase due to cumulative noise is unlikely as noise generating activities would need to occur simultaneously. However, even where a cumulative construction noise increase is predicted, the total construction noise level at that receiver is predicted to be below the NML.

Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5.

5.5.3 Construction related road traffic noise assessment

Vehicle access to the Flat Rock Drive construction support site (BL2) would be to and from the Warringah Freeway via Flat Rock Drive and Brook Street. Construction traffic would access the site directly from Flat Rock Drive.

Table 5-81 presents the forecast number of vehicles accessing the construction support site during the peak construction periods at this site. Up to 24 trucks would access the site per hour during the daytime period (7.00am to 10.00pm) and a maximum of one truck per hour (no more than 5 trucks in total) in the night time period (10.00pm to 7.00am) which would typically be concrete deliveries to support tunnelling.

Table 5-81 – Number of construction vehicles accessing the Flat Rock Drive construction support site (BL2)

Type of vehicle	Per day[1] over 15 hours[3,4]	Per night[2] over nine hours[3]
Heavy vehicle (deliveries, spoil haulage and concrete deliveries)	268	5
Light vehicle	126	52

Notes:
1. Day is 7.00am to 10.00pm
2. Night is 10.00pm to 7.00am
3. Numbers presented are individual vehicles, not vehicle movements
4. Vehicle numbers have been distributed onto the local road network based upon the proposed access roads. Where a vehicle accesses the site by one road and leaves by another, one vehicle movement is counted along each road once. Where a vehicle accesses and leaves the site by the same road, two vehicle movements are counted on that road.

The number of movements generated by the site is not substantial compared to existing traffic numbers on the Warringah Freeway; therefore, this assessment considers traffic generated by the site on Flat Rock Drive and Brook Street.

This assessment is based on predicted non-project traffic volumes. Table 5-82 presents the predicted increase in road traffic noise from additional construction traffic.

Table 5-82 – Road traffic noise impacts from the Flat Rock Drive construction support site (BL2)

Construction vehicle access road	Road type	Time of day	Predicted road traffic noise increase, dB(A)[1, 2]	Exceedance of the RNP criteria	Exceedance of sleep disturbance screening level (night only)
Flat Rock Drive	Sub-arterial	Day $L_{Aeq(15hr)}$	0.5	No	N/A
		Night $L_{Aeq(9hr)}$	<0.5	No	Yes
Brook Street	Sub-arterial	Day $L_{Aeq(15hr)}$	0.5	No	N/A
		Night $L_{Aeq(9hr)}$	<0.5	No	Yes

Notes:
1. Predicted road traffic noise levels are based upon the loudest heavy vehicle
2. Predicted road traffic noise levels are based upon the nearest residential receiver to the road. Receivers at further distances are expected to experience lower noise levels than those predicted.

The predicted road traffic noise increase due to the Flat Rock Drive construction support site (BL2) is less than 2 dB(A) during day and night time periods. Therefore, predicted noise levels on those roads comply with the RNP criteria identified in Section 3.4.2.

Maximum noise levels (L_{Amax}) from night period heavy vehicle movements are predicted to exceed both the sleep disturbance screening level and the adopted awakening reaction level.

However, night time heavy vehicle movements from this site would be limited to one vehicle per hour, which is not a substantial number when compared to existing heavy vehicle movements on Flat Rock Drive and Brook Street. Nearby receivers are not likely to notice the increase in the number of maximum noise events caused by the additional truck movements generated by the site.

During further design development and construction planning, in order to ensure that traffic noise impacts are minimised, the construction traffic associated with the project should include the mitigation and management measures detailed in Section 6.7 where feasible and reasonable.

5.5.4 Ground-borne construction noise

Ground-borne noise could result from the construction of the tunnel access decline between the Flat Rock Drive construction support site (BL2) and the mainline and ramp tunnels. However, due to the terrain and the depth of the tunnel access decline and the resulting slant distance to nearby occupied receiver buildings, no receiver buildings (occupied buildings) are predicted to be affected by ground-borne noise from tunnel access decline construction above the strictest NML of 35 dB(A), as shown in Annexure J.3.

5.5.5 Construction vibration

The vibration generated from construction works would vary depending on the level and type of activity carried out. For the Flat Rock Drive construction support site (BL2), the major stages which may include vibration intensive works are:

- Early works (FRD_01)
- Establishment of construction facilities (FRD_02)
- Road works (FRD_03)
- Build access decline and acoustic shed (FRD_04 and FRD_05)
- Tunnelling (FRD_07).

Proposed vibration intensive plant items are identified in Annexure E. Minimum working distances for a range of construction plant items are presented in in Table 4-11. Presented in Annexure L are the estimated minimum working distances from the construction support site for both structural damage and adverse human response to vibration for the most vibration intensive activity proposed.

The most vibration intensive activity at this site is likely to be the use of rock hammers for utility relocation during early works (FRD_01), or for demolition during site establishment (FRD_02) works and the road works (FRE_03). Tunnel access decline construction during tunnelling (FRD_07) works may also cause vibration impacts, as the tunnel access decline passes under receiver buildings. However, tunnel access decline construction at the site would use roadheaders and is not expected to result in vibration impacts.

The number of receiver buildings within the minimum working distances for vibration generating activities is presented in Table 5-83. Potential vibration generated to receivers depends on the vibration source levels, separation distance, intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. This assessment considers a worst case scenario that the proposed vibration intensive plant items could be used anywhere within the boundaries of the site. However, this is unlikely to occur and the location of the vibration intensive equipment should be reviewed during detailed construction planning, as recommended in Section 6.8.

Table 5-83 – Number of structures within nominated minimum working distance for vibration impacts – Flat Rock Drive construction support site (BL2)

NCA	Number of structures within minimum working distances		
	Cosmetic damage		Human response
	Sound structure	Unsound structure	
Early works and site establishment			
36.1	1	-	3
37.1	1	1	4
38.1	-	-	4
Tunnelling (tunnel access decline)			
38.1	-	-	-

For the tunnel access decline construction, due to the tunnel depth there are no structures that are identified within the minimum working distances presented in Section 4.4.1 for roadheader tunnelling for either cosmetic damage or human response screening levels. As such, vibration impacts above the screening levels from the tunnel access decline construction works are unlikely, but should be reviewed during further design development and construction planning.

5.5.5.1 Cosmetic damage

Two buildings been identified within the minimum working distance for cosmetic damage, as presented in Table 5-83 and Annexure L.

5.5.5.2 Heritage listed structures

One identified heritage item is within the unsound structure cosmetic damage minimum working distances, shown in Annexure L and identified in Table 5-84. Refer to the Technical working paper: Aboriginal cultural heritage assessment report (Appendix L of the environmental impact statement) for the assessment of impacts to heritage items.

Table 5-84 – Heritage receivers within the cosmetic damage minimum working distance – Flat Rock Drive construction support site (BL2)

Place/item name	Register	Type/classification[1]	Listing number	NCA
Flat Rock Creek potential archaeological deposits	-	Potential archaeological deposits (Aboriginal)	-	37.1

Notes: 1. Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

Before starting work with the potential to impact on heritage items, all nearby heritage items would be reviewed, structural surveys carried out where required, and appropriately revised minimum working distances and vibration limits determined to prevent cosmetic damage to heritage items.

Vibration monitoring should be carried out to ensure vibration levels do not exceed appropriate limits.

5.5.5.3 Human response

Rock hammering would occur for limited duration only at this site; therefore, the risk of substantial annoyance is considered low. However, occupants of up to eleven properties may be exposed to vibration levels above the human response screening level (ie residents may feel vibration from rock hammering) during early works and site establishment works, as presented in Table 5-83.

The extent of mitigation and management required to limit potential impacts to receivers would be determined by not only the level of vibration, but also the duration that receivers are likely to be exposed to vibration above the human response screening level.

No receivers are predicted to be exposed to vibration from tunnel access decline construction above the human response screening level. Mainline and ramp tunnel construction vibration impacts are presented in Section 5.16

After applying feasible and reasonable vibration mitigation measures, if vibration monitoring still identifies that measured vibration levels exceed the human response screening level, appropriate additional mitigation measures should be provided (see Section 6.10.3).

5.6 Punch Street construction support site (BL3)

This section assesses the potential construction noise and vibration impacts, and the reasonable and feasible treatment measures that would be considered to control impacts on noise and vibration sensitive receivers near the Punch Street construction support site (BL3).

5.6.1 Construction support site overview

5.6.1.1 Construction support site description

The site is located on Punch Street, Artarmon. It is bounded by the Gore Hill Freeway to the north and the North Shore Railway to the east. The site would be within the Artarmon industrial area. Works at the site are proposed to occur in stages as presented in Table 5-85.

Table 5-85 – Punch Street construction support site (BL3) – major stage activities overview

Stage	Representative activity	Major stage activities/description
Site establishment	1. Early works	Public utility adjustments and relocations Supply of utilities to construction facilities
	2. Establish the site	Installation of environmental controls Road and intersection modifications and installation of traffic controls Vegetation clearing Establishment of construction support sites Traffic management measures (including line marking and signage) Demolition of existing structures
Acoustic shed and surface level access decline construction	3. Surface level access decline excavation and acoustic shed construction	Pile access decline walls and shed footings at surface level Surface level excavation of access decline Acoustic shed construction
Tunnel construction (access decline and mainline and ramp tunnels)	4. Tunnelling	Tunnel spoil handling and haulage, tunnel support, tunnel lining and associated deliveries
Tunnel fitout	5. Tunnel fitout	Install mechanical and utilities services to the tunnel
Construction of operational facilities	6. Build operational motorway facilities	Build operational motorway facilities, including wastewater treatment plant
Tunnel commission and site rehabilitation	7. Site rehabilitation	Commission tunnel, decommission site and site rehabilitation

Following site establishment and the construction of a direct access road onto the Gore Hill Freeway, construction heavy vehicles would use this as the site departure route. The egress road onto the Gore Hill Freeway would be modified part way through the construction in order to allow for staging of the construction of the cut and cover structure at the tunnel portal. As this access road would not be used by the public, is has been included in the assessment of the construction support site noise emissions.

As part of the major activities presented above, the Punch Street construction support site (BL3) would also support up to four roadheaders constructing the mainline and ramp tunnels operating as follows:

- Two roadheaders excavating the ramp tunnels, from the Gore Hill Freeway Connection at Artarmon to Northbridge
- One roadheader excavating cross passages.

The construction of the mainline and ramp tunnels are assessed in Section 5.16.

5.6.1.2 Construction works program

An approximate timeframe for the operation of the site is presented in Table 5-86, subject to project approval. This site is planned to operate from the start of 2023 until late 2026. The longest duration activities at this construction support site would be building the operational motorway facilities and restoring the site.

Table 5-86 – Punch Street construction support site (BL3) – indicative program and timeline

Stage	Representative activity		Reference	Indicative construction timeframe																			
				2022				2023				2024				2025				2026				2027			
				1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Site establishment	1.	Early works	PUN_01																								
	2.	Establish the site	PUN_02																								
Acoustic shed and surface level tunnel access decline construction	3.	Surface level access decline excavation and acoustic shed construction	PUN_03																								
Tunnel construction (access decline and mainline and ramp tunnels)	4.	Tunnelling	PUN_04																								
Tunnel fitout	5.	Tunnel fitout	PUN_05																								
Construction of operational facilities	6.	Build operational motorway facilities	PUN_07																								
Tunnel commission and site rehabilitation	7.	Site rehabilitation	PUN_06																								

5.6.1.3 Nearby noise and vibration sensitive receivers

The site is located on Punch Street, Artarmon. It is mostly surrounded by industrial receivers to the south and west and residential receivers to the north (Artarmon) and east (Naremburn).

The location of the site, tunnel alignment, nearby NCAs and receiver locations are shown in Figure 5-12.

Figure 5-12 – Location of Punch Street construction support site (BL3)



5.6.1.4 Construction duration and working hours

Table 5-87 presents each of the major stages that have been assessed along with the representative activities that would take place during the stage for the Punch Street construction support site (BL3), along with the proposed time periods for each activity. During operation of the Punch Street construction support site (BL3), work would typically take place during the standard construction hours as presented in Table 3-2 (Section 3). However, some works would take place outside standard hours, as presented in Table 5-87.

Table 5-87 – Punch Street construction support site (BL3) – construction hours

Stage	Representative activity		Reference	Assessed activities[1]	Work hours[2]			
					Day (Standard)	Day (OOHW)	Evening	Night
Site establishment	1.	Early works	PUN_01	Utility works	♦			
	2.	Establish site	PUN_02	Install environmental controls	♦			
				Road and intersection modifications	♦			
				Demolition	♦			
				Clearing and grubbing	♦			
				Bulk earthwork	♦			
				Establish construction facilities	♦			
Acoustic shed and surface level tunnel access decline construction	3.	Surface level access decline excavation and acoustic shed construction	PUN_03	Piling for access decline and shed	♦			
				Access decline excavation	♦			
				Acoustic shed construction	♦			
Tunnel construction (access decline and mainline and ramp tunnels)	4.	Tunnelling	PUN_04	General site activities[4]	♦	♦	♦	♦
				Deliveries	♦			
				Tunnelling and support[4]	♦	♦	♦	♦
				Tunnel lining (concreting) deliveries[4]	♦	♦	♦	♦
				Spoil handling in an acoustic shed	♦	♦[3]	♦[3]	♦[3]
				Spoil haulage	♦			
Tunnel fitout	5.	Tunnel fitout	PUN_05	Deliveries[4]	♦	♦	♦	♦
				Laydown areas	♦			
Construction of operational facilities	6.	Build operational motorway facilities	PUN_06	Motorway facility structure construction	♦			
Tunnel commission and site rehabilitation	7.	Site rehabilitation	PUN_07	Decommission and site rehabilitation	♦			

Notes:
1. Annexure E describes the modelled plant for each activity
2. Day Standard is 7.00am to 6.00pm Monday to Friday and 8.00am to 1.00pm Saturday
   Day out of hours work is 1.00pm to 6.00pm Saturday and 8.00am to 6.00pm Sunday/Public holiday
   Evening is 6.00pm to 10.00pm Monday to Friday and 6.00pm to 10.00pm Saturday/Sunday/Public holiday
   Night is 10.00pm to 7.00am Monday to Friday and 10.00pm to 8.00am Saturday/ Sunday/Public holiday
3. Spoil haulage off the construction support site would occur during standard construction hours. OOHW spoil handling would occur inside acoustic shed
4. Activities typically within acoustic shed during OOHW periods.

5.6.1.5 Concurrent construction projects

The nearest construction support site associated with the project to Punch Street construction support site (BL3) would be the Gore Hill Freeway Connection surface road works, immediately adjacent to this site, and the Flat Rock Drive construction support site (BL2), Northbridge, about one kilometre east of this site.

The nearest construction support sites associated with other major infrastructure projects would be:

- Warringah Freeway Upgrade, about 900 metres southeast of this site
- Western Harbour Tunnel Waltham Street construction support site, about 300 metres west of the site.

However, it should be noted a construction site at Artarmon for the Sydney Metro City & Southwest project, including construction of a substation, on the south side of Gore Hill Freeway on Reserve Road, Artarmon, 650 metres west of the Punch Street construction support site (BL3) is expected to have been completed six months prior to works associated with the Beaches Link project.

5.6.1.6 Construction assessment scenarios

The airborne noise assessment of the Punch Street construction support site (BL3) was separated into seven stages. Each stage was assessed against the works periods presented in Table 5-87.

The equipment/plant listed in Annexure E represents the reasonable worst case equipment/plant assumed to be operating simultaneously in any 15 minute period (refer to Section 4.2.2 for further explanation of assessment scenarios). Multiple activities would at times occur concurrently within the one construction support site and were captured in the assessment as shown in Table 5-87.

5.6.1.7 Summary of assumed noise treatment and management measures

As part of the assessment process, feasible and reasonable noise treatment measures and management methods have been identified based on the preliminary site layout and the reasonable worst case plant/equipment operating, to assist in attenuating and managing noise emissions from the construction activities.

Identified feasible and reasonable noise treatment measures have been included in the noise model and are presented in Table 5-88. The results presented in this assessment are based on these noise treatments and management measures being implemented. The locations of physical noise treatment measures are shown on Figure 5-13.

Further design development and construction planning refinements to the construction support site layouts, equipment, construction methods or construction hours may require specific mitigation and management measures that are different from those outlined in this section. Final details for noise treatments and management measures will be confirmed during further design development and construction planning to determine what is feasible and reasonable, with consideration of cumulative construction impacts.

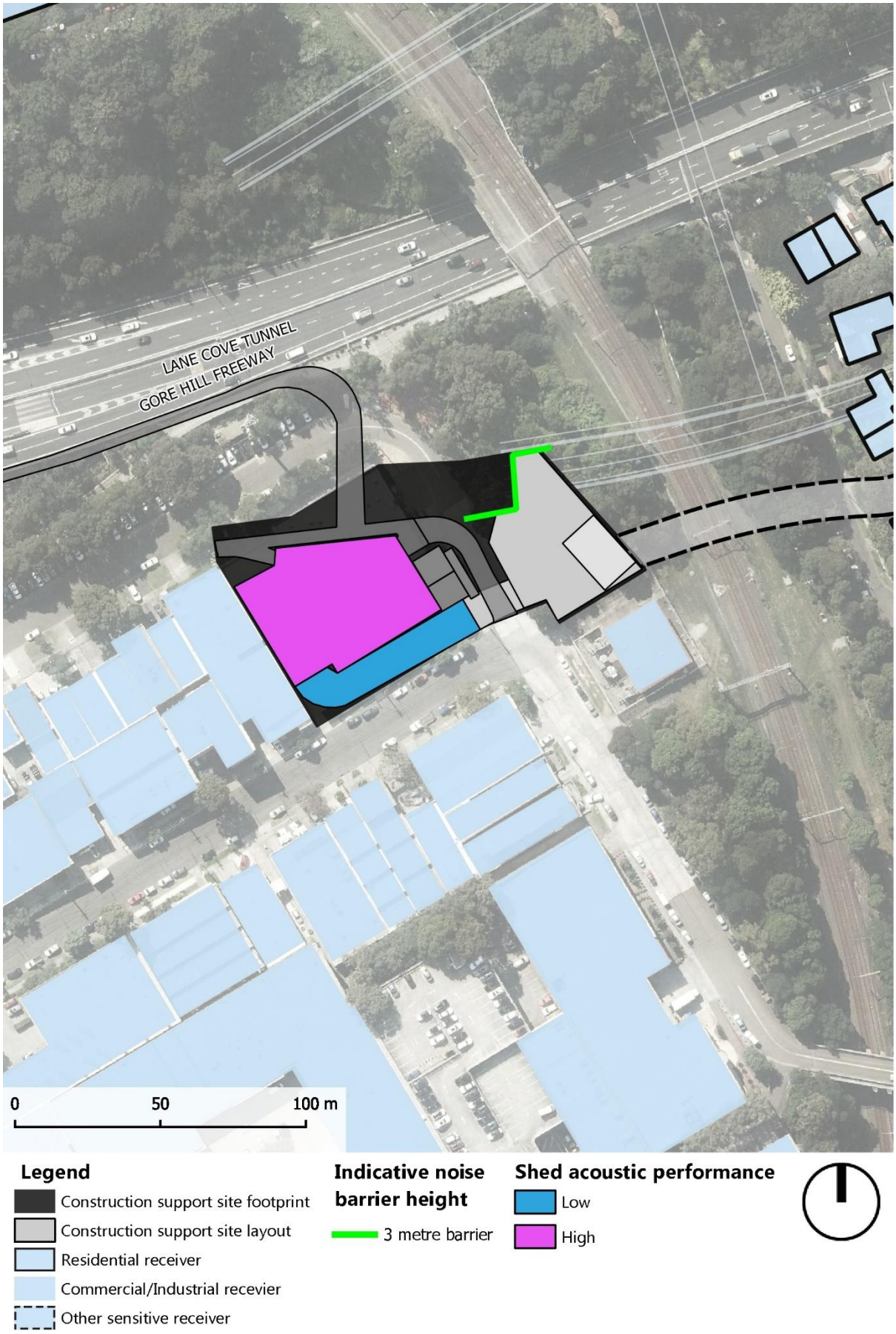
Table 5-88 – Assumed noise treatment and management measures – Punch Street construction support site (BL3)

Activity or plant/equipment	Management and treatment measures applied
Work outside standard hours	Work would only occur outside standard hours where it: • Meets the relevant NMLs • Occurs in an acoustic enclosure • Is required for safety reasons • Needs to occur outside standard hours to maintain the operational integrity of the road network. The following indicative noise barriers would be installed around the site to manage noise outside standard hours: • A three metre high barrier along the northern boundary of the storage and laydown area on the eastern side of the construction support site.
Tunnelling, support and fitout: Acoustic shed	An acoustic shed would be built to reduce noise from tunnelling, support and fitout works outside standard hours. Indicative elements and performance requirements are in Table 5-89. Outside standard hours, noise generating activities associated with laydown and deliveries outside the shed would be limited to quieter activities in order to achieve the NML. Or would take place within the acoustic shed. Additionally, other noise intensive works (ie. workshop related activities) will be conducted within the acoustic shed when outside standard construction hours.
Access decline cover	The access decline would be covered to reduce noise from spoil handling outside standard hours. Indicative elements and performance requirements are in Table 5-89.
Wastewater treatment plant	The wastewater treatment plant would achieve a total sound power level of 93 dB(A), which may require acoustic treatment or the use of an acoustic enclosure.
Substation	The substation is to achieve a total sound power level of 90 dB(A), which may require acoustic treatment or the use of an acoustic enclosure.
Ventilation plant	Plant items would be selected or acoustically treated to achieve a maximum combined sound power level of 90 dB(A). Three ventilation plants were assumed in the model.

Table 5-89 – Indicative acoustic shed construction and acoustic performance – Punch Street construction support site (BL3)

Shed / access decline element (Indicative example constructions are shown in Table 4-1)	Octave band frequency transmission loss, dB						
	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Acoustic shed (high performance)							
Walls – High performance	10	29	35	42	46	51	57
Roof – High performance	10	29	35	42	46	51	57
Access decline cover (low performance)							
Walls – Low performance	9	12	16	21	27	34	40
Roof – Low performance	9	12	16	21	27	34	40

Figure 5-13 – Punch Street construction support site (BL3) layout with acoustic treatment measures



5.6.2 Construction airborne noise

The methodology used for assessing airborne noise impacts from construction support sites is outlined in Section 4.2.2.

5.6.2.1 Nearby receiver summary and objectives

Table 5-90 presents NMLs and screening levels for assessing sleep disturbance for the nearest residential receivers surrounding the Punch Street construction support site (BL3). For all other NMLs refer to Annexure B.1. Noise management levels for other (non-residential) noise sensitive receivers are presented in Section 3.4.1. The locations of the NCAs surrounding the construction support site are shown in Figure 5-12.

Table 5-90 – Construction noise management levels and screening levels for residential receivers

NCA ID	Noise management level (NML) $L_{Aeq(15\ minute)}$				Sleep disturbance screening levels
	Standard Hours (RBL+10dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL+5dB)			L_{Amax} (RBL + 15dB)
	Day	Day	Evening	Night	Night
32.1	69	64	60	45	55
33.1	65	60	58	45	55
33.2	65	60	58	45	55
34.1	54	49	49	42	52
36.1	60	55	53	43	53

5.6.2.2 Predicted noise impacts

Table 5-91 provides a key to the cell shading and text formatting used to explain the results in the following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-91 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes: 1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless there are no receivers of that type in that NCA are expected to exceed NMLs.

The range presented is of noise levels for all receivers throughout the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented. The noise predictions include adjustments for annoying noise characteristics in accordance with the ICNG.

Noise contours for the loudest early works, site establishment, and longer term tunnelling stages are shown in Annexure H.1. Maps presenting the predicted exceedance for a sample of scenarios at the construction support site with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different assessment periods.

5.6.2.3 Residential

The predicted noise levels for residential receivers are presented in the following tables:

- Table 5-92 for standard hours
- Table 5-93 for works outside standard construction hours.

The number of receiver buildings predicted to exceed NMLs during each stage and time period are summarised in Table 5-94. Predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-92 – Predicted construction noise levels during standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Punch Street construction support site (BL3)

NCA	Noise Management Level		Predicted noise levels at each construction stage[1, 2]						
	HNA	NML	PUN_01	PUN_02	PUN_03	PUN_04	PUN_05	PUN_06	PUN_07
32.1	75	69	≤ 57	≤ 66	≤ 62	≤ 43	≤ 41	≤ 53	≤ 53
33.1	75	65	≤ 68	≤ 73	≤ 69	≤ 49	≤ 47	≤ 57	≤ 59
33.2	75	65	≤ 37	35 - 48	≤ 42	< 35	< 35	≤ 35	≤ 37
34.1	75	54	≤ 49	≤ 63	≤ 60	≤ 39	≤ 37	≤ 45	≤ 49
36.1	75	60	≤ 51	≤ 62	≤ 57	≤ 39	≤ 37	≤ 45	≤ 49

Notes:
1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))
2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-93 – Predicted construction noise levels outside standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Punch Street construction support site (BL3)

NCA	Noise Management Level				Predicted noise levels at each construction stage[3]						
	HNA	Day (O)	Eve	Night	PUN_01[1]	PUN_02[1]	PUN_03[1]	PUN_04	PUN_05	PUN_06[1]	PUN_07[1]
32.1	75	64	60	45	-	-	-	≤ 39	≤ 38	-	-
33.1	75	60	58	45	-	-	-	≤ 45	≤ 45	-	-
33.2	75	60	58	45	-	-	-	< 35	< 35	-	-
34.1	75	49	49	42	-	-	-	< 35	< 35	-	-
36.1	75	55	53	43	-	-	-	≤ 35	< 35	-	-

Note:
1. No typical work is proposed outside standard construction hours
2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML. Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))
3. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-94 – Number of receiver buildings over the noise management level (all NCAs) – residential receivers – Punch Street construction support site (BL3)

Modelled representative activity	Assessment reference	Highly noise affected > 75 dB(A) L_{Aeq}		Day (standard hours) L_{Aeq}			Day (outside standard hours) L_{Aeq}				Evening L_{Aeq}				Night L_{Aeq}				Sleep disturbance L_{Amax}	
		Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening	Awakening
Early works	PUN_01[1]	0	-	2	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Establish site	PUN_02[1]	0	-	97	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surface level access decline excavation and acoustic shed construction	PUN_03[1]	0	-	38	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunnelling	PUN_04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107	3
Tunnel fitout	PUN_05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107	3
Build operational motorway facilities	PUN_06[1]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site rehabilitation	PUN_07[1]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: 1. No typical work is proposed outside standard construction hours

2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period in accordance with the key presented in Table 5-91.

5.6.2.4 Residential – summary of airborne noise assessment

Standard construction hours

The highest predicted noise levels occur during site establishment (PUN_02) works. Up to 97 receiver buildings in NCAs 33.1, 34.1 and 36.1 are predicted to be noise affected (ie >NML) from site establishment (PUN_02), shed and access decline building (PUN_03) works during standard hours. The highest number of noise affected receivers during standard hours are due to the use of excavators with rock hammers to demolish existing buildings during site establishment. No receivers are predicted to be highly noise affected (ie >75 dB(A)) during the activities at the construction support site.

During other stages noise impacts would be less, with up to two noise affected residential receiver buildings. Once the access decline and acoustic shed are built, no receivers are predicted to be noise affected by work during standard hours.

Work outside standard construction hours

Due to 24 hour tunnelling requirements, some works are likely to occur outside standard construction hours, as presented in Table 5-87. At the Punch Street construction support site (BL3), the key stages requiring OOHW are:

- Tunnelling (PUN_04)
- Tunnel fitout (PUN_05).

During the OOHW longer term tunnel construction works (PUN_04) and tunnel fitout works (PUN_05) construction noise levels at nearby receivers are predicted to achieve NMLs.

The predicted noise levels are based on all plant operating concurrently during each assessment activity. However, in practice all plant would typically not operate all the time, so that for a substantial part of the time actual noise levels would likely be less than predicted noise levels.

Further analysis should be carried out once more specific detail regarding construction activity is available, as part of detailed construction planning, to confirm impacts outside standard hours and confirm feasible and reasonable mitigation measures.

Sleep disturbance

At the Punch Street construction support site, (BL3) the key OOHW stages which potentially include activities with maximum noise levels (L_{Amax}) are:

- Tunnelling (PUN_04)
- Tunnel fitout (PUN_05).

During longer term night time tunnel construction works (PUN_04) and tunnel fitout works (PUN_05), the following noise impacts are predicted:

- Occasional night time concrete or delivery trucks could result in high maximum noise levels on arrival or departure
- Up to 107 receiver buildings are predicted to exceed the sleep disturbance L_{Amax} screening level (up to 68 dB(A) L_{Amax}). Three receiver buildings could potentially experience noise levels above the awakening reaction level.

These noise impacts could occur if sources of high noise events (ie metal on metal bangs or air brake releases) from night period truck movements within the site are not managed. These noise sources would be mitigated and managed as outlined in Section 6.2 to minimise the chance of sleep disturbance impacts and remove the potential for exceedances of the sleep disturbance screening noise level. Additionally, potential for high noise events from night time truck movements to cause sleep disturbance impacts is unlikely considering the number of truck movements generated by the site, as they are is not substantial compared to existing traffic numbers on the Gore Hill Freeway.

5.6.2.5 Non-residential

Predicted noise levels for non-residential receivers are presented in Table 5-95. The number of receiver buildings predicted to exceed the NMLs are summarised in Table 5-96. The predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-95 – Predicted noise levels at other sensitive receivers – $L_{Aeq(15\ minute)}$, dB(A) – Punch Street construction support site (BL3)

Receiver type	NCA	NML	Predicted noise level at each construction stage[1, 2]						
			PUN_01	PUN_02	PUN_03	PUN_04	PUN_05	PUN_06	PUN_07
Commercial	33.2	70	41 - 98	57 - 88	50 - 87	38 - 66	36 - 65	42 - 76	45 - 82
Childcare	30.2	50	< 35	46 - 47	40 - 41	< 35	< 35	< 35	< 35
	32.1	50	< 35	≤ 43	38 - 38	< 35	< 35	< 35	< 35
	33.1	50	< 35	≤ 45	≤ 40	< 35	< 35	< 35	< 35
	33.2	50	39 - 43	43 - 66	40 - 52	≤ 40	≤ 39	≤ 47	≤ 47
	36.1	50	36 - 50	44 - 52	43 - 50	< 35	< 35	≤ 39	≤ 40
Educational	33.1	55	< 35	49 - 56	45 - 51	≤ 35	< 35	36 - 41	36 - 41
	33.2	55	< 35	46 - 52	44 - 46	< 35	< 35	≤ 38	≤ 36
Other sensitive receiver	33.2	55	≤ 38	≤ 49	≤ 47	< 35	< 35	≤ 38	< 35
Recreational	32.1	60	≤ 41	39 - 50	45 - 50	≤ 37	< 35	38 - 42	≤ 38
	33.1	60	40	≤ 55	53 - 54	≤ 38	≤ 35	≤ 43	≤ 39
	34.1	60	≤ 42	48 - 54	51 - 55	≤ 37	≤ 35	37 - 43	36 - 42
	36.1	60	38 - 42	42 - 46	41 - 46	< 35	< 35	< 35	< 35
Place of worship	33.1	55	< 35	≤ 47	≤ 41	< 35	< 35	< 35	< 35
	33.2	55	< 35	≤ 48	≤ 44	< 35	< 35	≤ 36	≤ 36

Notes:
1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML
2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-96 – Number of other sensitive receivers over the noise management levels (all NCAs) – Punch Street construction support site (BL3)

Modelled representative activity	Assessment reference	Commercial[1]			Childcare			Educational			Recreational[1]			Places of worship			Other sensitive receivers[1]		
		1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
Early works	PUN_01	6	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Establish site	PUN_02	8	4	0	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Surface level access decline excavation and acoustic shed construction	PUN_03	7	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tunnelling	PUN_04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tunnel fitout	PUN_05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Build operational motorway facilities	PUN_06	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site rehabilitation	PUN_07	4	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Notes: 1. Commercial, industrial, recreational active and passive, and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table.

After all feasible and reasonable noise treatment and management measures are applied, a number of other noise sensitive receivers are still predicted to be noise affected (ie >NML).

The greatest number of other noise sensitive receivers are predicted to be noise affected during site establishment (PUN_02) at the Punch Street construction support site (BL3). The other sensitive receivers identified as noise affected are:

- Up to six commercial receivers in NCA 33.2 which are predicted to be noise affected by up to 10 dB(A) above the NML, five commercial receivers in NCA 33.2 which are predicted to be noise affected by up to 20 dB(A) above the NML, and one commercial receiver in NCA 33.2 adjacent to the site at 5 Cleg Street, Artarmon, which is predicted to be noise affected more than 20 dB(A) above the NML which is located adjacent to the construction support site
- Two childcare receivers in NCA 33.2 (Creative Acorn Early Learning Centre and Butterflies Early Learning Childcare Centre) and one in NCA 36.1 (Tree of Life Early Learning School - Willoughby) where construction noise levels may be above the screening NML. For two of which the predicted construction level would only be marginally above the screening NML (up to 2 dB(A)), with one (Butterflies Early Learning Childcare Centre) predicted to be noise affected by up to 16 dB(A) above the NML, but only during site establishment (PUN_02)
- One school (Artarmon Public School) located in NCA 33.1 is predicted to experience construction noise levels marginally above the NML (up to 2 dB(A)).

5.6.2.6 Cumulative construction noise impacts

As outlined in Section 4.2.4, the potential for cumulative noise impacts from other major construction projects in the area around the Punch Street construction support site (BL3) would be considered when assessing the site and determining feasible and reasonable treatment and management measures.

Proposed staging of concurrent construction works associated with the project and other nearby major infrastructure projects that are considered for cumulative construction impacts are presented in Table 5-97. Timelines have been based on the relevant environmental impact statement.

Table 5-97 – Concurrent construction works near the Punch Street construction support site (BL3)

Project	2021	2022	2023	2024	2025	2026	2027
Punch Street construction support site (BL3/PUN)			■	■	■	■	
Gore Hill Freeway Connection surface road works (GHC)			■	■	■	■	■
Other major projects							
Warringah Freeway Upgrade (WFU)[1]	■	■	■	■	■		
Waltham Street construction support site (WHT11/WFU3K), part of the Western Harbour Tunnel and Warringah Freeway Upgrade project[2]				■	■	■	
Artarmon Substation, Sydney Metro City & Southwest (SMA)[3]	■	■					

Notes:
1. Refer to Western Harbour Tunnel and Warringah Freeway Upgrade Environmental Impact Statement (Transport for NSW, 2020).
2. Waltham Street construction support site (WHT11) forms part of the Western Harbour Tunnel project, refer to Western Harbour Tunnel and Warringah Freeway Upgrade environmental impact statement (Transport for NSW, 2020).
3. Artarmon Substation forms part of the Sydney Metro (City & Southwest) project, refer to Artarmon Substation Modification Report.

Proposed staging of concurrent work and noise impacts at the closest receivers to the Punch Street construction support site (BL3) have been reviewed. The loudest stages for both standard construction hours and OOHW have been used to calculate potential cumulative noise impacts for the closest receivers.

Available noise predictions for the Artarmon Substation (Sydney Metro City & Southwest) do not include residential receivers outside NCA 33.1. Therefore, cumulative impacts with the Artarmon Substation work have only been considered for NCA 33.1.

In the case where noise from one site dominates noise levels at the receiver (ie > 5-10 dB(A) above noise from other sites), that site would typically control construction noise levels at the receiver. As such, it is not likely to increase the overall $L_{Aeq,\ 15\ minute}$ construction noise level at these receivers.

However, where noise levels from each site are similar at a receiver, an increase of the total construction noise of up to 3 dB(A) could be expected. Two representative NCAs adjacent to the works have been assessed in Table 5-98,

Table 5-98 – Potential cumulative noise impacts from construction projects near the Punch Street construction support site (BL3)

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 33.1	Standard hours NML= 65 dB(A)	BL3/PUN	Establish site	≤ 73	Potential cumulative increase up to 1 dB(A) from Punch Street construction support site (BL3) and Gore Hill Freeway Connection surface road works (GHC), to a total up to 74 dB(A) which would only occur if noise intensive works at BL3 and GHC are concurrent and in a similar location. Receivers would likely be dominated by construction noise from either PUN or GHC,
		GHC	Utilities modification	57-71	
		WHT11/ WFU3K[1]	Waltham Street	59	
		WFU[1]	Miller Street to Willoughby Road	< 35[1]	

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 33.1		SMA	Construction and fitout	50-60[2]	and so may experience increased period of construction noise compared with a single area of works. The highest combined construction noise level would be above the NML but below the highly noise affected level.
NCA 33.1	OOHW NML D/E/N 60/58/45	BL3/PUN	Tunnelling	≤ 45	Generally, negligible cumulative increase as Gore Hill Freeway Connection surface road works typically dominate during the activity, except where Waltham Street construction support site (WFU3K) trenching works may be occurring. In the case that other projects are noise intensive concurrently with BL3, there is potential for cumulative increases. The noise levels due to the construction support site and the surface road works could be above the NML.
		GHC	Utilities modification	57-71	
		WHT11/ WFU3K[1]	Waltham Street (trenching)	59	
		WFU[1]	Miller Street to Willoughby Road	< 35[1]	
		SMA[2]	No night work[2]	N/A	
NCA 32.1	Standard hours NML= 69 dB(A)	BL3/PUN	Establish site	≤ 66	Cumulative increase due to concurrent works with the BL3 works unlikely, as PUN would likely dominate at nearby receivers during the construction works. Combined construction noise level would remain below NML.
		GHC	Utilities modification	46-57	
		WHT11/ WFU3K[1]	Waltham Street	≤ 45	
		WFU[1]	Miller Street to Willoughby Road	38-43	
		SMA	Construction and fitout	Not known	
	OOHW NML D/E/N 64/60/45	BL3/PUN	Tunnelling	≤ 39	Generally, construction noise levels would likely be dominated by other projects when they occur nearby. Gore Hill Freeway Connection surface road works would typically dominate, except where Waltham Street construction support site (WFU3K) trenching works may be occurring. If other construction works occur concurrently with BL3, then where a cumulative increase occurs, it would be dominated by the other project, or the combined construction noise level (increase up to 3 dB(A)), would remain below the NML.
		GHC	Utilities modification	46-57	
		WHT11/ WFU3K[1]	Waltham Street (trenching)	59	
		WFU[1]	Miller Street to Willoughby Road	37-42[1]	
		SMA[2]	No night work[2]	N/A	

Notes: 1. Waltham Street construction support site (WHT11) forms part of the Western Harbour Tunnel project, refer to Western Harbour Tunnel and Warringah Freeway Upgrade Environmental Impact Statement (Transport for NSW, 2020).

2. Artarmon Substation forms part of the Sydney Metro (City & Southwest) project, refer to Victoria Cross Station and Artarmon Substation Modification Report.

At the receivers most affected by noise from the site in NCA 33.1, there is potential for NMLs to be exceeded by cumulative construction noise from the Punch Street construction support site (BL3) combined with the Gore Hill Freeway Connection surface road works. However, cumulative noise impacts are not expected to be substantial based on the following:

- The combined noise level would be below the highly noise affected level

- Cumulative construction noise increases are likely to occur rarely, as noise generating activities would need to occur simultaneously, but could result in increased frequency and duration of impacts.

For receivers that are not directly adjacent to the Punch Street construction support site (BL3) the following are considered:

- There is potential for cumulative increases of construction noise from concurrent works at the Warringah Freeway Upgrade surface road works
- At more distant receiver locations, when an individual construction support site does not dominate construction noise levels at a receiver (ie it contributes < 5-10 dB(A) more than other sites), overall cumulative construction noise levels could potentially be up to 3 dB(A) higher than the noise levels predicted for any one site
- Cumulative construction noise increases are likely to occur rarely at these receivers, as noise generating activities would need to occur simultaneously, but could result in increased frequency and duration of impacts.

Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5.

5.6.3 Construction related road traffic noise assessment

Vehicle access to the Punch Street construction support site (BL3) would be from the Gore Hill Freeway, through an industrial area via Reserve Road and Cleg Street. During the site establishment stages, light and heavy vehicles would leave the site via Punch Street, Cleg Street and Reserve Road, however, once a temporary access road is constructed to provide direct access onto the Gore Hill Freeway, heavy vehicles would use this departure path. The egress road onto the Gore Hill Freeway would be modified part way through the construction in order to allow for staging of the cut and cover structure construction at the tunnel portal.

Table 5-99 presents the forecasted number of vehicles accessing the construction support site during the peak construction period at this site. Up to 19 trucks per hour in the daytime period and up to two trucks per hour (and no more than six heavy vehicles over the entire period) outside of these hours, would access the site.

Table 5-99 – Number of construction vehicles accessing the Punch Street construction support site (BL3)

Type of vehicle	Per day[1] over 15 hours[3,4]	Per night[2] over nine hours[3]
Heavy vehicle (deliveries, spoil haulage and concrete deliveries)	179	6
Light vehicle	182	108

Notes:
1. Day is 7.00am to 10.00pm
2. Night is 10.00pm to 7.00am
3. Numbers presented are individual vehicles, not vehicle movements
4. Vehicle numbers has been distributed onto the local road network based upon the proposed access roads. Where a vehicle accesses the site by one road and leaves by another, one vehicle movement is counted along each road once. Where a vehicle accesses and leaves the site by the same road, two vehicle movements are counted on that road.

As Cleg Street, Punch Street and Reserve Road are within an existing industrial area and the Gore Hill Freeway has high existing traffic movements, the road traffic noise levels are not expected to increase by more than 2 dB(A) during any construction stage at this site. This represents a minor impact, including both when heavy vehicles depart via Punch Street or via the temporary access road directly to the Gore Hill Freeway.

Over the entire night period there would be six vehicles (12 movements) typically accessing the construction support site. Since the night time heavy vehicle movements from this site would be limited to a worst case two vehicles during a one hour period and the Gore Hill Freeway has relatively high existing night time heavy vehicle movements, it is unlikely that there would be a substantial increase in the number of maximum noise level events with the potential to result in sleep disturbance at nearby receivers.

During further design development and construction planning, in order to ensure that traffic noise impacts are minimised, the construction traffic associated with the project should include the mitigation and management measures detailed in Section 6.7 where feasible and reasonable.

5.6.4 Ground-borne construction noise

Ground-borne noise could result from the construction of the tunnel access decline between the Punch Street construction support site (BL3) and ramp tunnels. The number of receiver buildings that could potentially be impacted by ground-borne noise levels are presented in Table 5-100.

Table 5-100 – Number of receiver buildings affected by ground-borne noise from tunnel access decline construction at Punch Street construction support site (BL3)

NCA	Number of ground-borne noise affected receiver buildings (ie above GBN[1,2] NML)				
	Residential			Other sensitive receivers	Commercial/ industrial receivers
	> 35[1] to <= 40 dB(A)	> 40[2] to <= 45 dB(A)	>45 dB(A)		
NCA 32.1	7	-	-	-	-

Notes:
1. Night ground-borne noise (GBN) NML
2. Evening ground-borne noise (GBN) NML.

Table 5-100 indicates that seven residential receiver buildings are predicted to be impacted by ground-borne noise levels above the strictest noise management level (ie night time 35 dB(A)). The locations where receiver buildings may be impacted by ground-borne noise are presented in Annexure J.3.

Ground-borne noise may be generated by vibration intensive works within the construction support site. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers. Section 4.3.2 outlines the potential impacts from ground-borne noise generated by surface construction works such as these and how any ground-borne noise generated from these works would be mitigated and managed.

5.6.5 Construction vibration

Vibration generated from construction works would vary depending on the level and type of activity carried out at each site during each activity. The major stages that would include vibration intensive works would be:

- Early works (PUN_01)
- Establish site (PUN_02)
- Build access decline and acoustic shed (PUN_03).

The proposed vibration intensive plant items are identified in Annexure E, with typical minimum working distances for a range of vibration intensive plant presented in Table 4-11. Annexure L presents the minimum working distances for both cosmetic damage and adverse human response to vibration, for the most vibration intensive activity proposed.

The most vibration intensive activity is likely to be the use of a large rock hammer during site establishment stages (PUN_01 to PUN_03). This is the basis of the vibration assessment and receiver building counts presented in Table 5-101.

Potential vibration generated at receivers for this project would be dependent on vibration source levels, separation distance, the intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. The assessment presented in this study considers a worst case scenario where the proposed vibration intensive plant items could be used anywhere within the boundaries of the site. However, this is unlikely to occur and the location of the vibration intensive equipment should be reviewed during detailed construction planning, as recommended in Section 6.8.

Table 5-101 – Number of structures within nominated minimum working distance for vibration impacts – Punch Street construction support site (BL3)

NCA	Number of structures within minimum working distances		
	Cosmetic damage		Human response
	Sound structure	Unsound structure	
Early works, establish site, build access decline and acoustic shed			
32.1	-	-	3
33.2	6	-	22
Tunnelling (tunnel access decline)			
32.1	-	-	-

For the tunnel access decline construction, due to the tunnel depth there are no occupied structures that are identified within the minimum working distances presented in Section 4.4.1 for roadheader tunnelling for either cosmetic damage or human response screening levels. As such, vibration impacts above the screening levels from the tunnel access decline construction works are unlikely but should be reviewed during further design development and construction planning.

5.6.5.1 Cosmetic damage

Six commercial/industrial buildings in NCA 33.2 have been identified to be within the minimum working distances for cosmetic damage, as presented in Table 5-101 and Annexure L.

5.6.5.2 Heritage listed structures

No heritage items have been identified within the unsound structure minimum working distance, as shown in Annexure L.

5.6.5.3 Human response

Rock hammering would occur for limited duration only at this site; therefore, the risk of annoyance is considered low. However, occupants of up to three properties in NCA 32.1 and 22 properties in NCA 33.2 may be exposed to vibration levels above the adverse human response level (ie residents may feel vibration from rock hammering), as presented in Table 5-101.

No receivers are predicted to be exposed to vibration from tunnel access decline construction above the human response screening level. Mainline and ramp tunnel construction vibration impacts are presented in Section 5.16

The extent of mitigation and management required to limit potential impacts to receivers would be determined by not only the level of vibration, but also the duration that receivers are likely to be exposed to vibration above the human response screening level.

After applying feasible and reasonable vibration treatment measures, if vibration monitoring determines that measured vibration levels exceed the relevant vibration criteria for human response, appropriate additional treatment measures should be considered (see Section 6.10.3).

5.7 Middle Harbour crossing

This section assesses the potential construction noise and vibration impacts, and the reasonable and feasible treatment measures that would be considered to control impacts on noise and vibration sensitive receivers near the proposed Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and the Middle Harbour crossing.

5.7.1 Construction support site overview

5.7.1.1 Construction support site description

Work at the site would occur in stages as presented in Table 5-102.

Table 5-102 – Middle Harbour crossing – major stage overview

Stage	Representative activity	Major stage activities/description
Installation of Middle Harbour north and south cofferdam structures (walls)	1. Build Middle Harbour north cofferdam 2. Build Middle Harbour south cofferdam	Construct cofferdams by: • Vibratory piling through sediment • Impact piling into rock.
	3. Dewater cofferdams	Pump water out to allow work in the cofferdams
Excavation of sediment and rock within cofferdam	4. Excavate cofferdams	Remove sediment and rock to make space for the interface structures
Pile temporary mooring facility east of Clive Park	5. Pile moorings	Pile mooring points for IMT storage
Construction of interface structure	6. Cast interface structures	Cast concrete interface structures to allow the driven tunnel to connect to the immersed tube tunnel
Inundation and removal of cofferdam structure	7. Remove cofferdams	Inundate then remove cofferdams
Dredging of a trench for the immersed tube tunnels	8. Prepare foundations	Dredge space for immersed tube tunnel
Construction of immersed tube tunnel piled supports	9. Pile foundations and install concrete headstocks	Construct pile foundations for immersed tube tunnel by: • Vibratory piling through sediment • Screw piling into rock. • Install concrete headstocks on piles
Installation of immersed tube tunnel units	10. Immerse tunnel units	Immerse and connect tube tunnel units

5.7.1.2 Construction works program

An approximate timeframe for the operation of the site is presented in Table 5-103 subject to project approval. This construction support site is planned to operate from the mid 2023 until the end of 2026.

The longest duration activity at this construction support site would be building cofferdams, which would take nine months. However, work in that stage would only occur during standard construction hours.

Table 5-103 – Middle Harbour crossing – indicative program and timeline

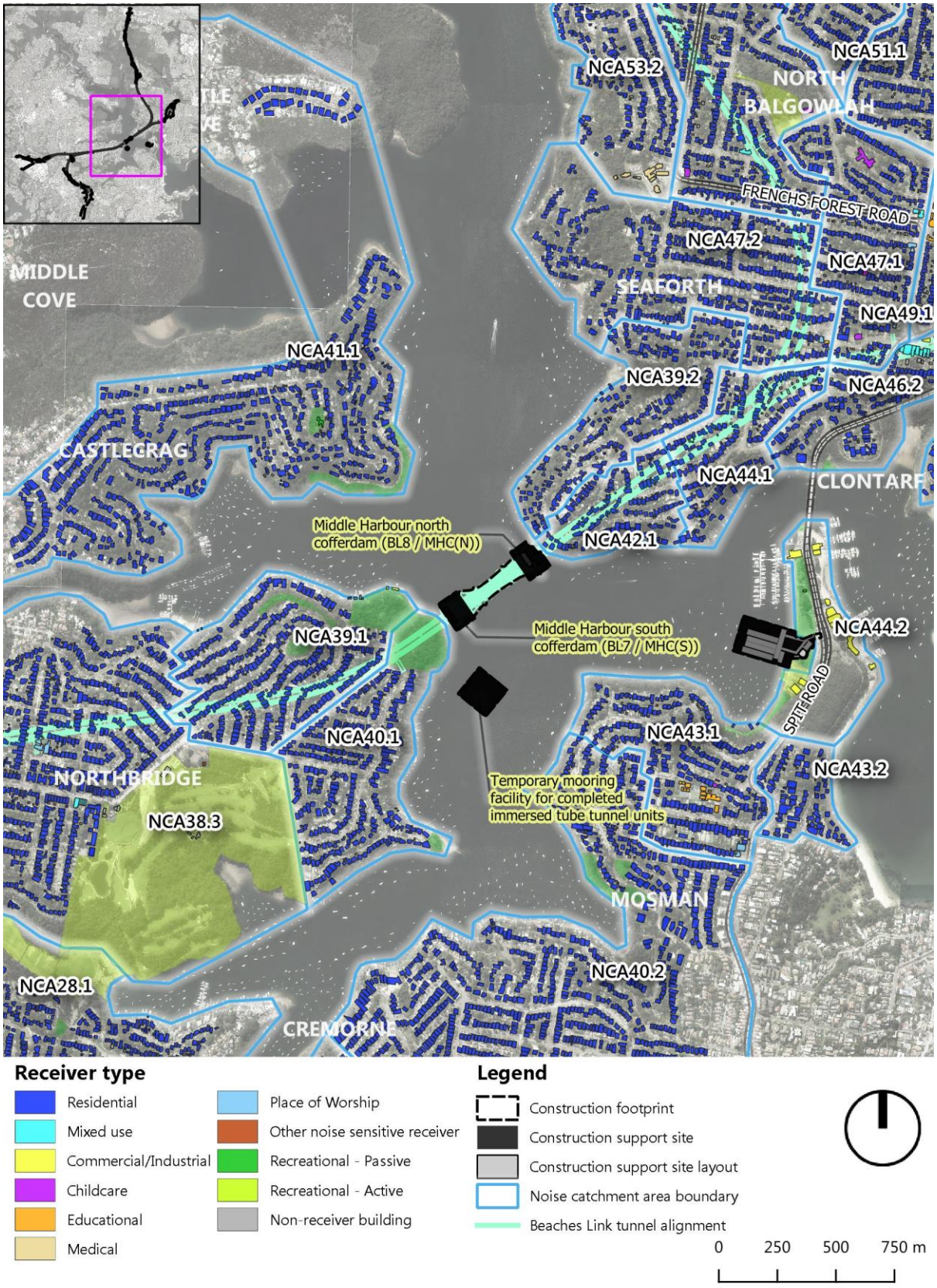
Stage	Representative activity	Reference	Indicative construction timeframe					
			2022	2023	2024	2025	2026	2027
			1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Installation of temporary cofferdam structure	1. Build Middle Harbour north cofferdam	MHC_01						
	2. Build Middle Harbour south cofferdam	MHC_02						
	3. Dewater cofferdams	MHC_03						
Excavation of sediment and rock within cofferdam	4. Excavate cofferdams	MHC_04						
Pile temporary mooring facility east of Clive Park	5. Pile moorings	MHC_05						
Construction of interface structure	6. Cast interface structures	MHC_06						
Inundation and removal of cofferdam structure	7. Remove cofferdams	MHC_07						
Dredging of a trench for the immersed tube tunnels	8. Prepare foundations	MHC_08						
Construction of immersed tube tunnel piled supports	9. Pile foundations and install concrete headstocks	MHC_09						
Installation of immersed tube tunnel units	10. Immerse tunnel units	MHC_10						

5.7.1.3 Nearby noise and vibration sensitive receivers

The site is in Middle Harbour between Northbridge and Seaforth. It is mostly surrounded by residential and recreational type receivers.

The locations of the site, nearby NCAs and receiver locations are shown in Figure 5-14.

Figure 5-14 – Location of the Middle Harbour crossing



5.7.1.4 Construction duration and working hours

Table 5-104 presents each of the major stages and each of the assessed activities for the Middle Harbour crossing, along with the duration and proposed periods of work for each activity. During the construction of the Middle Harbour crossing, work would typically take place during standard construction hours as presented in Table 3-2 (Section 3). As the crossing needs to be completed before the driven tunnels can connect, some works outside standard construction hours would take place outside standard hours:

- Dewatering and inundation of cofferdams would occur 24 hours a day, seven days a week
- Tunnel unit immersion would occur 24 hours a day to allow work to take place safely without impacting normal harbour traffic (immersion of each tunnel unit needs to be uninterrupted). It would typically take between 24 and 48 hours to safely sink each of the six tunnel units. Associated noise impacts would occur over six distinct 24 to 48-hour periods over a period of around nine months, providing appropriate respite for noise affected sensitive receivers in between individual tunnel tube immersions.

Table 5-104 – Middle Harbour crossing – construction hours

Stage	Representative activity		Reference	Activity description[1]	Work hours[2]			
					Day (Standard)	Day (OOHW)	Evening	Night
Installation of temporary cofferdam structure	1.	Build Middle Harbour north cofferdam	MHC_01	Piling for cofferdams	♦			
	2.	Build Middle Harbour south cofferdam	MHC_02	Piling for cofferdams	♦			
	3.	Dewater cofferdams	MHC_03	Pump water out of cofferdams	♦	♦[4]	♦[4]	♦[4]
Excavation of sediment and rock within cofferdam	4.	Excavate cofferdams	MHC_04	Remove sediment and rock from cofferdams	♦			
Pile temporary mooring facility east of Clive Park	5.	Pile moorings	MHC_05	Pile moorings	♦			
Construction of interface structure	6.	Cast interface structures	MHC_06	Cast concrete interface structures	♦			
Inundation and removal of cofferdam structure	7.	Remove cofferdams	MHC_07	Inundate and remove cofferdams	♦	♦[4]	♦[4]	♦[4]
Dredging of a trench for the immersed tube tunnels	8.	Prepare foundations	MHC_08	Dredge and place gravel foundations	♦[3]			
Construction of immersed tube tunnel piled supports	9.	Pile foundations	MHC_09	Pile foundations for immersed tube tunnel	♦			
Installation of immersed tube tunnel units	10.	Immerse tunnel units	MHC_10	Immerse and connect tube tunnel units	♦	♦	♦	♦

Notes:
1. Annexure E describes the modelled plant for each activity
2. Day Standard is 7.00am to 6.00pm Monday to Friday and 8.00am to 1.00pm Saturday
   Day Out-of-Hours Work is 1.00pm to 6.00pm Saturday and 8.00am to 6.00pm Sunday/Public holiday
   Evening is 6.00pm to 10.00pm Monday to Friday and 6.00pm to 10.00pm Saturday/Sunday/Public holiday
   Night is 10.00pm to 7.00am Monday to Friday and 10.00pm to 8.00am Saturday/ Sunday/Public holiday
3. Following the ceasing of dredging activities, the barge spoil transportation may extend beyond standard construction hours
4. Pumps are to remain operating, no other activities proposed.

5.7.1.5 Concurrent construction projects

The nearest construction works associated with this project would be the construction support site located at the Spit West Reserve construction support site (BL9), about 700 metres east of this site.

5.7.1.6 Construction assessment scenarios

The airborne noise assessment of the Middle Harbour crossing was separated into nine stages. Each stage was assessed against the works periods proposed in Table 5-104. The details of modelled construction plant items and corresponding sound power levels are presented in Annexure E.

The equipment/plant listed in Annexure E represent the reasonable worst case equipment/plant operating simultaneously in any 15 minute period (refer to Section 4.2.2 for further explanation of assessment scenarios).

Multiple activities would occasionally occur concurrently within the one construction support site and were captured in the assessment as shown in Annexure E.

5.7.1.7 Summary of assumed noise treatment and management measures

As part of the assessment process, feasible and reasonable noise treatment measures and management methods have been identified based on the preliminary site layout and the reasonable worst case plant/equipment operating, to assist in attenuating and managing noise emissions from construction activities.

Identified feasible and reasonable noise treatment measures have been included in the noise model and are presented in Table 5-105. The results presented in this assessment are based on these noise treatments and management measures being implemented.

Table 5-105 – Assumed noise treatment and management measures – Middle Harbour crossing

Activity or plant/equipment	Management and noise treatment measures applied
Water pumps	Pumps would be selected or acoustically treated (ie placed in an acoustic enclosure) to achieve a maximum sound power level of 82 dB(A).
Respite for high noise impact work	Respite would be provided from piling works (impact and vibratory) where required by the ICNG. Respite would be provided where required by the ICNG, from any activity which exceeds the 'highly noise affected' management level, including rock hammering works.

Further design development and construction planning refinements to the construction support site layout, the location of cofferdams or other Middle Harbour crossing design elements, required plant or equipment, construction methods or construction hours during further design development and construction planning may require specific mitigation and management measures that are different from those outlined in this section. Final details for noise treatments and management measures will be confirmed during further design development and construction planning to determine what is feasible and reasonable.

5.7.2 Construction airborne noise

The methodology used for assessing airborne noise impacts from construction support sites is outlined in Section 4.2.2.

5.7.2.1 Nearby receiver summary and objectives

Table 5-106 presents NMLs and the screening levels for the assessment of sleep disturbance for the nearest residential receivers surrounding the Middle Harbour crossing. Noise management levels for other (non-residential) noise sensitive receivers are presented in in Section 3.4.1. The locations of the NCAs surrounding the construction support site are shown in Figure 5-14.

Table 5-106 – Construction noise management levels and screening levels for residential receivers

NCA ID	Noise Management Level (NML) $L_{Aeq(15\ minute)}$				Sleep disturbance screening levels
	Standard Hours (RBL + 10dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL + 5dB)			L_{Amax} (RBL + 15dB)
	Day	Day	Evening	Night	Night
39.1	47	42	39	35	45
39.2	47	42	39	35	45
40.1	47	42	42	38	48
40.2	47	42	42	38	48
41.1	46	41	37	35	45
42.1	52	47	43	41	51
43.1	55	50	48	41	51
43.2	55	50	48	41	51
44.1	60	55	54	45	55
45.1	50	45	43	38	48
47.2	53	48	44	35	45

5.7.2.2 Predicted noise impacts

Table 5-107 provides a key to the cell shading and text formatting used to explain results in the following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-107 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes:
1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are expected to exceed NMLs. The range is of noise impacts throughout all receivers in the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented.

Noise predictions include adjustments for annoying noise in accordance with the ICNG.

Noise contours for the loudest early works, site establishment, and longer term tunnelling stages are shown in Annexure H.1. Maps presenting the predicted exceedance for a sample of scenarios at the construction support site with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different periods.

5.7.2.3 Residential

The predicted noise levels for residential receivers are presented in the following tables:

- Table 5-108: for standard hours
- Table 5-109: for works outside standard construction hours.

The number of receiver buildings predicted to exceed the noise management levels during each stage and time period are summarised in Table 5-110. Predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-108 – Predicted construction noise levels during standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Middle Harbour crossing

NCA	Noise Management Level		Predicted noise level at each construction stage[1, 2]									
	HNA	NML	MHC_01	MHC_02	MHC_03	MHC_04	MHC_05	MHC_06	MHC_07	MHC_08	MHC_09	MHC_10
39.1	75	47	≤ 64	≤ 68	< 35	≤ 57	≤ 50	≤ 51	< 35	≤ 52	≤ 67	≤ 48
39.2	75	47	≤ **82**	≤ 68	< 35	≤ 74	≤ 52	≤ 59	< 35	≤ 61	≤ 73	≤ 55
40.1	75	47	≤ 64	≤ 63	< 35	≤ 51	≤ 63	≤ 48	< 35	≤ 48	≤ 67	≤ 44
40.2	75	47	≤ 63	≤ 64	< 35	≤ 52	≤ 55	≤ 48	< 35	≤ 48	≤ 64	≤ 44
41.1	75	46	≤ 65	≤ 67	< 35	≤ 54	≤ 48	≤ 50	< 35	≤ 50	≤ 66	≤ 46
42.1	75	52	36 - **89**	≤ 68	< 35	36 - **77**	≤ 52	≤ 61	≤ 36	≤ 64	35 - 74	≤ 56
43.1	75	55	36 - 66	≤ 65	< 35	≤ 52	≤ 55	≤ 50	< 35	≤ 50	≤ 66	≤ 46
43.2	75	55	≤ 58	≤ 48	< 35	≤ 39	≤ 35	≤ 39	< 35	≤ 39	≤ 56	≤ 35
44.1	75	60	≤ 55	≤ 60	< 35	≤ 45	≤ 47	≤ 44	< 35	≤ 46	≤ 62	≤ 42
45.1	75	50	≤ 53	≤ 51	< 35	< 35	≤ 40	< 35	< 35	≤ 37	≤ 53	< 35
47.2	75	53	< 35	≤ 59	< 35	< 35	< 35	≤ 35	< 35	≤ 35	≤ 48	≤ 35

Notes: 1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))

2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-109 – Predicted construction noise levels outside standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Middle Harbour crossing

NCA	Noise Management Level				Predicted noise level at each construction stage[3]									
	HNA	Day (O)	Eve	Night	MHC_01[1]	MHC_02[1]	MHC_03	MHC_04[1]	MHC_05[1]	MHC_06[1]	MHC_07	MHC_08[1]	MHC_09[1]	MHC_10
39.1	75	42	39	35	-	-	< 35	-	-	-	< 35	-	-	≤ 48
39.2	75	42	39	35	-	-	< 35	-	-	-	< 35	-	-	≤ 55
40.1	75	42	42	38	-	-	< 35	-	-	-	< 35	-	-	≤ 44
40.2	75	42	42	38	-	-	< 35	-	-	-	< 35	-	-	≤ 44
41.1	75	41	37	35	-	-	< 35	-	-	-	< 35	-	-	≤ 46
42.1	75	47	43	41	-	-	< 35	-	-	-	≤ 36	-	-	≤ 56
43.1	75	50	48	41	-	-	< 35	-	-	-	< 35	-	-	≤ 46
43.2	75	50	48	41	-	-	< 35	-	-	-	< 35	-	-	≤ 35
44.1	75	55	54	45	-	-	< 35	-	-	-	< 35	-	-	≤ 42
45.1	75	45	43	38	-	-	< 35	-	-	-	< 35	-	-	< 35
47.2	75	48	44	35	-	-	< 35	-	-	-	< 35	-	-	≤ 35

Note: 1. No typical work is proposed outside standard construction hours

2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))

3. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-110 – Number of receiver buildings over the noise management level (all NCAs) – residential receivers – Middle Harbour crossing

Modelled representative activity	Assessment reference	Highly noise affected > 75 dB(A) L_{Aeq}		Day (standard hours) L_{Aeq}			Day (outside standard hours) L_{Aeq}				Evening L_{Aeq}				Night L_{Aeq}				Sleep disturbance L_{Amax}	
		Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening	Awakening
Build Middle Harbour north cofferdam	MHC_01[1]	**10**	-	794	175	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Build Middle Harbour south cofferdam	MHC_02[1]	0	-	882	185	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dewater cofferdams	MHC_03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Excavate cofferdams	MHC_04[1]	**1**	-	200	15	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pile moorings	MHC_05[1]	0	-	110	14	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cast interface structures	MHC_06[1]	0	-	54	3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Remove cofferdams	MHC_07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prepare foundations	MHC_08[1]	0	-	50	6	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pile foundations	MHC_09[1]	0	-	555	206	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Immerse tunnel units	MHC_10	0	0	23	0	0	65	23	0	0	94	56	1	0	195	93	7	0	224	13

Note: 1. No typical work is proposed outside standard construction hours

2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period in accordance with the key presented in Table 5-107.

5.7.2.4 Residential – summary of airborne noise assessment

Standard construction hours

The highest predicted noise levels occur while building cofferdams (MHC_01 and MHC_02). During these stages, impact piling with large (23 tonne) hammers has the greatest impact such that:

- Ten receiver buildings located in NCAs 39.2 and 42.1 (Seaforth) are predicted to be highly noise affected (ie >75 dB(A)) during piling for the Middle Harbour north cofferdam. Ten receiver buildings are predicted to be highly noise affected during piling for the Middle Harbour south cofferdam
- A total of up to 1075 receiver buildings across Northbridge, Castlecrag, Seaforth, Clontarf and Mosman in NCAs 39.1, 39.2, 40.1, 40.2, 41.1, 42.1, 43.1, 43.2, 45.1 and 47.2, as shown in Figure 5-14, are predicted to be noise affected (ie >NML) during piling for cofferdams.

It is difficult to effectively reduce noise from impact piling with large hammers using physical noise mitigation measures. Due to the construction methods required for the cofferdams there are very limited modifications available to the construction methodology. It is likely that some impact piling would be required during the installation of each pile. As such, impact piling best management practices should be adopted where feasible to minimise noise impacts at nearby receivers.

In relation the potential noise generated during this activity it is noted that:

- Impact piling would take place only during standard construction hours, and over the 12 month period identified for cofferdam construction in Table 5-103
- High noise generating impact piling activities would typically occur for about one to two hours per day during the week, with the quieter piling preparation and setup activities occurring during the rest of the day
- The piling preparation and setup activities associated with impact piling would provide receivers with longer respite periods as outlined in CNVG. This is in line with the respite periods typically required by the NSW EPA for high noise work
- Vibratory piling would also only take place during standard construction hours throughout the day and would generate lower noise levels than impact piling. Respite would be provided where required.

During excavation within the cofferdams (MHC_04):

- One receiver building in NCA 42.1 is predicted to be highly noise affected (ie >75 dB(A))
- Up to a total of 222 receiver buildings in NCAs 39.1, 39.2, 40.1, 40.2, 41.1 and 42.1 are predicted to be noise affected (ie >NML).

The worst case predicted noise impacts are due to excavation in cofferdams using two (32 tonne) excavators with large rock hammer attachments. Excavation is only proposed during standard construction hours, and respite periods would be provided as outlined in CNVG, which is in line with the respite periods

typically required by the NSW EPA requirements for high noise work. Where feasible and reasonable quieter alternative excavation equipment would be adopted, such as the use of rock saws.

During piling for moorings temporary mooring east of Clive Park (MHC_05), no receiver buildings are predicted to be highly noise affected (>75 dB(A)), as moorings would be screw piles bored into rock (quieter than impact piling). However, up to 124 receiver buildings are predicted to be noise affected (>NML) across Northbridge, Castlecrag and Seaforth in NCAs 39.1, 39.2, 40.1, 40.2 and 41.1.

During the piling for immersed tunnel tube foundations (MHC_09), no receivers are predicted to be highly noise affected (ie >75 dB(A)). However, up to a total of 775 receiver buildings are predicted to be noise affected (ie >NML) in NCAs 39.1, 39.2, 40.1, 40.2, 41.1, 42.1, 43.1, 43.2 and 44.1. Due to the required piling method (piling with large (23 tonne) hammers) these impacts would be difficult to physically mitigate and so are proposed only during standard construction hours.

The construction methodology for the installation of the immersed tube tunnel units supporting piles would be refined during detailed construction planning. Consideration should be given to adopting methods that limit noise impacts. This may include vibrating the piles through the softer sediments and then screwing into the rock on the bed of the harbour.

Immersed tunnel tube foundation piling (MHC_09) would take place only during standard construction hours, and for less than six hours a week over about a three month period:

- Impact piling high noise generating activities would typically occur for about one to two hours per day during the week, with the piling preparation and setup activities occurring during the rest of the day
- The piling preparation and setup activities associated with the impact piling would provide receivers with longer respite periods as outlined in CNVG and in line with the respite periods typically required by the NSW EPA for high noise work
- Vibratory piling would take place throughout the day, but and would contribute lower noise levels than impact piling. These works would be limited to standard construction hours, and respite would be provided where required.

During other stages at the Middle Harbour crossing, noise impacts would be less with up to 57 noise receiver buildings predicted to be noise affected (ie >NML) by up to 14 dB(A)construction noise impacts would limited to standard construction hours.

Work outside standard construction hours

Due to harbour navigation and safety requirements and lengthy vessel turn around times, some works are likely to be completed out of standard construction hours (OOHW) – refer to Table 5-104. At the Middle Harbour crossing, the key stages requiring OOHW are:

- Dewater cofferdams (MHC_03)
- Immerse tunnel units (MHC_10).

During stage 3 (MHC_03), the only work proposed outside standard hours is pumping water into or out of the cofferdams. The pumps would be enclosed or otherwise treated to ensure that that NMLs are not exceeded.

During tunnel tube immersion (Stage 10, MHC_10) up to 195 residential receiver buildings are predicted to be noise affected (ie >NML) by 1-5 dB(A), 93 residential receiver buildings are predicted to be noise affected by 6-15 dB(A), and seven receiver buildings are predicted to be noise affected by 16-25 dB(A).

Each of the six tunnel tubes would take between 24 and 48 hours each to immerse. For safety reasons, immersion of each individual tunnel tube needs to be continuous during that period of time. As per the indicative program in Table 5-102, these impacts would occur over six distinct 24 to 48-hour periods over a period of around nine months, providing appropriate respite for noise affected sensitive receivers in between individual tunnel tube immersions.

The predicted noise levels are based on all plant operating concurrently during each assessment activity. However, in practice not all plant would typically operate all the time, meaning that for a substantial part of the time actual noise levels would be less than the predicted noise levels.

Sleep disturbance

At the Middle Harbour crossing, the key OOHW stage which potentially includes activities with maximum noise levels (L_{Amax}) is:

- Stage 10 (MHC_10): Immerse tunnel units.

Immersion of tunnel units (MHC_10) is predicted to result in the following:

- Immersion of each tunnel tube would be required to occur continuously for 24 to 48 hours. During this stage, up to 224 receiver buildings in NCAs 39.1, 39.2, 40.1, 40.2, 41.1, 42.1 and 43.1 are predicted to potentially be exposed to maximum noise levels above the sleep disturbance screening level (up to L_{Amax} 70 dB(A)), including 13 receiver buildings in NCAs 39.2 and 42.1 where noise may be above the awakening level
- Maximum noise level events may occur occasionally during crane/plant/equipment operation, for example if chains are dropped on to the barge deck. These events could be minimised as far as practicable, by scheduling each immersion to start and end outside the night time period and adopting quiet work practices through the CNVMP.

5.7.2.5 Non-residential

The predicted noise levels for non-residential receivers are presented in Table 5-111. The number of receiver buildings predicted to exceed the NMLs are summarised in Table 5-112. The predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-111 – Predicted construction noise levels at other sensitive receivers – $L_{Aeq(15\ minute)}$, dB(A) – Middle Harbour crossing

Receiver type	NCA	NML	Predicted noise levels at each construction stage[1, 2]									
			MHC_01	MHC_02	MHC_03	MHC_04	MHC_05	MHC_06	MHC_07	MHC_08	MHC_09	MHC_10
Commercial	39.1	70	67	76	22	54	35	51	< 35	56	71	52
Childcare	43.1	50	49	38 - 45	< 35	< 35	< 35	< 35	< 35	< 35	41 - 47	< 35
Educational	43.1	55	40 - 50	37 - 48	< 35	≤ 39	≤ 35	< 35	< 35	< 35	40 - 49	< 35
	47.2	55	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
Recreational	39.1	65	≤ 36	36	< 35	36 - 37	< 35	< 35	< 35	< 35	≤ 38	< 35
	40.1	65	≤ 41	≤ 54	< 35	≤ 48	< 35	< 35	< 35	< 35	36 - 46	< 35
	40.2	65	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
	41.1	65	41 - 56	43 - 57	< 35	39 - 50	≤ 37	≤ 40	< 35	≤ 40	42 - 57	≤ 39
	45.1	65	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
Place of worship	43.1	55	47	≤ 46	< 35	< 35	35 - 36	< 35	< 35	< 35	36 - 47	< 35
	47.2	55	< 35	43	< 35	< 35	< 35	< 35	< 35	< 35	43	< 35

Notes: 1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML

2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-112 – Number of other sensitive receivers over the noise management level (all NCAs) – Middle Harbour crossing

Modelled representative activity	Assessment reference	Commercial[1]			Childcare			Educational			Recreational[1]			Places of worship			Other sensitive receivers[1]		
		1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
Build Middle Harbour north cofferdam	MHC_01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Build Middle Harbour south cofferdam	MHC_02	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dewater cofferdams	MHC_03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Excavate cofferdams	MHC_04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pile moorings	MHC_05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cast interface structures	MHC_06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Remove cofferdams	MHC_07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prepare foundations	MHC_08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pile foundations	MHC_09	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Immerse tunnel units	MHC_10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table.

One commercial receiver in NCA 39.1 (Northbridge Sailing Club) is predicted to be noise affected (ie >NML) during construction of the Middle Harbour south cofferdam (MHC_02) and piling for the foundations for immersed tube tunnel (MHC_09). The highest construction noise levels would be during noise intensive works for the construction of the Middle Harbour south cofferdam (MHC_02) where this receiver would experience noise levels up to 7 dB(A) above the NML. During other stages than these construction noise levels would be below the NML.

5.7.2.6 Cumulative construction noise impacts

As outlined in Section 4.2.4, the potential for cumulative noise impacts from other major construction projects in the area around the Middle Harbour crossing would be considered when assessing the site and determining feasible and reasonable treatment and management measures.

Proposed staging of concurrent construction works associated with the project and other nearby major infrastructure projects that are considered for cumulative construction impacts are presented in Table 5-113, based on relevant publicly available reports.

Table 5-113 – Concurrent construction works near the Middle Harbour crossing

Project	2022	2023	2024	2025	2026	2027
Middle Harbour crossing						
Spit West Reserve construction support site						

Proposed staging of concurrent work has been reviewed for the closest receivers to the Middle Harbour crossing. The loudest stages for both standard construction hours and out-of-hours works have been used to calculate potential cumulative noise impacts.

If noise from one site dominates noise levels at the receiver (ie > 5-10 dB(A) above noise from other sites), that site would typically control construction noise levels at the receiver. As such, it is not likely to increase the overall $L_{Aeq,\ 15\ minute}$ construction noise level at these receivers.

If noise levels from each site are similar at a receiver, a total construction noise increase of up to 3 dB(A) is expected. Two representative NCAs adjacent to the works have been assessed in Table 5-114.

Table 5-114 – Potential cumulative noise impacts from construction projects – Middle Harbour crossing

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 42.1	Standard hours NML= 52 dB(A)	MHC	Build Middle Harbour north cofferdam	36 - 89	Negligible cumulative increase as Middle Harbour crossing dominates during the activity.
		SMH	Early works	≤ 59	
	OOHW NML D/E/N 47/43/41	MHC	Immerse tunnel units	≤ 58	Negligible cumulative increase as Middle Harbour crossing dominates during the activity.
		SMH	Support Middle Harbour crossing	≤ 46	

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 43.1	Standard hours NML= 55 dB(A)	MHC	Build Middle Harbour north cofferdam	36 - 66	Up to 3 dB(A) increase at some receivers as both sites contribute a similar noise level. Negligible increase at the most affected receivers as one site dominates during the activity.
		SMH	Early works	≤ 63	
	OOHW NML D/E/N 50/48/41	MHC	Immerse tunnel units	≤ 49	Up to 3 dB(A) increase at some receivers as both sites contribute a similar noise level. Negligible increase at the most affected receivers as one site dominates during the activity.
		SMH	Support Middle Harbour crossing	41 – 48	

At some receivers in NCA 43.1, there is the potential for cumulative construction noise to be 3 dB(A) higher than predicted construction noise from any one site. However, cumulative noise impacts are not expected to be substantial as:

- Impact piling at the Middle Harbour crossing would be short in duration and intermittent, and impact piling would not occur at both cofferdams concurrently
- Increases in cumulative construction noise would not occur at the most affected receivers.

Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5.

5.7.3 Construction related traffic noise assessment

The Middle Harbour crossing construction support site would be accessed by barges and small boats usually from the Spit West Reserve construction support site (BL9). Construction related water traffic is discussed in Section 4.2.6.

Construction related road traffic noise impacts are therefore not addressed here, but as part of the assessment for the Spit West Reserve construction support site (BL9) in Section 5.8.

5.7.4 Ground-borne construction noise

Airborne noise is expected to dominate noise emitted from this site, even though ground-borne noise levels could be generated by piling activities. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers. Similar to the case study impacts presented in Section 4.3.2, airborne noise is expected to dominate over ground-borne noise levels at nearby receivers. As such, the management measures to address airborne noise impacts at these receivers are also likely to manage associated ground-borne noise impacts.

Ground-borne noise impacts from the construction of the mainline and ramp tunnel are assessed through ground-borne vibration impacts presented in Section 5.16.1.

5.7.5 Construction vibration

The vibration generated from construction works would vary depending on the level and type of activity carried out. For the Middle Harbour crossing, the major stages which may include vibration intensive works are:

- Build Middle Harbour north cofferdam (MHC_01)
- Build Middle Harbour south cofferdam (MHC_02)
- Excavate cofferdams (MHC_04)
- Pile foundations (MHC_08).

Proposed vibration intensive plant items are identified in Annexure E. Minimum working distances for a range of plant are presented in Table 4-11.

Presented in Annexure L are the estimated minimum working distances from the work site for both structural damage and adverse human response for the most vibration intensive activity proposed.

The most vibration intensive activity at this site is likely to be impact and vibratory piling for cofferdam construction (MHC_01 and MHC_02), rock hammering for cofferdam excavation (MHC_04), or impact and vibratory piling of foundations (MHC_08). The number of receiver buildings within the minimum working distances for these activities is presented in Table 5-115.

Potential vibration generated to the receivers depends on the vibration source levels, separation distance, intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. This assessment considers a worst case scenario that the proposed vibration intensive plant items could be used anywhere with the boundaries of the cofferdams and the crossing work areas, with lower vibration levels expected when works are not at the closest distances to individual sensitive receiver. When construction works occur within the minimum working distance of nearby sensitive structures they should be assessed during further design development and construction planning, as recommended in Section 6.8.

Table 5-115 – Number of structures within nominated minimum working distance for vibration impacts – Middle Harbour crossing

NCA	Number of structures within minimum working distances		
	Cosmetic damage		Human response
	Sound structure	Unsound structure	
Build or excavate cofferdams, pile foundations			
39.1	-	1	19
39.2	2	-	51
40.1	-	5	17
42.1	6	1	61

5.7.5.1 Cosmetic damage

Seven heritage items have been identified within the unsound structure minimum working distance and eight buildings have been identified within the sound structure minimum working distance established for cosmetic damage, as presented in Table 5-115 and Annexure L.

This assessment considers a worst case scenario that the proposed vibration intensive plant items could occur at all locations across the cofferdams work areas. However, the sensitivity of the nearby potentially impacted structures would vary. The specific vibration intensive equipment and where it occurs should be reviewed during detailed construction planning.

Where vibration intensive works are required to take place within the Site specific and activity specific minimum working distance, then the process outlined in Section 6.8 would be followed.

5.7.5.1.1 Specific mitigation and management of cofferdam construction and IMT support piles

Due to the proximity of vibration sensitive structures, including heritage items, to the cofferdam construction work area there is the potential for cosmetic damage of these structures/items if mitigation and management measures are not implemented.

This is of importance when considering the use of impact piling, which can generate high levels of vibration. Ground resistance varies as the pile is driven into the ground, causing vibration from impact piling to change over the course of the pile driving. Considering this, it is important that the potential worst case vibration impacts are used when reviewing the piling methodology and potential vibration levels, and why continuous vibration monitoring is crucial to ensure that vibration limits are maintained.

The management of vibration impacts from cofferdam piling in addition to the immersed tube tunnel supports piling should require specific reviews of the methodology during further design development and construction planning to be used by the construction contractor to minimise impacts from vibration. Where vibration levels are likely to be higher than the acceptable limits, the feasibility of alternative piling techniques such as vibratory piling and screw piling should be considered. These piling methods could also assist in reducing the airborne noise impacts on the surrounding receivers. It is likely that some impact piling for each cofferdam pile would be necessary to securely embed piles into the rock and ensure the piles can be connected together to provide a watertight and safe work environment. Due to the construction methods required for the cofferdam construction, the feasibility of adopting an alternative construction methodology is expected to be extremely unlikely. As such, options should be reviewed to use best management practice impact piling equipment to ensure vibration impacts are reduced to the minimum possible.

Once the vibration intensive works methodologies are determined, site specific minimum working distances for all vibration intensive activities (eg compaction, rock hammering, piling) that may impact vibration sensitive structures/items should be confirmed on site where plant and equipment are likely to operate close to or within the minimum working distances (see Table 4-11) prior to the vibration intensive construction works commencing. Site specific minimum working distances should be maintained where feasible and reasonable to comply with relevant vibration limits for cosmetic damage for each vibration

sensitive structure/item. If they cannot be maintained, the management approach presented in Section 6.8 should be followed.

5.7.5.2 Heritage listed structures

Seven heritage items have been identified within the unsound structure cosmetic damage minimum working distance and are identified in Table 5-116.

Refer to the Technical working paper: Aboriginal cultural heritage assessment report (Appendix L of the environmental impact statement), Technical working paper: Maritime heritage (Appendix K) and Technical working paper: Non-Aboriginal heritage (Appendix J) of the environmental impact statement for the assessment of impacts to heritage items.

A number of underwater maritime heritage items are located in proximity to the Middle Harbour crossing and may experience potential direct or indirect impacts from construction works. These items are not specifically addressed in this report. This is because of the submerged nature of these heritage items and because they are generally not building structures that require structural integrity for any specific purpose. This means that the standards and limits, presented in Section 3.4.5, for managing structural damage from vibration are not directly applicable. For further information on impacts from construction works on these items refer to the Technical working paper: Maritime heritage (Appendix K).

Table 5-116 – Heritage receivers within the cosmetic damage minimum working distance for the Middle Harbour crossing

Place/item name	Register	Type/classification[1]	Listing number	NCA
Harbour foreshores	Local Environmental Plan	Item - Landscape	I1	42.1
Clive Park and Tidal Pool	Local Environmental Plan Maritime heritage item	Item - General	I179	40.1
Clive Park One; Northbridge	NPW Act (AHIMS registered site)[2]	-	45-6-0654	40.1
Clive Park Two; Northbridge; Cicada Pupa Cave	NPW Act (AHIMS registered site)[2]	-	45-6-0996	40.1
Clive Park 4; Northbridge;	NPW Act (AHIMS registered site)[2]	-	45-6-2222	40.1
Clive Park 8, Shelter Midden WILL 170	NPW Act (AHIMS registered site)[2]	-	45-6-3012	40.1
Clive Park Midden WILL 169	NPW Act (AHIMS registered site)[2]	-	45-6-3011	39.1

Notes: 1. Conservation areas have not been considered as they do not form a structure that would be impacted by vibration
2. National Parks and Wildlife Act (AHIMS registered site).

Where vibration intensive works are required to take place within the site specific and activity specific minimum working distance, then the mitigation and management process outlined in Section 6.8 would be followed.

5.7.5.3 Human response

Piling and rock hammering would occur for limited duration only at this site; therefore, the risk of substantial annoyance is considered low. However, residents at up to 148 buildings may be exposed to vibration levels above the human response screening level (ie residents may feel vibration from piling or rock hammering), as presented in Table 5-115. These impacts would, however, be temporary and would only be likely during the most vibration-intensive activities occurring in close proximity to the affected receivers. At other times and during less vibration-intensive works it is unlikely the vibrations would be perceived.

Mainline and ramp tunnel construction ground-borne vibration impacts are presented in Section 5.16.1.

After applying feasible and reasonable vibration treatment measures, if vibration monitoring still identifies that measured vibration levels exceed the human response screening level, appropriate additional treatment measures should be provided (see Section 6.10.3).

5.8 Spit West Reserve construction support site (BL9)

This section assesses the potential construction noise and vibration impacts, and the reasonable and feasible mitigation measures that would be considered to control impacts on noise and vibration sensitive receivers near the Spit West Reserve construction support site (BL9). This support site is critical for casting the immersed tube tunnel units with concrete and for providing a marine supply point/barging point for all construction activities at the immersed tube tunnel installation site.

5.8.1 Construction support site overview

5.8.1.1 Construction support site description

Work at the site would occur in stages as presented in Table 5-117.

Table 5-117 – Spit West Reserve construction support site (BL9) – major stage overview

Stage	Representative activity	Major stage activities/description
Site establishment	1. Early works	Connect and relocate services at the site such as electricity, sewerage and water
	2. Establish site	Install environmental controls
	3. Construct office and wharf	Pile moorings for tunnel units and barges, install site office and wharf
Support dredging, pile installation and cofferdam/ interface structure	4. Support dredging, pile installation and cofferdam/ interface structure works	Support foundation preparation of the Middle Harbour crossing
Immersed tube tunnel unit casting and fitout	5. Cast and fitout tunnel units	Cast concrete in each tunnel unit's steel shell, then install bulkheads and ballast tanks.
Tube tunnel immersion construction support	6. Support tunnel unit immersion	Support tunnel unit immersion at the Middle Harbour crossing
Site rehabilitation	7. Site rehabilitation	Decommission site and restore to existing use

5.8.1.2 Construction works program

An approximate timeframe for the operation of the site is presented in Table 5-118, subject to project approval. This site is planned to operate from the middle of 2023 until early of 2026. The longest duration activity at this site would be dredging support works.

Table 5-118 – Spit West Reserve construction support site (BL9) – indicative program and timeline

Stage	Representative activity		Reference	Indicative construction timeframe																			
				2023				2024				2025				2026				2027				2028			
				1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Site establishment	1.	Early works	SMH_01																								
	2.	Establish site	SMH_02																								
	3.	Construct office and wharf	SMH_03																								
Support dredging, pile installation and cofferdam/interface structure	4.	Support dredging, pile installation and cofferdam/ interface structure works	SMH_04																								
Immersed tube tunnel unit casting and fitout	5.	Cast and fitout tunnel units	SMH_05																								
Tube tunnel immersion construction support	6.	Support tunnel unit immersion	SMH_06																								
Site rehabilitation	7.	Site rehabilitation	SMH_07																								

5.8.1.3 Nearby noise and vibration sensitive receivers

The site is located on Middle Harbour at The Spit. The location features commercial receivers at The Spit to the north and east, recreational receivers at The Spit and residential receivers across the harbour to the south, west and north.

The location of the site, nearby NCAs and receiver locations are shown in Figure 5-3.

Figure 5-15 – Location of the Spit West Reserve construction support site (BL9)



5.8.1.4 Construction duration and working hours

Table 5-119 presents each of the major stages and each of the assessed activities for the Spit West Reserve construction support site (BL9), along with the duration and proposed periods of works for each activity.

During the operation of the Spit West Reserve construction support site (BL9), work would typically take place during standard construction hours, presented in Table 3-2 (Section 3). However, some works would take place outside standard hours, as presented in Table 5-119.

Table 5-119 – Spit West Reserve construction support site (BL9) – construction hours

Stage	Representative activity		Reference	Assessed activities[1]	Work hours[2]			
					Day (Standard)	Day (OOHW)	Evening	Night
Site establishment	1.	Early works	SMH_01	Utility works	♦			
	2.	Establish site	SMH_02	Install environmental controls	♦			
	3.	Construct office and wharf	SMH_03	Piling for moorings and wharf	♦			
				Wharf construction	♦			
				Install offices	♦			
Support dredging, pile installation and cofferdam/interface structure	4.	Support dredging, pile installation and cofferdam/ interface structure works	SMH_04	Crane barge and truck activities	♦			
Immersed tube tunnel unit casting and fitout	5.	Cast and fitout tunnel units	SMH_05	Concrete pours	♦	♦	♦	
				Deliveries to site	♦			
				Install bulkheads and ballast tanks	♦			
Tube tunnel immersion construction support	6.	Support tunnel unit immersion	SMH_06	Support tunnel unit immersion	♦	♦	♦	♦
Site rehabilitation	7.	Site rehabilitation	SMH_07	Decommission site and return to existing use	♦			

Notes: 1. Annexure E describes the modelled plant for each activity

2. Day Standard is 7.00am to 6.00pm Monday to Friday and 8.00am to 1.00pm Saturday
Day Out-of-Hours Work is 1.00pm to 6.00pm Saturday and 8.00am to 6.00pm Sunday/Public holiday
Evening is 6.00pm to 10.00pm Monday to Friday and 6.00pm to 10.00pm Saturday/Sunday/Public holiday
Night is 10.00pm to 7.00am Monday to Friday and 10.00pm to 8.00am Saturday/ Sunday/Public holiday.

5.8.1.5 Concurrent construction projects

The nearest construction support sites associated with this project would be the Middle Harbour crossing, about 700 metres west of this site and the Balgowlah Golf Course construction support site (BL10) and Balgowlah surface road works, about 1.5 kilometres northeast of this site. Due to the distance of the Balgowlah Golf Course construction support site (BL10) and Balgowlah surface road works and the level of noise emissions expected from these construction activities, cumulative noise impacts are unlikely.

The nearest construction support site associated with another major infrastructure project would be the Cammeray Golf Course construction support sites (WHT10 & WFU8), more than three kilometres southwest of this site and part of the Western Harbour Tunnel and Warringah Freeway Upgrade project. At this distance, it is unlikely that both sites would have a substantial cumulative noise impact on any receiver.

5.8.1.6 Construction assessment scenarios

The airborne noise assessment of the Spit West Reserve construction support site (BL9) was separated into seven stages. Each stage was assessed against the work periods proposed in Table 5-119. The details of modelled construction plant items and corresponding sound power levels are presented in Annexure E.

The equipment/plant listed in Annexure E represent the reasonable worst case equipment/plant operating simultaneously in any 15 minute period (refer to Section 4.2.2 for further explanation of assessment scenarios).

Multiple activities would at times occur concurrently within the one construction support site and were captured in the assessment as shown in Table 5-119.

5.8.1.7 Summary of assumed noise treatment and management measures

As part of the assessment process, feasible and reasonable noise treatment measures and management methods have been identified based on the preliminary site layout and the reasonable worst case plant/equipment operating, to assist in attenuating and managing noise emissions from the construction activities.

Identified feasible and reasonable noise treatment measures have been included in the noise model and are presented in Table 5-23. The results presented in this assessment are based on those noise treatments and management measures being implemented.

Due to the nature of work at this site, no physical noise treatment measures are proposed.

Table 5-120 – Assumed noise treatment and management measures – Spit West Reserve construction support site (BL9)

Activity or plant/equipment	Description of management and mitigation measures
Work outside standard hours	Work would only occur outside standard hours during extended concrete pours for the immersed tunnel tube fitout, and to support tunnel unit immersion at the Middle Harbour crossing, which needs to occur 24 hours a day for safety reasons. All other work at this site would occur only in standard hours. Following the dredging activities during standard construction hours, the barge spoil transportation may extend beyond standard construction hours.

Further design development and construction planning refinements to the construction support site layouts, equipment, construction methods or construction hours may require specific mitigation and management measures that are different from those outlined in this section. Final details for noise treatments and management measures will be confirmed during further design development and

construction planning to determine what is feasible and reasonable, with consideration of cumulative construction impacts.

5.8.2 Construction airborne noise

The methodology used for assessing airborne noise impacts from construction support sites is outlined in Section 4.2.2.

5.8.2.1 Nearby receiver summary and objectives

Table 5-121 presents NMLs and screening levels for the assessment of sleep disturbance, for the nearest residential receivers surrounding the Spit West Reserve construction support site (BL9). Noise management levels for other (non-residential) noise sensitive receivers are presented in in Section 3.4.1. The locations of the NCAs surrounding the construction support site are shown in Figure 5-15.

Table 5-121 – Construction noise management levels and screening levels for residential receivers

NCA ID	Noise management levels (NML) $L_{Aeq(15\ minute)}$				Sleep disturbance screening levels
	Standard hours (RBL + 10dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL + 5dB)			L_{Amax} (RBL + 15dB)
	Day	Day	Evening	Night	Night
39.2	47	42	39	35	45
40.2	47	42	42	38	48
42.1	52	47	43	41	51
43.1	55	50	48	41	51
43.2	55	50	48	41	51
44.1	60	55	54	45	55
44.2[1]	60	55	54	45	55
45.1	50	45	43	38	48
46.1	68	63	59	42	52
46.2	68	63	59	42	52

Notes: 1. No residential receivers within this NCA

5.8.2.2 Predicted noise impacts

Table 5-122 provides a key to the cell shading and text formatting used to explain results in the following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-122 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes: 1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are expected to exceed NMLs. The range is of noise impacts throughout all receivers in the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented. It is noted that the noise predictions include adjustments for annoying activities, in accordance with the ICNG.

Noise contours for the loudest early works, site establishment, and longer term tunnelling stages are shown in Annexure H.1. Maps presenting the predicted exceedance for a sample of scenarios at the construction support site with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different periods.

5.8.2.3 Residential

The predicted noise levels for residential receivers are presented in the following tables:

- Table 5-123: for standard hours
- Table 5-124: for works outside standard construction hours.

The number of receiver buildings predicted to exceed NMLs during each stage and time period are summarised in Table 5-125.

Predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-123 – Predicted construction noise levels during standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Spit West Reserve construction support site (BL9)

NCA	Noise Management Level		Predicted noise levels at each construction stage[1,2]						
	HNA	NML	SMH_01	SMH_02	SMH_03	SMH_04	SMH_05	SMH_06	SMH_07
39.2	75	47	≤ 48	≤ 37	≤ 45	≤ 35	≤ 43	≤ 35	≤ 45
40.2	75	47	≤ 53	≤ 42	≤ 48	≤ 37	≤ 47	≤ 37	≤ 50
42.1	75	52	≤ 59	≤ 48	≤ 57	≤ 46	≤ 52	≤ 46	≤ 56
43.1	75	55	≤ 63	≤ 54	≤ 63	≤ 49	≤ 58	≤ 49	≤ 61
43.2	75	55	≤ 62	≤ 50	≤ 58	≤ 46	≤ 54	≤ 46	≤ 56
44.1	75	60	≤ 60	≤ 49	≤ 58	≤ 47	≤ 54	≤ 47	≤ 57
45.1	75	50	≤ 50	≤ 41	≤ 48	≤ 39	≤ 44	≤ 39	≤ 47
46.1	75	68	≤49	≤38	≤49	≤36	≤44	≤36	≤45
46.2	75	68	36 - 57	≤ 44	≤ 53	≤ 43	≤ 48	≤ 43	≤ 53

Notes:
1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))
2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-124 – Predicted construction noise levels outside standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Spit West Reserve construction support site (BL9)

NCA	Noise Management Level				Predicted noise levels at each construction stage[3]						
	HNA	Day (O)	Eve	Night	SMH_01[1]	SMH_02[1]	SMH_03[1]	SMH_04[1]	SMH_05[1,4]	SMH_06	SMH_07[1]
39.2	75	42	39	35	-	-	-	-	≤ 43	≤ 35	-
40.2	75	42	42	38	-	-	-	-	≤ 47	≤ 37	-
42.1	75	47	43	41	-	-	-	-	≤ 52	≤ 46	-
43.1	75	50	48	41	-	-	-	-	≤ 58	≤ 49	-
43.2	75	50	48	41	-	-	-	-	≤ 54	≤ 46	-
44.1	75	55	54	45	-	-	-	-	≤ 54	≤ 47	-
45.1	75	45	43	38	-	-	-	-	≤ 44	≤ 39	-
46.1	75	63	59	42	-	-	-	-	≤ 44	≤ 36	-
46.2	75	63	59	42	-	-	-	-	≤ 48	≤ 43	-

Note:
1. No typical work is proposed outside standard construction hours, although some concrete pours might be required outside standard construction hours on occasion
2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))
3. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.
4. Exceedances shown against the evening NML, as per hours shown in Section 5.8.1.4.

Table 5-125 – Number of receiver buildings over the noise management level (all NCAs) – residential receivers – Spit West Reserve construction support site (BL9)

Modelled representative activity	Assessment reference	Highly noise affected > 75 dB(A) L_{Aeq}		Day (standard hours) L_{Aeq}			Day (outside standard hours) L_{Aeq}				Evening L_{Aeq}				Night L_{Aeq}				Sleep disturbance L_{Amax}	
		Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening	Awakening
Early works	SMH_01[1]	0	-	131	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Establish site	SMH_02[1]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Construct office and wharf	SMH_03[1]	0	-	52	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Support dredging, pile installation and cofferdam/ interface structure works	SMH_04[1]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cast and fitout tunnel units	SMH_05	0	0	11	0	0	92	11	0	0	171	48	0	0	-	-	-	-	-	-
Support tunnel unit immersion	SMH_06	0	0	0	0	0	0	0	0	0	10	0	0	0	66	13	0	0	132	0
Site rehabilitation	SMH_07[1]	0	-	45	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: 1. No typical work is proposed outside standard construction hours

2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period in accordance with the key presented in Table 5-122.

5.8.2.4 Residential – summary of airborne noise assessment

Standard construction hours

The highest predicted level is up to 63 dB(A) in NCA 43.1 at up to five receiver buildings during early works and office and wharf build stages (SMH_01 and SMH_03). However, no receivers are predicted to be highly noise affected (ie >75 dB(A)) at any stage.

Up to 131 receiver buildings in NCAs 39.2, 40.2, 42.1, 43.1 and 43.2 are predicted to be noise affected (ie >NML) from short-term early works during standard hours by up to 8 dB(A).

During other stages, noise impacts would be less, with up to 52 receiver buildings noise affected by up to 8 dB(A) while the office and wharf are built (SMH_03) and during site restoration (SMH_07) works.

No receiver buildings are predicted to be noise affected during site establishment, support dredging or support tunnel unit immersion (SMH_02, SMH_04 and SMH_06) works.

Work outside standard construction hours

Due to construction limitations of concrete pours associated with the casting of the tunnel units, these activities may be required to extend outside standard construction hours. Where possible concrete pours would be scheduled to take place within standard construction hours; however, the process of casting the tunnel units means that once the concrete pour commences it must be completed to ensure appropriate concrete curing and structural integrity. If concrete pours extend into the evening period (SMH_05) up to 171 residential receiver buildings are predicted to be noise affected by 1-5 dB(A) and 48 residential receiver buildings are predicted to be noise affected by 6-15 dB(A).

For safety and operational installation reasons, immersion of tunnel units at the Middle Harbour crossing needs to be completed outside standard construction hours. This means that the Spit West Reserve construction support site (BL9) would support those works as part of immersion support (Stage 6, SMH_06) works as presented in Table 5-119.

During tunnel unit immersion support works at night (SMH_06) up to 66 residential receiver buildings are predicted to be noise affected by 1-5 dB(A) and 13 residential receiver buildings are predicted to be noise affected by 6-15 dB(A). Six individual tunnel tube immersions would be required, taking around 24 to 48 hours each over a nine month period. The use of the Spit West Reserve construction support site (BL9) would operate outside standard construction hours during these immersion activities. providing appropriate respite for a noise affected receivers in between individual tube immersions

The predicted noise levels are based on all plant operating concurrently during each assessed activity. However, in practice not all plant would typically operate all the time, meaning that for a substantial part of the time actual noise levels would be less than the predicted noise levels.

Sleep disturbance

During tunnel unit immersion (SMH_06) activities need to take place outside standard hours to safely immerse the tunnel units. Sleep disturbance noise sources (ie metal on metal bangs) should be managed; however, it should also be noted that the impacts tunnel unit immersions would occur for only six periods of 24 to 48 hours. During this work, up to 132 receiver buildings are predicted to potentially be exposed to maximum noise levels above the L_{Amax} sleep disturbance screening level. The awakening reaction level, however, is not predicted to be exceeded. As these noise levels are only likely during six periods of up 48 hours over nine months they are not expected to result in substantial sleep disturbance impacts.

5.8.2.5 Non-residential

The predicted noise levels for non-residential receiver buildings are presented in Table 5-126. The number of receiver buildings predicted to exceed the NMLs are summarised in Table 5-127. The predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-126 – Predicted construction noise levels at other sensitive receivers – $L_{Aeq(15\ minute)}$, dB(A) – Spit West Reserve construction support site (BL9)

Receiver type	NCA	NML	Predicted noise levels at each construction stage[1,2]						
			SMH_01	SMH_02	SMH_03	SMH_04	SMH_05	SMH_06	SMH_07
Commercial	44.2	70	48 - 75	39 - 63	41 - 66	≤ 51	38 - 60	≤ 51	42 - 65
	46.2	70	≤ 42	< 35	≤ 36	< 35	< 35	< 35	≤ 36
Childcare	46.2	50	45	38	44	< 35	38	< 35	42
Educational	43.1	55	39 - 55	≤ 44	37 - 51	≤ 39	≤ 48	≤ 39	38 - 51
Recreational	44.2	65	55 - 77	43 - 66	49 - 70	39 - 55	44 - 62	39 - 55	49 - 71
	45.1	65	49	39	43	< 35	37	< 35	42
	46.2	65	52	40	45	< 35	39	< 35	46
Place of worship	43.1	55	≤ 48	≤ 37	36 - 44	≤ 36	≤ 44	≤ 36	≤ 47

Notes: 1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, and Dark blue is >20 dB(A) above NML

2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-127 – Number of other sensitive receivers over the noise management levels (all NCAs) – Spit West Reserve construction support site (BL9)

Modelled representative activity	Assessment reference	Commercial[1]			Childcare			Educational			Recreational[1]			Places of worship			Other sensitive receivers[1]		
		1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
Early works	SMH_01	5	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Establish site	SMH_02	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Construct office and wharf	SMH_03	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Support dredging, pile installation and cofferdam/ interface structure works	SMH_04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cast and fitout tunnel units	SMH_05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Support tunnel unit immersion	SMH_06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site rehabilitation	SMH_07	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0

Notes: 1. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table.

Up to seven non-residential receiver buildings would be noise affected (ie >NML) by work in Stage 1 (SMH_01), Stage 2 (SMH_02), Stage 3 (SMH_03) and Stage 7 (SMH_07). The following other sensitive receivers predicted as being noise affected are in NCAs 43.1 and 44.2:

- Five commercial receiver buildings on the eastern side of Spit Road are predicted to be noise affected by up to 5 dB(A) in Stage 1 (SMH_01)
- Two recreational receivers adjacent to the construction support site are predicted to be noise affected by up to 12 dB(A) in Stage 1 (SMH_01) and by up to 6 dB(A) in Stage 2, Stage 3 and Stage 7 (SMH_02, SMH_03 and SMH_07).

5.8.2.6 Cumulative construction noise impacts

As outlined in Section 4.2.4, the potential for cumulative noise impacts from other major construction projects in the area around Spit West Reserve would be considered when assessing the site and determining feasible and reasonable mitigation and management measures.

Proposed staging of concurrent construction works associated with the project and other nearby major infrastructure projects that are considered for cumulative construction impacts are presented in Table 5-128.

Table 5-128 – Concurrent construction works near the Spit West Reserve construction support site

Project	2022	2023	2024	2025	2026	2027
Spit West Reserve (SMH) construction support site		[redacted]				
Middle Harbour crossing (MHC)		[redacted]				

Proposed staging of concurrent work has been reviewed for the closest receivers to the site. The loudest stages for both standard construction hours and out of hours works have been used to calculate potential cumulative noise impacts.

If noise from one site dominates noise levels at the receiver (ie > 5-10 dB(A) above noise from other sites), that site would typically control construction noise levels at the receiver. As such, it is not likely to increase the overall $L_{Aeq,\ 15\ minute}$ construction noise level at these receivers.

If noise levels from each site are similar at a receiver, a total construction noise increase of up to 3 dB(A) is expected. Two representative NCAs adjacent to the works have been assessed in Table 5-129.

Table 5-129 – Potential cumulative noise impacts from construction projects near Spit West Reserve

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 43.1	Standard hours NML= 55 dB(A)	SMH	Early Works	≤ 63	Up to 3 dB(A) increase at some receivers as Spit West Reserve (SMH) and Middle Harbour crossing (MHC) contribute a similar noise level. Negligible increase at the most affected receivers as one site dominates during the activity.
		MHC	Piling	40-69	

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 43.1	OOHW NML D/E/N 50/48/41	SMH	Support tunnel unit immersion	41-48	Up to 3 dB(A) increase at some receivers as Spit West Reserve and Middle Harbour crossing contribute a similar noise level. Negligible increase at the most affected receivers as one site dominates during the activity.
		MHC	Immerse tunnel units	≤ 49	
NCA 44.1	Standard hours NML= 60 dB(A)	SMH	Early Works	≤ 60	Up to 3 dB(A) increase at some receivers as Spit West Reserve and Middle Harbour crossing contribute a similar noise level. Negligible increase at the most affected receivers as one site dominates during the activity.
		MHC	Piling	≤ 61	
	OOHW NML D/E/N 55/54/45	SMH	Support tunnel unit immersion	≤ 47	Negligible increase as Spit West Reserve dominates during the activity.
		MHC	Immerse tunnel units	≤ 43	

At receivers not directly adjacent to the Spit West Reserve construction support site, there is potential for cumulative increases of construction noise from concurrent works with the Middle Harbour crossing construction activities.

At some receiver locations, when an individual site does not dominate construction noise levels at the receiver (ie it does not contribute more than 5 dB(A) more noise than other sites), cumulative construction noise levels could be up to 3 dB(A) higher than the noise levels predicted for any one activity.

Any increase due to cumulative noise is unlikely as noise generating activities would need to occur simultaneously. However, even where a cumulative construction noise increase is predicted, the total construction noise level at that receiver is predicted to be below the NML.

Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5.

5.8.3 Construction related traffic noise assessment

The Middle Harbour crossing would be accessed by barges and small boats from the Spit West Reserve construction support site (BL9). Construction related water traffic is discussed in Section 4.2.6.

Road vehicle access to the Spit West Reserve construction support site (BL9) would be from the Warringah Freeway and Burnt Bridge Creek Deviation via Manly Road.

Table 5-130 presents forecasted number of vehicles accessing the construction support site during the peak construction periods at this site. Up to ten trucks would access the site per hour during the daytime period (7.00am to 10.00pm), and no trucks would access the site at night.

Table 5-130 – Number of construction vehicles accessing the Spit West Reserve construction support site (BL9)

Type of vehicle	Per day[1] over 15 hours[3,4]	Per night[2] over nine hours[3,4]
Heavy vehicle (deliveries, spoil haulage and concrete deliveries)	110	0
Light vehicle	62	40

Notes:
1. Day is 7.00am to 10.00pm
2. Night is 10.00pm to 7.00am
3. Numbers presented are individual vehicles, not vehicle movements
4. Vehicle numbers has been distributed onto the local road network based upon the proposed access roads. Where a vehicle accesses the site by one road and leaves by another, one vehicle movement is counted along each road once. Where a vehicle accesses and leaves the site by the same road, two vehicle movements are counted on that road.

The number of movements generated by the site is not substantial compared to existing traffic numbers on the Warringah Freeway and the Burnt Bridge Creek Deviation, so this assessment considers traffic generated by the site on Military Road and Spit Road.

This assessment is based on predicted non-project traffic volumes. Table 5-131 presents the predicted increase in road traffic noise from additional construction traffic.

Table 5-131 – Road traffic noise impacts from the Spit West Reserve construction support site (BL9)

Construction vehicle access road	Road type	Time of day	Predicted road traffic noise increase, dB(A)[1, 2]	Exceedance of the RNP criteria	Exceedance of sleep disturbance screening level (night only)
Military Road, Spit Road	Arterial	Day $L_{Aeq(15hr)}$	<0.5	No	N/A
		Night $L_{Aeq(9hr)}$	<0.5	No	No

Notes:
1. Predicted road traffic noise levels are based upon the loudest heavy vehicle
2. Predicted road traffic noise levels are based upon the nearest residential receiver to the road. Receivers at further distances are expected to experience lower noise levels than those predicted.

The predicted overall road traffic noise increases due to the Spit West Reserve construction support site (BL9) are less than 2 dB(A) during day and night time periods. Therefore, predicted noise levels on those roads comply with the RNP criteria identified in Section 3.4.2.

No night time heavy vehicle movements would occur from this site, so it is not predicted to increase the number of maximum noise level (L_{Amax}) events above the screening level at receivers exposed to noise from the assessed roads.

Mitigation and management measures detailed in Section 6.7 should be considered during further design development and construction planning and, where feasible and reasonable, adopted to minimise construction traffic noise impacts associated with the project.

5.8.4 Ground-borne construction noise

Ground-borne noise may be generated by vibration intensive works within the construction support site. Given the closest building to the site is around 60 metres away, throughout these construction works it is

likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Ground-borne noise impacts from the construction of the mainline and ramp tunnels and ramps are assessed through ground-borne vibration impacts presented in Section 5.16.1.

5.8.5 Construction vibration

The vibration generated from construction works would vary depending on the level and type of activity carried out. For the Spit West Reserve construction support site (BL9), the only stages which could include vibration intensive works are:

- Early works (SMH_01)
- Construct office and wharf (SMH_03)

Proposed vibration intensive plant items are identified in Annexure E. Minimum working distances for a range of construction plant items are presented in in Table 4-11. Presented in Annexure L are the estimated minimum working distances from the construction support site for both structural damage and adverse human response to vibration for the most vibration intensive activity proposed.

The most vibration intensive activities at this site are likely to be utility relocations with rock hammers (if needed) during early works (SMH_01), and screw pile driving during office and wharf building (SMH_03) works.

No vibration sensitive receiver buildings/structures have been identified within the minimum working distances for vibration generating activities.

A number of underwater maritime heritage items are located in proximity to the Spit West Reserve construction support site (BL9) and may experience potential direct or indirect impacts from construction works. These items are not specifically addressed in this report. This is because of the submerged nature of these heritage items and because they are generally not building structures that require structural integrity for any specific purpose. This means that the standards and limits, presented in Section 3.4.5, for managing structural damage from vibration are not directly applicable. For further information on impacts from construction works on these items refer to the Technical working paper: Maritime heritage (Appendix K).

5.8.5.1 Cosmetic damage

No buildings have been identified within the minimum working distance for cosmetic damage. Cosmetic damage to buildings due to works are therefore unlikely.

5.8.5.2 Heritage listed structures

No heritage items have been identified within the unsound structure minimum working distance. Vibration-induced damage to heritage listed structures due to works are therefore unlikely.

5.8.5.3 Human response

Piling and rock hammering would occur for limited duration only at this site; therefore, the risk of substantial annoyance is considered low. However, occupants of up to two commercial properties may be exposed to vibration levels above the human response screening level during early works and the construction of the office and wharf (ie residents may feel vibration from piling or rock hammering. After applying feasible and reasonable vibration mitigation measures, if vibration monitoring identifies that measured vibration levels exceed the human response screening level, appropriate additional mitigation measures should be provided (see Section 6.10.3).

5.9 Balgowlah Golf Course construction support site (BL10)

This section assesses the potential construction noise and vibration impacts, and the reasonable and feasible mitigation measures that would be considered to control impacts on noise and vibration sensitive receivers near the Balgowlah Golf Course construction support site (BL10). The construction noise and vibration impact from the Balgowlah surface road works are considered in Section 5.10.

5.9.1 Construction support site overview

5.9.1.1 Construction support site description

Work at the site would occur in stages as presented in Table 5-132.

Table 5-132 – Balgowlah Golf Course construction support site (BL10) – major stage overview

Stage	Representative activities	Major stage activities/description
Site establishment	1. Early works	Connect and relocate services at the site such as electricity, sewerage and water
	2. Establish site	Install environmental controls, demolish existing structures, clearing and grubbing
	3. Modify intersections/roads	Road and intersection modifications and installation of traffic controls
	4. Bulk earthworks	Bulk excavation, site shaping and earthworks
Acoustic shed and surface level tunnel access construction	5. Build surface level access decline	Excavate access decline walls and construct access decline cover
	6. Establish construction facilities	Establish site offices, workshops, batch plant
	7. Piling for acoustic shed	Pilling for the shed foundations
	8. Build acoustic shed	Erect shed elements
Balgowlah surface road works support	9. Support works	Support surface road works
Tunnel construction (access decline, ventilation and mainline and ramp tunnels)	10. Tunnelling	Tunnel spoil handling and haulage, tunnel support, tunnel lining and associated deliveries
Tunnel fitout	11. Tunnel fitout	Install mechanical and utilities services to the tunnel
Concrete batching	12. Concrete batching	Operation of concrete batch plant
Golf course north works	13. Construct new recreational facilities	Fill, landscaping, drainage, turfing and recreational facilities
Construction of operational facilities	14. Build operational motorway facilities	Build ventilation outlet and motorway facilities building and operational building structures
Tunnel commission and site rehabilitation	15. Remove acoustic shed	Remove acoustic shed
	16. Decommission site	Commission tunnel, decommission site and site rehabilitation
Golf course south works, new oval and new field	17. Construct new recreational oval	Fill, landscaping, drainage, turfing and recreational facilities
	18. Construct new recreational field	Fill, landscaping, drainage, turfing and recreational facilities

As part of the major activities presented above, the Balgowlah Golf Course construction support site (BL10) would support up to three roadheaders constructing the mainline and ramp tunnels operating as follows:

- Two digging the mainline and ramp tunnels towards the Middle Harbour crossing
- One digging cross passages.

The construction of the mainline and ramp tunnels are assessed in Section 5.16.

5.9.1.2 Construction works program

An approximate timeframe for the establishing and operating the site is presented in Table 5-133, subject to project approval. This construction support site is planned to operate from the start of 2023 until the end of 2027. The longest duration activity at this construction support site would be supporting surface road works and concrete batching.

Staged construction of the open space and recreation facilities would be delivered progressively, with the golf course area to the north of the proposed access road to be redeveloped first followed by the remaining golf course area inclusive of residual Dudley Street land to the south west of the proposed access road. Consultation with relevant stakeholders separate to this environmental impact statement process would be carried out to determine the open space and recreation facilities to be constructed and final layout.

Table 5-133 – Balgowlah Golf Course construction support site (BL10) – indicative program and timeline

Stage	Representative activity	Reference	Indicative construction timeframe					
			2023	2024	2025	2026	2027	2028
			1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Site establishment	1. Early works	BAL_01						
	2. Establish site	BAL_02						
	3. Modify intersections/roads	BAL_03						
	4. Bulk earthworks	BAL_04						
Acoustic shed and surface level tunnel access construction	5. Build surface level access decline	BAL_05						
	6. Establish construction facilities	BAL_06						
	7. Piling for acoustic shed	BAL_07						
	8. Build acoustic shed	BAL_08						
Balgowlah surface road works support	9. Support surface road works	BAL_09						
Tunnel construction (ventilation, mainline and ramp tunnels)	10. Tunnelling	BAL_10						

Stage	Representative activity	Reference	Indicative construction timeframe					
			2023	2024	2025	2026	2027	2028
			1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Tunnel fitout	11. Tunnel fitout	BAL_11						
Concrete batching	12. Concrete batching	BAL_12						
Golf course north works	13. Construct new recreational facilities	BAL_13						
Construction of operational facilities	14. Build operational motorway facilities	BAL_14						
Tunnel commission and site rehabilitation	15. Remove acoustic shed	BAL_15						
	16. Decommission site	BAL_16						
Golf course south works, new oval and new field	17. Construct new recreational oval	BAL_17						
	18. Construct new recreational field	BAL_18						

5.9.1.3 Nearby noise and vibration sensitive receivers

The construction support site is located at the existing Balgowlah Golf Course between Burnt Bridge Creek Deviation and Sydney Road at Balgowlah. It is mostly surrounded by residential, recreational, some commercial and educational type receivers.

The location of the site, nearby NCAs and receiver locations are shown Figure 5-16.

Figure 5-16 – Location of Balgowlah Golf Course construction support site (BL10)



5.9.1.4 Construction duration and working hours

Table 5-134 presents each of the major stages and each of the assessed activities for the Balgowlah Golf Course construction support site (BL10), along with the proposed periods of works for each activity. During the operation of the Balgowlah Golf Course construction support site (BL10), work would typically take place during the standard construction hours, presented in Table 3-2 (Section 3). Some of the works would take place outside standard hours, as presented in Table 5-134.

Table 5-134 – Balgowlah Golf Course construction support site (BL10) – construction hours

Stage	Representative activity	Assessment reference	Activity description[1]	Work hours[2]			
				Day (Std)	Day (OH)	Evening	Night
Site establishment	1. Early works	BAL_01	Utility works	♦			
	2. Establish site	BAL_02	Install environmental controls	♦			
			Clearing and grubbing	♦			
			Demolition of existing structures	♦			
	3. Modify intersections/roads	BAL_03	Road and intersection modification and installation of traffic controls	♦	♦	♦	♦
	4. Bulk excavation	BAL_04	Bulk excavation, site shaping and earthworks	♦			
Acoustic shed and surface level tunnel access construction	5. Build surface level access decline	BAL_05	Surface level excavation of access decline and ventilation tunnels	♦			
	6. Establish construction facilities	BAL_06	Establish construction facilities (site offices, workshops, batch plant)	♦			
	7. Piling for acoustic shed	BAL_07	Piling for acoustic shed	♦			
	8. Build acoustic shed	BAL_08	Erect shed elements	♦			
Balgowlah surface road works support	9. Support surface road works	BAL_09	Deliveries[4]	♦	♦	♦	♦
			Laydown areas[4]	♦	♦	♦	♦
Tunnel construction (access decline, ventilation and mainline and ramp tunnels)	10. Tunnelling	BAL_10	General site activities[4]	♦	♦	♦	♦
			Deliveries	♦			
			Tunnelling and support[4]	♦	♦	♦	♦
			Tunnel lining (concreting) deliveries[4]	♦	♦	♦	♦
			Spoil handling in an acoustic shed	♦	♦[3]	♦[3]	♦[3]
			Spoil haulage	♦			
Tunnel fitout	11. Tunnel fitout	BAL_11	Deliveries[4]	♦	♦	♦	♦
			Laydown areas	♦			

Stage	Representative activity	Assessment reference	Activity description[1]	Work hours[2]			
				Day (Std)	Day (OH)	Evening	Night
Concrete batching	12. Concrete batching	BAL_12	Concrete batch plant	♦			
Golf course north works	13. Construct new recreational facilities	BAL_13	Support earthworks (no rock hammer)	♦			
Construction of operational facilities	14. Build operational motorway facilities	BAL_14	Build operational building structures	♦			
Tunnel commission and site rehabilitation	15. Remove acoustic shed	BAL_15	Removal of spoil shed	♦			
	16. Decommission site	BAL_16	Decommission site and site rehabilitation	♦			
Golf course south works (new oval and new field)	17. Construct new oval	BAL_17	Support earthworks (no rock hammer)	♦			
	18. Construct new field	BAL_18	Support earthworks (no rock hammer)	♦			

Notes:
1. Annexure E describes the modelled plant for each activity
2. Day Standard is 7.00am to 6.00pm Monday to Friday and 8.00am to 1.00pm Saturday
   Day Out-of-Hours Work is 1.00pm to 6.00pm Saturday and 8.00am to 6.00pm Sunday/Public holiday
   Evening is 6.00pm to 10.00pm Monday to Friday and 6.00pm to 10.00pm Saturday/Sunday/Public holiday
   Night is 10.00pm to 7.00am Monday to Friday and 10.00pm to 8.00am Saturday/ Sunday/Public holiday.
3. Spoil haulage off the construction support site would occur during standard construction hours. OOHW spoil handling would occur inside acoustic shed
4. Activities typically within acoustic shed during OOHW periods.

5.9.1.5 Concurrent construction projects

The nearest construction site associated with this project would be the Balgowlah surface road works, which are located directly adjacent to the Balgowlah Golf Course construction support site (BL10) with some elements of the Balgowlah surface road works occurring within the Balgowlah Golf Course construction support site (BL10) footprint.

The Balgowlah surface road works would be supported from the Balgowlah Golf Course construction support site (BL10). The Balgowlah surface road work support activities within the site footprint have been assessed together with the other construction support site activities.

The nearest other construction sites associated with this project would be the Spit West Reserve construction support site (BL9) and Middle Harbour crossing, about 1.5 kilometres southwest of this site and construction support sites on Wakehurst Parkway about two kilometres northwest of this site. At this distance, it is unlikely that there would be a substantial cumulative construction noise impact on any receiver from these sites.

The nearest construction support site associated with another major infrastructure project would be the Cammeray Golf Course construction support site (BL1), more than three kilometres southwest of this site and part of the Western Harbour Tunnel and Warringah Freeway Upgrade project. At this distance, it is unlikely that both sites would have a substantial cumulative noise impact on any receiver.

5.9.1.6 Construction assessment scenarios

The airborne noise assessment of the Balgowlah Golf Course construction support site (BL10) was separated into 18 stages. Each stage has been assessed against the works periods presented in Table 5-134. The details of the modelled construction plant items and corresponding sound power levels are presented in Annexure E.

The equipment/plant listed in Annexure E represent the reasonable worst case equipment/plant operating simultaneously in any 15 minute period (refer to Section 4.2.2 for further explanation of assessment scenarios).

Multiple activities would at times occur concurrently within the one construction support site and were captured in the assessment as shown in Table 5-134.

5.9.1.7 Summary of assumed noise treatment and management measures

As part of the assessment process, feasible and reasonable noise treatment measures and management methods have been identified based on the preliminary site layout and the reasonable worst case plant/equipment operating, to assist in attenuating and managing noise emissions from the construction activities.

Identified feasible and reasonable noise treatment measures have been included in the noise model and are presented in Table 5-135. The results presented in this assessment are based on those noise treatments and management measures being implemented. The locations of physical noise treatment measures are shown on Figure 5-17.

Further design development and construction planning refinements to the construction support site layouts, equipment, construction methods or construction hours may require specific mitigation and management measures that are different from those outlined in this section. Final details for noise treatments and management measures will be confirmed during further design development and construction planning to determine what is feasible and reasonable, with consideration of cumulative construction impacts.

Table 5-135 – Assumed noise treatment and management measures – Balgowlah Golf Course construction support site (BL10)

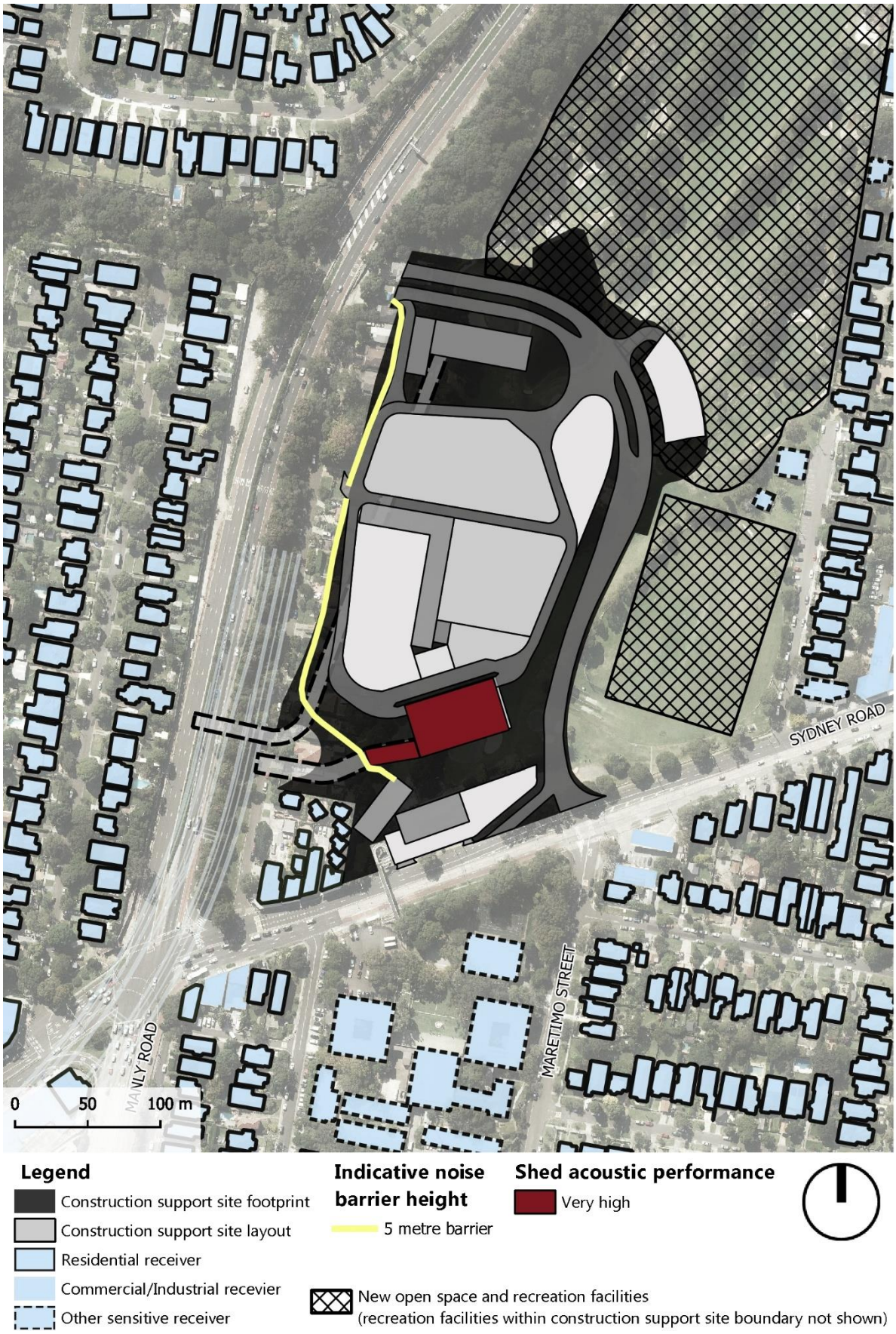
Activity or plant/equipment	Management and mitigation measures applied
Work outside standard hours	Work would only occur outside standard hours where it: • Meets the relevant NMLs • Occurs in an acoustic enclosure • Is required for safety reasons • Needs to occur outside standard hours to maintain the operational integrity of the road network. The following indicative noise barriers would be installed around the site to manage noise emissions: • A five metre high barrier to the western boundary • A five metre high barrier to the south western boundary.

Activity or plant/equipment	Management and mitigation measures applied
Concrete deliveries at night to support tunnelling	All night time delivery vehicles would enter the site through the slip lane and site entrance off Burnt Bridge Creek Deviation and leave the site via the Burnt Bridge Creek Deviation intersection. The onsite vehicle route would maximise distances and acoustic shielding with internal structures, from receivers to the direct south and west of the site. To enable this, delivery vehicles would enter and exit the acoustic shed through an entrance in the eastern facade of the acoustic shed during the night. Night time deliveries would be limited to one movement (in or out) within any one 15 minute period.
Tunnelling, support and fitout: acoustic shed and covered access decline	An acoustic shed and covered access decline would be built to reduce noise from tunnelling, support and fitout work outside standard hours. Indicative performance for shed elements are presented in Table 5-136. Outside standard hours, noise generating activities associated with laydown and deliveries would occur within the acoustic shed. Additionally, other noise intensive works (ie. workshop related activities) will be conducted within the acoustic shed when outside standard construction hours.
Wastewater treatment plant	Plant would be selected, acoustically treated or located within an acoustic enclosure to achieve a total sound power level of 93 dB(A).
Substation	The substation would be selected, acoustically treated or located within an acoustic enclosure to achieve a total sound power level of 85 dB(A).
Ventilation plant	Plant would be selected, acoustically treated or located within an acoustic enclosure to achieve a maximum total sound power level of 93 dB(A), accounting for directivity. Three ventilation plant were assumed.
Concrete batch plant	The batch plant noise levels would be reviewed. The concrete batch plant should be selected or acoustically treated to achieve total sound power level of 106 dB(A) $L_{Aeq\ 15minute}$ to ensure cumulative noise from the Balgowlah Golf Course construction support site (BL10) is below the NML.

Table 5-136 – Indicative acoustic shed construction and acoustic performance – Balgowlah Golf Course construction support site (BL10)

Shed / access decline element	Octave band frequency transmission loss, dB						
(Indicative example constructions are shown in Table 4-1)	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Acoustic shed (very high performance)							
Walls – Very high performance	25	31	40	49	61	69	75
Roof – High performance	20	27	36	45	51	56	62
Access decline cover (very high performance)							
Walls – Very high performance	25	31	40	49	61	69	75
Roof – High performance	20	27	36	45	51	56	62

Figure 5-17 – Site layout with indicative acoustic treatment measures for the Balgowlah Golf Course construction support site (BL10)



5.9.2 Construction airborne noise

The methodology used for assessing airborne noise impacts from construction support sites is outlined in Section 4.2.2.

5.9.2.1 Nearby receiver summary and objectives

Table 5-137 presents NMLs and the screening levels for the assessment of sleep disturbance for the nearest residential receivers surrounding the Balgowlah Golf Course construction support site (BL10). Noise management levels for other (non-residential) noise sensitive receivers are presented in Section 3.4.1. The locations of the NCAs surrounding the construction support site are shown in Figure 5-16.

Table 5-137 – Construction noise management levels and screening levels for residential receivers

NCA ID	Noise management levels (NML) $L_{Aeq(15\ minute)}$				Sleep disturbance screening levels
	Standard Hours (RBL+10dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL+5dB)			L_{Amax} (RBL + 15dB)
	Day	Day	Evening	Night	Night
46.1	68	63	59	42	52
46.2	68	63	59	42	52
47.1	53	48	44	35	45
48.1	65	60	55	37	47
49.1	55	50	47	36	46
50.1	57	52	50	40	50
51.1	53	48	45	38	48
52.1	59	54	50	41	51

5.9.2.2 Predicted noise impacts

Table 5-138 provides a key to the cell shading and text formatting used to explain results in following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-138 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes: 1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are expected to exceed NMLs. The range is of noise impacts throughout all receivers in the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented. It is noted that the noise predictions include adjustments for annoying activities, in accordance with the ICNG.

Noise contours for the loudest early works, site establishment, and longer term tunnelling stages are shown in Annexure H.1. Maps presenting the predicted exceedance for a sample of scenarios at the construction support site with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different assessment periods.

5.9.2.3 Residential

The predicted noise levels for residential receivers are presented in the following tables:

- Table 5-139 and Table 5-140: for standard hours
- Table 5-141 and Table 5-142: for works outside standard construction hours.

The number of receiver buildings predicted to exceed NMLs during each stage and time period are summarised in Table 5-143. Predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-139 – Predicted construction noise levels - standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Balgowlah Golf Course construction support site (BL10) (activity 1-9)

NCA	Noise Management Level		Predicted noise level at each construction stage								
	HNA	NML	BAL_01	BAL_02	BAL_03	BAL_04	BAL_05	BAL_06	BAL_07	BAL_08	BAL_09+BAL_10
46.1	75	68	≤ 65	≤ 66	≤ 53	≤ 54	≤ 60	≤ 49	≤ 55	≤ 49	≤ 44
46.2	75	68	≤ 53	≤ 58	≤ 37	≤ 45	≤ 43	≤ 40	≤ 41	< 35	≤ 35
47.1	75	53	≤ 58	38 - 64	≤ 40	≤ 51	≤ 55	≤ 46	≤ 49	≤ 43	≤ 41
48.1	75	65	≤ 72	≤ 72	≤ 66	≤ 60	≤ 65	≤ 56	≤ 58	≤ 52	≤ 54
49.1	75	55	36 - 73	**≤ 76**	≤ 56	≤ 62	≤ 73	≤ 57	≤ 65	≤ 61	≤ 51
50.1	75	57	≤ 71	≤ 74	≤ 56	≤ 68	≤ 65	≤ 56	≤ 55	≤ 50	≤ 53
51.1	75	53	≤ 64	35 - 74	≤ 46	≤ 62	≤ 65	≤ 55	≤ 57	≤ 51	≤ 51
52.1	75	59	≤ 50	39 - 56	< 35	≤ 48	35 - 51	≤ 39	≤ 43	≤ 36	≤ 36

Notes: 1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)).

Table 5-140 – Predicted construction noise levels – standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Balgowlah Golf Course construction support site (BL10) (activity 10-18)

NCA	Noise Management Level		Predicted noise level at each construction stage								
	HNA	NML	BAL_10+ BAL_09+BAL_12	BAL_11+BAL_09	BAL_11+ BAL_09+BAL_12	BAL_13+BAL_09+ BAL_10+BAL_12	BAL_14	BAL_15	BAL_16	BAL_17	BAL_18
46.1	75	68	≤ 47	≤ 38	≤ 44	≤ 50	≤ 43	≤ 45	≤ 48	≤ 56	≤ 57
46.2	75	68	≤ 38	< 35	≤ 37	≤ 44	≤ 38	< 35	≤ 38	≤ 47	≤ 46
47.1	75	53	≤ 47	≤ 36	≤ 46	≤ 51	≤ 45	≤ 39	≤ 43	≤ 51	≤ 49
48.1	75	65	≤ 56	≤ 50	≤ 55	≤ 58	≤ 50	≤ 48	≤ 52	≤ 62	≤ 69
49.1	75	55	≤ 55	≤ 47	≤ 55	≤ 58	≤ 52	≤ 51	≤ 57	≤ 66	≤ 61
50.1	75	57	≤ 57	≤ 51	≤ 56	≤ 70	≤ 56	≤ 46	≤ 52	≤ 60	≤ 72
51.1	75	53	≤ 57	≤ 46	≤ 56	≤ 62	≤ 60	≤ 44	≤ 51	≤ 60	≤ 54
52.1	75	59	≤ 40	≤ 35	≤ 39	≤ 49	≤ 37	< 35	≤ 36	≤ 44	≤ 42

Notes: 1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)).

Table 5-141 – Predicted construction noise levels – outside standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Balgowlah Golf Course construction support site (BL10) (activity 1-9)

NCA	Noise Management Level				Predicted noise levels at each construction stage[3]								
	HNA	Day (O)	Eve	Night	BAL_01[1]	BAL_02[1]	BAL_03	BAL_04[1]	BAL_05[1]	BAL_06[1]	BAL_07[1]	BAL_08[1]	BAL_09+BAL_10
46.1	75	63	59	42	-	-	≤ 53	-	-	-	-	-	< 35
46.2	75	63	59	42	-	-	≤ 37	-	-	-	-	-	< 35
47.1	75	48	44	35	-	-	≤ 40	-	-	-	-	-	< 35
48.1	75	60	55	37	-	-	≤ 66	-	-	-	-	-	≤ 37
49.1	75	50	47	36	-	-	≤ 56	-	-	-	-	-	≤ 36
50.1	75	52	50	40	-	-	≤ 56	-	-	-	-	-	≤ 39
51.1	75	48	45	38	-	-	≤ 46	-	-	-	-	-	≤ 36
52.1	75	54	50	41	-	-	< 35	-	-	-	-	-	< 35

Notes:
1. No typical work is proposed outside standard construction hours
2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))
3. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-142 – Predicted construction noise levels – outside standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Balgowlah Golf Course construction support site (BL10) (activity 10-18)

NCA	Noise Management Level				Predicted noise levels at each construction stage[3]							
	HNA	Day (O)	Eve	Night	BAL_10+ BAL_09	BAL_11+BAL_09	BAL_11+ BAL_09+BAL_12	BAL_13+BAL_09+ BAL_10+BAL_12	BAL_14[1]	BAL_15[1]	BAL_16[1]	BAL_17[1]	BAL_18[1]
46.1	75	63	59	42	< 35	< 35	< 35	< 35	-	-	-	-	-
46.2	75	63	59	42	< 35	< 35	< 35	< 35	-	-	-	-	-
47.1	75	48	44	35	< 35	< 35	< 35	< 35	-	-	-	-	-
48.1	75	60	55	37	≤ 37	< 35	< 35	≤ 37	-	-	-	-	-
49.1	75	50	47	36	≤ 36	< 35	< 35	≤ 36	-	-	-	-	-
50.1	75	52	50	40	≤ 39	< 35	< 35	≤ 39	-	-	-	-	-
51.1	75	48	45	38	≤ 36	< 35	< 35	≤ 36	-	-	-	-	-
52.1	75	54	50	41	< 35	< 35	< 35	< 35	-	-	-	-	-

Notes:
1. No typical work is proposed outside standard construction hours
2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))
3. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-143 – Number of receiver buildings over the noise management level (all NCAs) – residential receivers – Balgowlah Golf Course construction support site (BL10)

Modelled representative activity	Assessment reference	Highly noise affected > 75 dB(A) L_{Aeq}		Day (standard hours) L_{Aeq}			Day (outside standard hours) L_{Aeq}				Evening L_{Aeq}				Night L_{Aeq}				Sleep disturbance L_{Amax}	
		Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening	Awakening
Early works	BAL_01[2]	0	-	299	21	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Establish site	BAL_02[2]	**2**	-	863	137	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Modify intersections/roads	BAL_03	0	0	3	0	0	16	3	0	0	26	10	0	0	388	136	21	3	256	**11**
Bulk earthworks	BAL_04[2]	0	-	188	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Build surface level access decline	BAL_05[2]	0	-	332	12	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Establish construction facilities	BAL_06[2]	0	-	10	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Piling for acoustic shed	BAL_07[2]	0	-	35	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Build acoustic shed	BAL_08[2]	0	-	6	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surface road works support and tunnelling[1]	BAL_09 + BAL_10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136	0
Surface road works support, tunnelling and concrete batching[1]	BAL_09 + BAL_10 + BAL_12	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136	0
Surface road support and tunnel fitout[1]	BAL_09 + BAL_11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	0
Surface road works support, tunnel fitout and concrete batching[1]	BAL_09 + BAL_11 + BAL_12	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	0
Golf course north works, surface road works support, tunnelling and concrete batching[1]	BAL_13 + BAL_09 + BAL_10 + BAL_12	0	0	208	9	0	0	0	0	0	0	0	0	0	0	0	0	0	136	0
Build operational motorway facilities	BAL_14[2]	0	-	14	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Remove acoustic shed	BAL_15[2]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Decommission site	BAL_16[2]	0	-	5	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Construct new oval (golf course south)	BAL_17[2]	0	-	70	2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Construct new field (gold course south)	BAL_18[2]	0	-	34	9	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:
1. Cumulative assessment of daytime activities
2. No typical work is proposed outside standard construction hours
3. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period in accordance with the key presented in Table 5-138.

5.9.2.4 Residential – summary of airborne noise assessment

Standard construction hours

The highest predicted levels occur during early works, site establishment and access decline construction (assessed activities BAL_01, BAL_02 and BAL_05).

During site establishment works (BAL_02), two receiver buildings in NCA 49.1 are predicted to be highly noise affected. This is due to the use of excavators with rock hammers, chainsaws and mulchers.

Up to 1004 receiver buildings in NCAs 47.1, 48.1, 49.1, 50.1 and 51.1 are predicted to be above the NML from works during standard hours during site establishment (BAL_02). Other construction activities that affect a number of nearby receivers are early works (BAL_01), bulk earthworks (BAL_04), access decline construction works (BAL_05) and golf course north works (BAL_13). The highest numbers of noise affected receivers during standard hours are due to the use of excavators with rock hammers as part of site establishment (BAL_02).

During other construction activities noise impacts would be less, with up to 72 noise affected receiver buildings predicted during the construction of the new oval (BAL_17). These standard hours construction noise impacts would be managed through a CNVMP.

Work outside standard construction hours

Due to road operation, worker safety and 24 hour tunnelling requirements, some works are proposed outside standard construction hours as presented in Table 5-134. At the Balgowlah Golf Course construction support site (BL10), the key stages requiring OOHW are during:

- Road and intersection modifications and installation of traffic controls (BAL_03)
- Balgowlah surface road work support (BAL_09)
- Tunnelling and tunnel support works (BAL_10)
- Tunnel fitout works (BAL_11).

During night road works (BAL_03):

- 388 residential receiver buildings are predicted to be noise affected by up to 1-5 dB(A)
- 136 receiver buildings are predicted to be noise affected by 6-15 dB(A)
- 21 receiver buildings are predicted to be noise affected by 16-25 dB(A)
- Three receiver buildings are predicted to be noise affected by more than 25 dB(A).

This is due to short term intersection works performed under a ROL, which typically require that works take place outside standard hours to minimise disruption to the road network and protect the safety of road users and workers. These short term intersection works are likely to occur over a few nights per week, for a couple of weeks.

During longer term surface road works support, tunnelling and tunnelling fitout (BAL_09, BAL_10 and BAL_11) no residential receivers are predicted to be noise affected (ie >NML) during OOHW.

The predicted noise levels are based on all plant operating concurrently during each assessment activity. However, in practice not all plant would typically operate all the time, meaning that for a substantial part of the time actual noise levels may be less than the predicted noise levels.

Sleep disturbance

At the Balgowlah Golf Course construction support site (BL10), the key OOHW stages which potentially include activities with maximum noise levels (L_{Amax}) are:

- Road and intersection modifications and installation of traffic controls (BAL_03)
- Balgowlah surface road work support(BAL_09)
- Tunnelling and tunnel support works (BAL_10)
- Tunnel fitout works (BAL_11).

Road and intersection modification (Stage 3, BAL_03) works would be short term. During this work, up to 267 receiver buildings are predicted to potentially be exposed to maximum noise levels above the sleep disturbance screening level (up to L_{Amax} 52 dB(A)). Of those, 11 receiver buildings could potentially be exposed to noise levels above the awakening reaction level.

During night time tunnelling (BAL_10) and tunnel fitout works (BAL_11), occasional night time concrete truck movements could result in the high instantaneous noise impacts during arrival or departure. Up to 136 receiver buildings are predicted to potentially be exposed to maximum noise levels above the sleep disturbance screening level (up to L_{Amax} 52 dB(A)). No receivers are predicted to exceed the awakening reaction level.

Only two to three concrete trucks per night are expected to provide shotcrete for ground support work during tunnelling and tunnel fitout works in the night time period. While predicted L_{Amax} noise levels are greater than the screening levels, substantial sleep disturbance impacts are not likely to occur from up to three trucks a night.

Since the number of night truck movements generated by the site is not substantial compared to existing traffic numbers on Sydney Road and Burnt Bridge Creek Deviation, sleep disturbance impacts are not likely to occur from truck movements accessing the site at night.

5.9.2.5 Non-residential

The predicted noise levels for non-residential receivers are presented in Table 5-144 and Table 5-145. The number of receiver buildings predicted to exceed the NMLs are summarised in Table 5-146. The predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-144 – Predicted construction noise levels at other sensitive receiver locations – $L_{Aeq(15\ minute)}$, dB(A) –Balgowlah Golf Course construction support site (BL10) (activity 1-9)

Receiver type	NCA	NML	Predicted noise levels at each construction stage[1, 2]								
			BAL_01	BAL_02	BAL_03	BAL_04	BAL_05	BAL_06	BAL_07	BAL_08	BAL_09+BAL_10
Commercial	46.1	70	54 - 56	65 - 66	51 - 52	50 - 50	53 - 55	≤ 45	49 - 52	41 - 45	≤ 42
	46.2	70	50 - 55	55 - 62	≤ 44	44 - 50	42 - 46	39 - 44	41 - 46	≤ 38	≤ 39
	48.1	70	36 - 68	40 - 68	≤ 67	≤ 57	37 - 64	≤ 53	≤ 55	≤ 48	≤ 53
	49.1	70	≤ 41	≤ 56	≤ 39	≤ 44	≤ 42	≤ 38	≤ 37	< 35	< 35
	50.1	70	≤ 67	35 - 70	≤ 55	≤ 58	≤ 63	≤ 53	≤ 54	≤ 48	≤ 51
	51.1	70	≤ 50	≤ 56	< 35	≤ 47	≤ 52	≤ 39	≤ 45	≤ 39	≤ 37
Childcare	46.2	50	< 35	≤ 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
	47.1	50	41 - 53	47 - 60	≤ 37	39 - 48	37 - 53	≤ 43	≤ 46	≤ 39	≤ 38
	50.1	50	≤ 71	≤ 70	≤ 58	≤ 59	≤ 66	≤ 54	≤ 56	≤ 51	≤ 52
Educational	46.1	55	≤ 56	≤ 59	< 35	≤ 47	≤ 48	≤ 42	≤ 43	≤ 36	≤ 37
	48.1	55	43 - 71	49 - 70	≤ 61	39 - 59	48 - 64	≤ 56	41 - 58	≤ 51	≤ 52
	49.1	55	54 - 60	59 - 65	38 - 43	47 - 52	49 - 58	45 - 48	48 - 51	40 - 46	39 - 43
	50.1	55	40 - 52	51 - 59	≤ 36	46 - 53	43 - 53	≤ 43	37 - 45	≤ 38	≤ 41
	52.1	55	41 - 46	47 - 53	< 35	40 - 45	43 - 48	≤ 37	37 - 42	≤ 35	< 35
Other sensitive receiver	50.1	70	≤ 57	≤ 69	≤ 40	≤ 65	≤ 58	≤ 48	≤ 50	≤ 44	≤ 46
Place of worship	47.1	55	46 - 56	52 - 62	35 - 41	42 - 49	40 - 52	36 - 45	37 - 48	≤ 42	≤ 39
	48.1	55	54 - 62	57 - 62	44 - 46	43 - 51	51 - 58	43 - 48	45 - 50	37 - 44	38 - 44
Recreational	45.1	65	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
	46.2	65	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
	50.1	60	70 - 74	74 - 75	52 - 57	61 - 64	64 - 66	54 - 56	56 - 58	50 - 52	54 - 56
	51.1	65	49 - 50	56 - 57	≤ 35	46 - 51	46 - 51	39 - 41	43 - 45	≤ 39	36 - 38

Notes:
1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML
2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-145 – Predicted construction noise levels at other sensitive receiver locations – $L_{Aeq(15\ minute)}$, dB(A) – Balgowlah Golf Course construction support site (BL10) (activity 10-18)

Receiver type	NCA	NML	Predicted noise levels at each construction stage[1, 2]								
			BAL_10+ BAL_09+BAL_12	BAL_11+BAL_09	BAL_11+ BAL_09+BAL_12	BAL_13+BAL_09 +BAL_10+BAL_12	BAL_14	BAL_15	BAL_16	BAL_17	BAL_18
Commercial	46.1	70	≤ 44	35 - 36	≤ 42	≤ 49	54 - 56	65 - 66	51 - 52	50 - 50	53 - 55
	46.2	70	36 - 42	< 35	≤ 41	43 - 47	50 - 55	55 - 62	≤ 44	44 - 50	42 - 46
	48.1	70	≤ 55	≤ 47	≤ 52	≤ 57	36 - 68	41 - 68	≤ 67	≤ 57	37 - 64
	49.1	70	≤ 37	< 35	≤ 35	≤ 44	≤ 41	≤ 55	≤ 39	≤ 44	≤ 42
	50.1	70	≤ 54	≤ 49	≤ 53	≤ 57	≤ 67	≤ 70	≤ 55	≤ 58	≤ 63
	51.1	70	≤ 40	< 35	≤ 40	≤ 48	≤ 50	≤ 55	< 35	≤ 47	≤ 52
Childcare	46.2	50	< 35	< 35	< 35	< 35	< 35	≤ 35	< 35	< 35	< 35
	47.1	50	≤ 43	< 35	≤ 42	39 - 48	41 - 53	47 - 59	≤ 37	39 - 48	38 - 53
	50.1	50	≤ 56	≤ 50	≤ 55	≤ 58	≤ 71	≤ 70	≤ 58	≤ 59	≤ 66
Educational	46.1	55	≤ 40	< 35	≤ 38	≤ 46	≤ 56	≤ 59	< 35	≤ 47	≤ 48
	48.1	55	≤ 54	≤ 46	≤ 51	38 - 57	43 - 71	49 - 70	≤ 61	39 - 59	48 - 64
	49.1	55	45 - 49	≤ 38	44 - 48	47 - 53	54 - 60	59 - 66	38 - 43	47 - 52	49 - 58
	50.1	55	36 - 44	≤ 39	35 - 43	51 - 56	40 - 52	50 - 59	≤ 36	46 - 53	43 - 53
	52.1	55	≤ 38	< 35	≤ 37	40 - 46	41 - 46	47 - 53	< 35	40 - 45	43 - 48
Other sensitive receiver	50.1	70	≤ 49	≤ 45	≤ 49	≤ 68	≤ 57	≤ 67	≤ 40	≤ 65	≤ 58
Place of worship	47.1	55	≤ 44	≤ 35	≤ 43	41 - 49	46 - 56	52 - 62	35 - 41	42 - 49	40 - 52
	48.1	55	42 - 48	35 - 41	41 - 47	43 - 52	54 - 62	57 - 62	44 - 46	43 - 51	51 - 58
Recreational	45.1	65	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
	46.2	65	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
	50.1	60	56 - 59	51 - 53	55 - 57	60 - 68	70 - 74	73 - 75	52 - 57	61 - 64	64 - 66
	51.1	65	40 - 42	≤ 35	39 - 41	47 - 53	49 - 50	≤ 55	≤ 35	46 - 51	46 - 51

Notes:
1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML
2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-146 – Number of other sensitive receivers over the noise management levels (all NCAs) – Balgowlah Golf Course construction support site (BL10)

Modelled representative activity	Assessment reference	Commercial[1]			Childcare			Educational[3]			Recreational[1]			Places of worship			Other sensitive receivers[1]		
		1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
Early Works	BAL_01	0	0	0	2	0	1	13	3	0	1	2	0	3	0	0	0	0	0
Establish site	BAL_02	0	0	0	3	1	0	15	4	0	3	1	0	3	0	0	0	2	0
Modify intersections/roads	BAL_03	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Bulk earthworks	BAL_04	0	0	0	1	0	0	3	0	0	1	0	0	0	0	0	2	0	0
Build surface level access decline	BAL_05	0	0	0	1	1	0	12	0	0	1	0	0	2	0	0	2	0	0
Establish construction facilities	BAL_06	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Piling for acoustic shed	BAL_07	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Build acoustic shed	BAL_08	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface road works support and tunnelling[1]	BAL_09 + BAL_10	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface road works support, tunnelling and concrete batching[1]	BAL_09 + BAL_10 + BAL_12	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface road works support and tunnel fitout[1]	BAL_09 + BAL_11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface road works support, tunnel fitout and concrete batching[1]	BAL_09 + BAL_11 + BAL_12	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Golf course north works, surface road works support, tunnel fitout and concrete batching[1]	BAL_13 + BAL_09 + BAL_10 + BAL_12	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	2	0	0
Build operational motorway facilities	BAL_14	0	0	0	2	0	1	13	3	0	1	2	0	3	0	0	0	0	0
Remove acoustic shed	BAL_15	0	0	0	3	1	0	14	5	0	3	1	0	3	0	0	0	2	0
Decommission site	BAL_16	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Construct new oval (golf course south)	BAL_17	0	0	0	1	0	0	3	0	0	1	0	0	0	0	0	2	0	0
Construct new field (golf course south)	BAL_18	0	0	0	1	1	0	12	0	0	1	0	0	2	0	0	2	0	0

Notes:
1. Cumulative assessment of daytime activities
2. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table
3. Multiple buildings at Northern Beaches Secondary College Balgowlah Boys (NCA 48.1), Seaforth Public School (NCA 49.1) are identified as potentially ground-borne noise affected. All buildings are included in the count.

After the feasible and reasonable noise treatment and management measures are applied, several non-residential receivers are predicted to be noise affected (ie >NML) during some stages of construction works. The highest number of noise affected receivers include up to 32 non-residential receivers during site establishment. The identified receivers include:

- Childcare – two receivers in NCA 47.1 (Peacock Street Long Day Care and Seaforth Infants School) are predicted to be noise affected by up to 10 dB(A) above the NML, and one childcare receiver in NCA 50.1 (Balgowlah Kinder Haven) is predicted to be noise affected by up to 21 dB(A) above the NML
- Educational – three schools are predicted to be noise affected, mainly during works to establish the site (BAL_02). The highest predicted noise levels is for Northern Beaches Secondary College Balgowlah Boys in NCA 48.1, which is predicted to be noise affected by up to 16 dB(A) above the NML; and Seaforth Public School in NCA 49.1, which is predicted to be noise affected by up to 10 dB(A) above the NML
- Recreational – Balgowlah Oval is predicted to be noise affected by up to 14 dB(A) above the NML
- Places of worship – two receivers in NCA 47.1 (Seaforth Anglican Church and Seaforth Baptist Church), and one receiver in NCA 48.1 (The Catholic Community of North Harbour), are predicted to be noise affected by up to 7 dB(A) above the NML.

5.9.2.6 Cumulative construction noise impacts

As outlined in Section 4.2.4, the potential for cumulative noise impacts from other major construction projects in the area around the Balgowlah Golf Course construction support site (BL10) would be considered when assessing the site and determining feasible and reasonable mitigation and management measures.

Proposed staging of concurrent construction works associated with the project and other nearby major infrastructure projects that are considered for cumulative construction impacts are presented in Table 5-147.

Table 5-147 – Concurrent construction works near the Balgowlah Golf Course construction support site

Project	2022	2023	2024	2025	2026	2027	2028
Balgowlah Golf Course construction support site (BAL)							
Balgowlah surface road works (BGC)							

Proposed staging of concurrent work has been reviewed for the closest receivers to the site within Balgowlah Golf Course. The loudest stages for both standard construction hours and out-of-hours works have been used to calculate potential cumulative noise impacts.

If noise from one site dominates noise levels at the receiver (ie > 5-10 dB(A) above noise from other sites), that site would typically control construction noise levels at the receiver. As such, it is not likely to increase the overall $L_{Aeq,\ 15\ minute}$ construction noise level at these receivers.

If noise levels from each site are similar at a receiver, a total construction noise increase of up to 3 dB(A) is expected. Two representative NCAs adjacent to the works have been assessed in Table 5-148.

Table 5-148 – Potential cumulative noise impacts from construction projects (BAL)

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq,\ 15\ minute}$ dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 50.1	Standard hours NML= 57 dB(A)	BAL	Tunnelling	≤ 53	Negligible cumulative increase as Balgowlah surface road works (BGC) dominates during the activity. Construction noise from the Balgowlah Golf Course construction support site (BAL) is below NML.
		BGC	Paving / asphalting / road works (including concrete saw)	56 - 78	
	OOHW NML D/E/N 52/50/40	BAL	Tunnelling	≤ 39	Negligible cumulative increase as Balgowlah surface road works (BGC) dominates during the activity, Balgowlah Golf Course construction support site (BAL) is below NML.
		BGC	Demolition (rock hammering)	54 - 67	
NCA 51.1	Standard hours NML= 60 dB(A)	BAL	Tunnelling	≤ 51	Negligible cumulative increase as Balgowlah surface road works (BGC) dominates during the activity. Construction noise from the Balgowlah Golf Course construction support site (BAL) is below NML.
		BGC	Demolition (rock hammering)	62 - 76	
	OOHW NML D/E/N 48/45/38	BAL	Tunnelling	< 36	Negligible cumulative increase as Balgowlah surface road works (BGC) dominates during the activity, Balgowlah Golf Course construction support site (BAL) is below NML.
		BGC	Demolition (rock hammering)	62 - 76	

At receivers not directly adjacent to the Balgowlah Golf Course construction support site, there is potential for cumulative increases of construction noise from concurrent construction works with the Balgowlah surface road works.

At some receiver locations, when an individual site does not dominate construction noise levels at the receiver (ie it does not contribute more than 5 dB(A) more noise than other sites), cumulative construction noise levels could be up to 3 dB(A) higher than the noise levels predicted for any one activity.

Any increase due to cumulative noise is unlikely as noise generating activities would need to occur simultaneously. However, even where a cumulative construction noise increase is predicted, the total construction noise level at that receiver is predicted to be below the NML.

Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5.

5.9.3 Construction related road traffic noise assessment

The vehicle and haulage routes to access the Balgowlah Golf Course construction support site (BL10) would be via the proposed access road to and from Sydney Road and Burnt Bridge Creek Deviation, then along the arterial road network. Vehicle movements would be onto Sydney Road and Burnt Bridge Creek Deviation via new signalised intersections.

Table 5-149 presents forecasted number of vehicles accessing the construction support site during the peak construction period at this construction support site. The site would contribute up to 22 trucks per worst case one hour during the daytime period (7.00am to 10.00pm), and a maximum of one truck per hour (no more than four trucks in total) in the night time period (10.00pm and 7.00am). It is expected that half of all traffic movements would enter or exit via the Sydney Road intersection and the other half of the traffic movements would enter or exit via the Burnt Bridge Creek Deviation intersection.

Table 5-149 – Number of construction vehicles accessing the Balgowlah Golf Course construction support site (BL10)

Type of vehicle	Per day[1] over 15 hours[3,4]	Per night[2] over nine hours[3,4]
Heavy vehicle (deliveries, spoil haulage and concrete deliveries)	250	4
Light vehicle	445	153

Notes:
1. Day is 7.00am to 10.00pm
2. Night is 10.00pm to 7.00am
3. Numbers presented are individual vehicles, not vehicle movements
4. Vehicle numbers has been distributed onto the local road network based upon the proposed access roads. Where a vehicle accesses the site by one road and leaves by another, one vehicle movement is counted along each road once. Where a vehicle accesses and leaves the site by the same road, two vehicle movements are counted on that road.

Table 5-150 – Road traffic noise impacts from the Balgowlah Golf Course construction support site (BL10)

Construction vehicle access road	Road type	Time of day	Predicted road traffic noise increase, dB(A)[1, 2]	Exceedance of the RNP criteria	Exceedance of sleep disturbance screening level
Sydney Road	Arterial	Day $L_{Aeq(15hr)}$	<0.5	No	N/A
		Night $L_{Aeq(9hr)}$	<0.5	No	Yes
Burnt Bridge Creek Deviation	Arterial	Day $L_{Aeq(15hr)}$	<0.5	No	N/A
		Night $L_{Aeq(9hr)}$	<0.5	No	Yes

Notes:
1. Predicted road traffic noise levels are based upon the loudest heavy vehicle
2. Predicted road traffic noise levels are based upon the nearest residential receiver to the road. Receivers further distances are expected to experience lower noise levels than those predicted.

The predicted road traffic noise increase due to the Balgowlah Golf Course construction support site (BL10) is less than 2 dB(A) during the day and night time periods. Therefore, predicted traffic noise levels on Sydney Road, Burnt Bridge Creek Deviation and the subsequent arterial roads are predicted to comply with the RNP criteria identified in Section 3.4.2.

Maximum noise levels (L_{Amax}) from night period time heavy vehicle movements associated with the Balgowlah Golf Course construction support site (BL10) are predicted to exceed both the sleep disturbance screening level and the adopted awakening reaction level.

However, night time heavy vehicle movements from this site would be limited to one vehicle per hour, which is not a substantial number when compared to existing heavy vehicle movements on the Burnt Bridge Creek Deviation. Nearby receivers are not likely to notice the increase in the number of maximum noise events caused by the additional truck movements generated by the site.

Mitigation and management measures detailed in Section 6.7 should be considered during further design development and construction planning and, where feasible and reasonable, adopted to minimise construction traffic noise impacts associated with the project.

5.9.4 Ground-borne construction noise

Ground-borne noise could result from the construction of the tunnel access decline between the Balgowlah Golf Course construction support site (BL10) and mainline and ramp tunnel alignment. A separate ventilation tunnel would also be constructed between the tunnel and the ventilation outlet and motorway facilities building. The ventilation tunnel would be constructed by roadheader from the ramp tunnel alignment to below the ventilation outlet and motorway facilities building, and then a shaft constructed from within the building down the tunnel. It has been assumed the shaft would be constructed using rock hammers. Both the tunnel access decline and the ventilation tunnel are not located directly below residential receivers, limiting the potential ground-borne noise impacts. The number of receiver buildings that could potentially be impacted by ground-borne noise levels are presented in Table 5-151.

Table 5-151 – Number of receiver buildings affected by ground-borne noise from tunnel access decline construction at Balgowlah Golf Course construction support site (BL10)

NCA	Number of ground-borne noise affected receiver buildings (ie above GBN[1,2] NML)				
	Residential			Other sensitive receivers	Commercial/ industrial receivers
	> 35[1] to ≤ 40 dB(A)	> 40[2] to ≤ 45 dB(A)	>45 dB(A)		
Tunnelling (tunnel access decline)					
49.1	3	1	-	-	-
Tunnelling (ventilation tunnel and shaft)					
49.1	1	-	-	-	-

Notes: 1. Night ground-borne noise (GBN) NML
2. Evening ground-borne noise (GBN) NML.

Table 5-151 indicates that during excavation of the tunnel access decline, four residential receiver buildings are predicted to be impacted by ground-borne noise levels above the strictest NML (ie night time 35 dB(A)), of which one may receive ground-borne noise levels above 40 dB(A). During the construction of the ventilation tunnel and shaft one residential receiver building is predicted to be impacted by ground-borne noise levels above the strictest NML (ie night time 35 dB(A)).

The locations where receiver buildings may be impacted by ground-borne noise are presented in Annexure J.3.

Ground-borne noise may be generated by vibration intensive works within the construction support site. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers. Section 4.3.2 outlines the potential impacts from ground-borne noise generated by surface construction works such as these and how any ground-borne noise generated from these works would be mitigated and managed.

5.9.5 Construction vibration

The vibration generated from construction works would vary depending on the level and type of activity carried out. For the Balgowlah Golf Course construction support site (BL10), the major stages which may include vibration intensive works are:

- Early works (BAL_01)
- Site establishment (BAL_02)
- Road and intersection modification (BAL_03)
- Bulk excavation (BAL_04)
- Access decline construction (BAL_05)
- Piling for shed (BAL_07)
- Tunnelling (BAL_10)
- Construct new oval (BAL_17)
- Construct new field (BAL_18).

Proposed vibration intensive plant items are identified in Annexure E. Minimum working distances for a range of construction plant items are presented in in Table 4-11. Presented in Annexure L are the estimated minimum working distances from the construction support site for both structural damage and adverse human response to vibration for the most vibration intensive activity proposed.

The most vibration intensive activities at this site are likely to be the use of rock hammers for demolition during site establishment stages (BAL_01 to BAL_03), and for bulk earthworks excavation works (BAL_04 and BAL_05). Tunnel access decline construction during tunnelling works (BAL_10) may also cause vibration impacts, as the tunnel access decline passes adjacent to receiver buildings.

The number of receiver buildings within the minimum working distances for vibration generating activities is presented in Table 5-152. Potential vibration generated to receivers would depend on the vibration source levels, separation distance, intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. The location of the vibration intensive equipment should be reviewed during detailed construction planning, as recommended in Section 6.8.

Tunnel access decline construction at the site would use roadheaders and is not expected to result in vibration impacts.

This assessment considers a worst case scenario that the proposed vibration intensive plant items could be used anywhere within the boundaries of the site. However, this is unlikely to occur, and the location of the vibration intensive equipment would be reviewed during detailed construction planning.

Table 5-152 – Potential vibration impacts – Balgowlah Golf Course construction support site (BL10)

NCA	Number of structures within minimum working distances		
	Cosmetic damage		Human response
	Sound structure	Unsound structure	
Demolition or excavation with rock hammer, piling for acoustic shed[1]			
46.1	-	-	4
48.1	1	-	30
49.1	10	-	37
50.1	26	-	101
51.1	-	-	26
Tunnelling (tunnel access decline)			
49.1	-	-	-
Tunnelling (ventilation tunnel and shaft)			
49.1	-	-	-
51.1	-	-	-

Notes: 1. Buildings to be acquired by the project and to be demolished are not included in the counts.

For the access decline and ventilation tunnel construction, due to the tunnel depth there are no structures that are identified within the minimum working distances presented in Section 4.4.1 for roadheader tunnelling for either cosmetic damage or human response screening levels. As such, vibration impacts above the screening levels from the tunnel access decline construction works are unlikely but should be reviewed during further design development and construction planning.

5.9.5.1 Cosmetic damage

One building in NCA 48.1, ten buildings in NCA 49.1 and 26 buildings in NCA 50.1 have been identified within the minimum working distance for cosmetic damage, as presented in Table 5-152 and Annexure L.

5.9.5.2 Heritage listed structures

No heritage items have been identified within the unsound structure cosmetic damage minimum working distances, with the exception of an area with potential archaeological deposits associated with Burnt Bridge Creek to the west of Burnt Bridge Creek Deviation, as shown in Annexure L.

Refer to the Technical working paper: Aboriginal cultural heritage assessment report (Appendix L of the environmental impact statement)for the assessment of impacts to heritage items.

5.9.5.3 Human response

Piling, earth compaction works and rock hammering would occur for limited duration only at this site; therefore, the risk of substantial annoyance is considered low. However, occupants of up to 198 receiver buildings may be exposed to vibration levels above the human response screening level during early works, general site establishment works and earthworks associated with the establishment of the construction support site and the new and improved open space and recreation facilities at Balgowlah (ie residents may feel vibration from piling, vibratory rollers or rock hammering), as presented in Table 5-152.

No receivers are expected to be exposed to vibration from tunnel access decline construction above the human response screening level. Mainline and ramp tunnel construction vibration impacts are presented in Section 5.16. After applying feasible and reasonable vibration mitigation measures, if vibration monitoring still identifies that measured vibration levels exceed the human response screening level, appropriate additional mitigation measures should be provided (see Section 6.10.3).

5.10 Balgowlah surface road works

5.10.1 Construction works overview

5.10.1.1 Summary of construction works

The project would provide linkages to the southern areas of the Northern Beaches, including Seaforth, Manly and Brookvale. On and off ramps would connect the Beaches Link mainline tunnel to Burnt Bridge Creek Deviation at Balgowlah and with Sydney Road via the access road east of the Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection. The key works that would be carried out are:

- Realignment and widening of the Burnt Bridge Creek Deviation including cut and cover and trough works east of Hope Street
- A new access road through Balgowlah Golf Course which would:
  - Provide connectivity to new car parking facilities for the new and improved open space and recreation facilities
  - Provide connectivity from the Beaches Link tunnel to and from Sydney Road via a new traffic light intersection on the Burnt Bridge Creek Deviation to a new traffic light intersection at Sydney Road/Maretimo Street
- Minor changes to local roads, including intersection works at Maretimo Street and localised traffic calming works as required
- Retaining walls to support lower strength cut rock faces and retain fill embankments
- Relocation of existing utilities impacted by the project at various locations where surface works are required
- Local access for motorway facilities
- A localised adjustment of Burnt Bridge Creek to facilitate an extension of the existing box culvert crossing of Burnt Bridge Creek Deviation
- A new cul-de-sac on Dudley Street to the south to accommodate the re-alignment of Burnt Bridge Creek Deviation align with the reconfigured Balgowlah precinct.

The noise assessment has assessed seven major works areas in addition to one minor construction support site which have been identified for potential use during the construction works. The locations of overall work areas and surrounding noise sensitive receivers is presented in Figure 5-18, with the locations of the major works areas are presented in Figure 5-19.

The key features of the proposed Balgowlah surface road works are provided in Table 5-153.

Table 5-153 – Balgowlah surface road works – key works summary

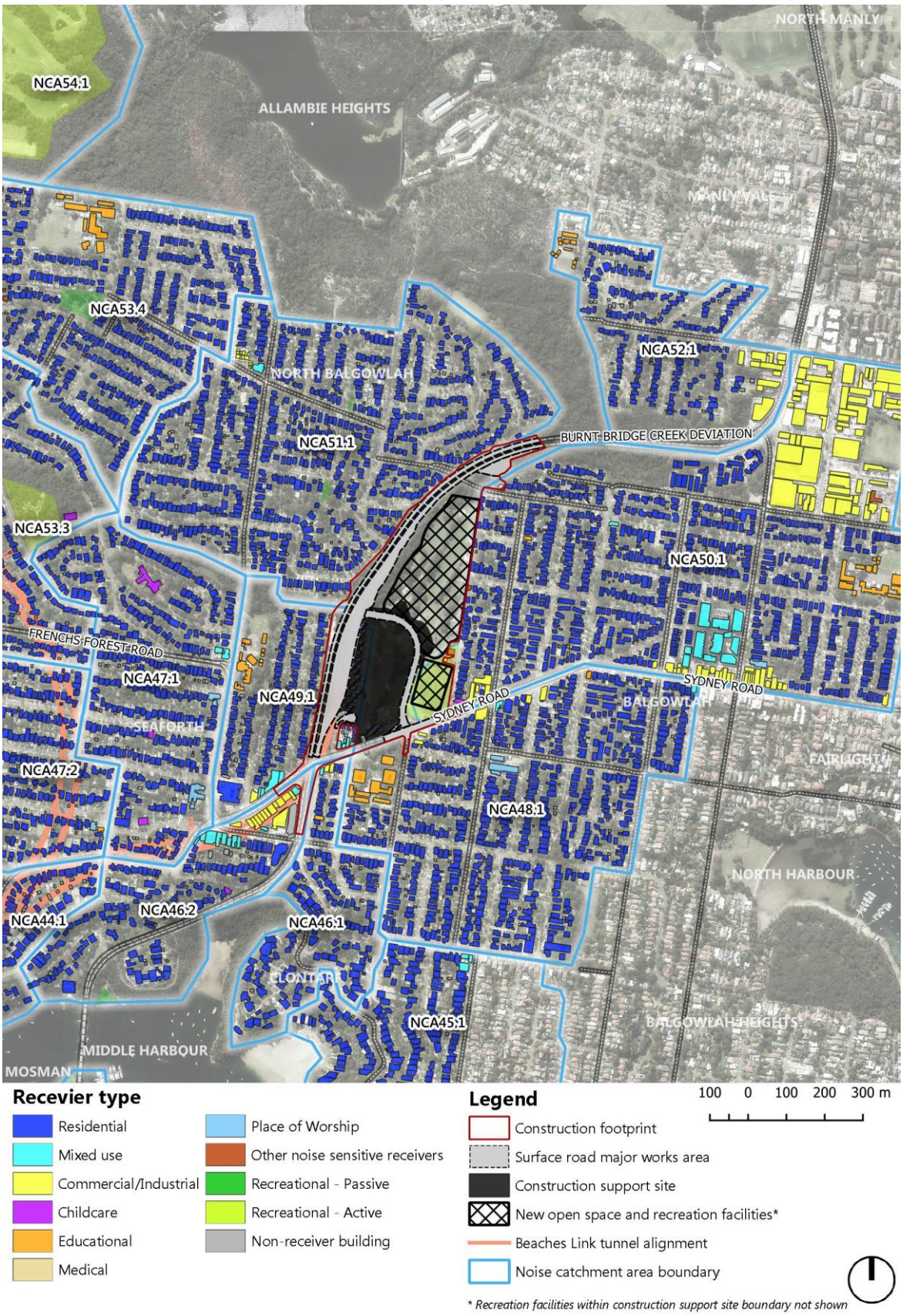
Key works element	Description
Beaches Link connections	
On ramp	Two lanes southbound from Burnt Bridge Creek Deviation
Off ramp	Two lanes northbound to Burnt Bridge Creek Deviation and two right turning traffic lanes into the new access road
Local road and intersection changes	
New access road to Sydney Road and open space and recreation facilities	A new access road would be constructed within Balgowlah Golf Course to connect the project to Sydney Road, including a new traffic light intersection about 200 metres east of the existing Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection
Maretimo Street/Sydney Road and Burnt Bridge Creek Deviation	New traffic lights for the access road and Maretimo Street/Sydney Road intersection and for the access road/Burnt Bridge Creek Deviation intersection
Dudley Street	Relocation of the existing cul-de-sac at Dudley Street
Utilities, sewerage and infrastructure works	
Surface and tunnel drainage works and stormwater modifications	Channels, culverts throughout works areas as required
Waterway realignment	Localised adjustment of Burnt Bridge Creek
Pedestrian and bike infrastructure	Realignment and reconstruction of the shared user path along the south eastern side of the Burnt Bridge Creek Deviation between the Kitchener Street bridge and Dudley Street. The realigned and reconstructed shared user path would be connected with the existing shared user path at Dudley Street and the existing shared user underpass beneath the Burnt Bridge Creek Deviation to the north of Dudley Street A new shared user path along the eastern side of the new access road between Burnt Bridge Creek Deviation and Sydney Road A new at-grade pedestrian crossing of the new access road adjacent to the intersection with Sydney Road, the intersection with Burnt Bridge Creek Deviation and the new public carpark within the open space and recreation facilities area.
Lighting, signage and road infrastructure	Throughout works areas
Utilities modification works	Throughout works areas
Landscaping	Throughout works areas

5.10.1.2 Nearby noise and vibration sensitive receivers

Figure 5-18 presents the site location, nearby noise sensitive receivers, and the NCA boundaries.

The NCAs that are in proximity to the Balgowlah surface road works are NCA 39.2 through to NCA 53.4. Refer to Annexure B.1 for more detailed information on the nearby noise sensitive receivers and the NCA boundaries.

Figure 5-18 – Balgowlah surface road works major works areas, nearby noise sensitive receivers, and noise catchment area (NCA) boundaries



5.10.1.3 Assessed construction works

The assessment of construction noise and vibration impacts associated with the Balgowlah surface road works focused on the seven major works areas, which are presented in Figure 5-19. Each stage was assessed against the works periods proposed in Section 3.3. The major works areas that have been assessed are identified in Table 5-154 and Table 5-172. A summary of the works areas that have been assessed, as well as a description of the required construction works and the associated locations is presented in Table 5-154. To support the surface road works one minor construction support site has been identified for assessment which is located adjacent the Kitchener Street bridge. The Kitchener Street construction support site (B11) (assessment reference BGC8) is presented in Figure 5-19. Additionally, a designated area to support the Balgowlah surface road works would be established as part of site establishment for the Balgowlah Golf Course construction support site (BL10) (Section 5.9) and the operation of this is assessed in Section 5.9, assessment reference BAL_09.

Table 5-154 – Balgowlah surface road works assessment areas

Major works area reference	Major works area description	Works description
BGC1	Burnt Bridge Creek Deviation surface works (southbound)	Surface road upgrade and modification works Installation of road furniture, lighting and signage Landscaping and architectural finishes
BGC2	Burnt Bridge Creek Deviation surface works (northbound)	
BGC3	Trough works	Tunnel portals and Burnt Bridge Creek Deviation tunnel connection
BGC4	Cut and cover portal works	
BGC5	Access road within Balgowlah Golf Course	Construction of a new road connecting Burnt Bridge Creek Deviation to Sydney Road and providing local connectivity to open space and recreation facilities
BGC6	Access road intersection works at Burnt Bridge Creek Deviation	Surface road upgrade and modification works Construction works for a signalised intersection
BGC7	Sydney Road roadworks	Surface road upgrade and modification works Construction works for a signalised intersection
BGC8	Kitchener Street construction support site (B11)	Construction support site for the Balgowlah surface road works

The construction footprint extends along the Burnt Bridge Creek Deviation north of the Kitchener Street bridge and further south from the main construction works onto Sydney Road and Manly Road. There would also be minor construction activities required at various locations within the construction footprint such as local area road works and utility adjustment works, pavement works, linemarking, or tie-in construction works, that would take place for relatively short periods (less than one month). An example includes the works associated with the new cul-de-sac on Dudley Street. The works would occur during standard hours where practicable, however, OOHW may be required if works need to be performed under a ROL, which typically require that works take place outside standard hours to minimise disruption to the road network and protect the safety of road users and workers, which is presented in Section 5.15.1.

Figure 5-19 – Balgowlah surface road works – works areas



5.10.1.4 Construction works program

The proposed approximate timeframe for the Balgowlah surface road works is presented in Table 5-155 and Table 5-156, subject to project approval. These works would take place from mid 2023 until late 2026. The activity with the longest duration is the surface road works along the existing road corridor.

An area within the construction support site would be established as part of site establishment to support the Balgowlah surface road works during both standard construction hours and outside of standard construction hours. This site is assessed in Section 5.9.

Table 5-155 – Balgowlah surface road works – indicative program and timeline

Project component	Indicative construction timeframe																			
	2022				2023				2024				2025				2026				2027			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Balgowlah surface road works																								

Table 5-156 – Balgowlah surface road works – indicative duration of construction work

Works area reference (Figure 5-19)	Major works area	Indicative duration of works
BGC1	Burnt Bridge Creek Deviation surface works (southbound)	21 months
BGC2	Burnt Bridge Creek Deviation surface works (northbound)	18 months
BGC3	Trough works	12 months
BGC4	Cut and cover portal works	12 months
BGC5	Access road within Balgowlah Golf Course	12 months
BGC6	Access road intersection works at Burnt Bridge Creek Deviation	9 months
BGC7	Sydney Road roadworks	12 months
BGC8	Kitchener Street construction support site (BL11)	39 months

5.10.1.5 Construction working hours and required out of hours work

Where feasible and reasonable, works would be scheduled to be carried out during standard construction hours, as outlined in Section 3.3. However, some key activities need to be carried out during night time road closures, as the works would require occupancy of the Burnt Bridge Creek Deviation, Sydney Road and key connection roads. Road occupancy licence conditions can vary and depend on existing road traffic volumes.

Key works outside standard construction hours required as part of the Balgowlah surface road works and the justification as to why the works would need to be completed outside standard construction hours are presented in Table 5-157.

Table 5-157 – Specific required out of hours work – Balgowlah surface road works

Works area reference (Figure 5-19)	Required OOHW	Percentage of program days OOHW is required	Justification
BGC1	Completion of temporary diversions and traffic switch works, including installing and moving of traffic controls	10	ROL required to minimise impacts on road network performance, worker safety and road user safety
BGC2	1. Completion of temporary diversions and traffic switch works, including installing and moving of traffic controls 2. Road resurfacing works	10	ROL required to minimise impacts on road network performance, worker safety and road user safety
BGC3	OOHW unlikely	< 10	-
BGC4	1. Completion of temporary diversions and traffic switch works and works adjacent to live corridor 2. Delivery and installation of oversized plant/structures/portal elements	10	1. ROL required to minimise impacts on road network performance, worker safety and road user safety during construction of portal elements, or road interface works. 2. Lifts of large construction elements over/adjacent to existing roads 3. Impacts on road network performance/safety from delivery of oversized loads
BGC5	OOHW unlikely	< 10	-
BGC6	Road surface placement and completion of tie-ins at the extents of the road construction	10	ROL required to minimise impacts on road network performance, worker safety and road user safety
BGC7	1. Road surface placement and completion of tie-ins at the extents of the road construction 2. Utility adjustment works within the road corridor.	10	ROL required to minimise impacts on road network performance, worker safety and road user safety
BGC8	Minimal proposed	< 10	-

Notes: 1. Based on an estimated number of days of the overall stage duration that may require OOHW, rounded up to the nearest 10 per cent. Estimated period of OOHW would be refined during detailed construction planning stage.

In addition, works that may be required to be carried out outside standard construction hours, for safety reasons or to minimise traffic disruptions, including when an ROL is required to undertake the works, are as follows:

- Utilities modifications, including sewage infrastructure modifications (where the works is in proximity to live traffic)
- Delivery of oversized loads, precast units and other materials
- Road tie in works
- Traffic management, set up and traffic switches
- Erection of traffic signs (where the erection is in proximity to traffic)
- Pavement and temporary median works

- Asphalt works and line marking
- Use of construction support sites to support out of hours works.

Section 6.4 outlines the mitigation and management measures recommended to specifically approach OOHW noise impacts associated with the project.

5.10.1.6 Concurrent construction projects

The nearest construction works associated with this project would be the Balgowlah Golf Course construction support site (BL10), supporting tunnelling for the project, directly adjacent to the major works areas. Some elements of the Balgowlah surface road works would also occur within the Balgowlah Golf Course construction support site (BL10) footprint.

In addition, the Balgowlah surface road works would be supported from the Balgowlah Golf Course construction support site (BL10). These Balgowlah surface road work support activities are assessed as part of the Balgowlah Golf Course construction support site (BL10) (Section 5.9).

The nearest other construction sites associated with this project would be the Spit West Reserve construction support site (BL9) and Middle Harbour crossing, about 1.5 kilometres southwest of the Balgowlah surface road work areas and construction support sites on Wakehurst Parkway about 2 kilometres northwest of the Balgowlah surface road work areas. At this distance, it is unlikely there would be a substantial cumulative construction noise impact on any receiver.

There are no other currently known state significant projects which are proposed to be occurring in the vicinity of the Balgowlah surface road works over the same time period.

5.10.2 Construction airborne noise

The methodology used to assess airborne noise impacts from surface road works is outlined in Section 4.2.3.

5.10.2.1 Construction activities and noise sources

A range of construction activities are to be carried out within each of the major works areas. Presented in Table 5-159 is the range of potential types of construction activities along with the associated SWLs that may occur as part of the surface road works, and an indication if these are to occur in each major works area. Works that could occur during standard construction hours are indicated as 'D', works modelled during OOHW periods are indicated as 'O', and where the activity may occur during both period it is indicated as 'DO'.

For assessment purposes, only the most noise intensive activities have been modelled which are highlighted in Table 5-159 with **blue** shading where the activity has been modelled during standard construction hours, and **orange** shading where the activity has been modelling outside standard

construction hours. However, the other activities may also occur as part of the construction works. As presented the noise impacts would vary as the construction activities vary.

A construction contractor, once appointed, would review and refine the project design and construction methodology during further design development and construction planning. The contractor should review noise impacts with a better understanding of the construction plant and equipment required for specific works, the locations they would likely operate, and the potential for concurrent activities in order to make more accurate predictions of the nature and duration of impacts.

Table 5-158 – Proposed construction activities and construction hours across the works areas and assessed works activities – Balgowlah surface road works

Assessment scenario and major works area reference (Refer to Figure 5-19)		Road works	Concrete barriers and traffic controls	Demolition (rock hammering)	Demolition (non-rock hammering)	Pavement/road modification works	Paving/asphalting/road surface road works (with concrete saw)	Resurfacing works	Road furniture installation/modify	Earthworks	Clearing and grubbing works	Bulk earthwork	Pile breaking	Piling - bored	Rock drilling	Rock trimming	Shotcrete	Structures	Concrete formwork/reinforcement	Concrete pours	Erection of structural steelwork	Erection/removal large items	Noise barrier installations	Services/utilities	Utilities modification works	Support activities	Deliveries	Deliveries (oversized)	Mobilisation/demobilise/site setup	Spoil handling	Support site activities
Worst case SWL[1]			105	121	112	120	120	118	114		116	119	122	117	117	121	112		113	116	117	111	118		120		104	111	110	106	105
Typical case SWL[1]			99	109	109	110	109	112	107		112	116	113	108	95	116	109		104	112	111	110	111		110		98	110	108	104	100
BBCD surface works (southbound)	BGC1		D/O	D	D	D	D	D	D		D	D							D	D		D	D		D		D		D	D	
BBCD works (northbound)	BGC2		D/O	D	D	D	D	D/O	D		D	D								D			D		D		D		D	D	
Trough works	BGC3		D	D	D		D		D			D	D	D	D	D	D		D			D				D	D	D	D	
Cut and cover portal works	BGC4		D	D	D		D		D			D	D	D	D	D	D		D	D		D/O				D/O	D/O	D/O	D	
Access road within Balgowlah Golf Course	BGC5						D		D		D	D							D	D							D	D	D	D	
Access road intersection works at Burnt Bridge Creek Deviation	BGC6		D/O			D	D/O	D	D										D	D					D/O		D		D/O		
Sydney Road roadworks	BGC7		D/O			D	D/O	D	D		D	D							D	D					D/O		D/O		D/O	D	
Minor construction support sites																															
Kitchener Street construction support site (B11)	BGC8																										D	D	D		D

Notes:
1. The activity SWL includes the adjustments for quantity of equipment assumed operating, equipment usage factor, and penalties for annoying characteristics in accordance with the ICNG. Refer to Annexure F
2. ACTIVITY KEY - Standard construction hours = 'D', OOHW = 'O', Standard construction hours and OOHW = 'DO'
3. MODELLED SCENARIO KEY – Shaded **blue** = Standard construction hours, Shaded **orange** = OOHW.

5.10.2.2 Construction assessment scenarios

Presented in Table 5-159 are the assessed activities for each works area, which represents the reasonable most intensive noise activity required as part of the works. Works that would occur occasionally have not been included in this assessment. However, it should be noted that the type of plant and equipment used throughout the stage would vary depending upon the construction activities being carried out. Table 5-159 summaries the noise generating works that have been assessed for the work areas. The activities that have been modelled during either standard construction hours or outside of standard construction hours are also coloured-coded accordingly in Table 5-158.

More details of the modelled plant items and relevant sound power levels are presented in Annexure F. The equipment/plant listed in Annexure F represent the reasonable 'typical' and 'worst case' equipment/plant operating simultaneously in any 15 minute period (refer to Section 4.2.3 for further explanation of assessment scenarios). Where plant items are not operating simultaneously, or for reduced times in the 15 minute period, noise impacts could be lower than predicted.

Table 5-159 – Assessed construction activities – Balgowlah surface road works

Works area reference (Figure 5-19)	Standard hours works	SWL range, $L_{Aeq\ 15\ minute}$ dB(A)		Out-of-hours works	SWL range $L_{Aeq\ 15\ minute}$ dB(A)	
		Typical	Worst case		Typical	Worst case
BGC1	Demolition (rock hammering)	109	121	Concrete barriers and traffic controls	99	105
BGC2	Demolition (rock hammering)	109	121	Resurfacing works	112	118
BGC3	Pile breaking	113	122	-	-	-
BGC4	Pile breaking	113	122	Deliveries (oversized)	110	111
BGC5	Paving/asphalting/ surface road works (including road saws)	109	120	-	-	-
BGC6	Utilities modification works	110	120	Utilities modification works	110	120
BGC7	Utilities modification works	110	120	Utilities modification works	110	120
BGC8	Deliveries (oversized)	110	111	-	-	-

Notes: 1. The activity SWL includes the adjustments for quantity of equipment assumed operating, equipment usage factor, and penalties for annoying characteristics in accordance with the ICNG. Refer to Annexure F for a description of the assumed equipment/plant that are operating.

5.10.2.3 Construction noise prediction summary

5.10.2.3.1 Major works areas

Table 5-161 to Table 5-166 present the predicted noise levels from construction activities and compare them with the NMLs for residential and non-residential receiver buildings. Table 5-167 and Table 5-168 present the approximate number of residential and non-residential receiver buildings respectively that exceed the NMLs in each NCA, as well as the number of residential receiver buildings that could potentially be highly noise affected over the duration of the works stage.

All receiver building counts presented in this assessment are based upon the reasonably highest noise levels that would occur throughout a works stage and when the works are working closest to each receiver building, defined as the highest noise level envelope explained in Section 4.2.3.2.1. In practice during any individual period of construction works the actual number of receiver buildings that could experience the highest predicted noise levels would be less that these maximum receiver building counts.

Residential receivers

The predicted noise levels are above standard construction hours NMLs in most NCAs nearby to the works, including NCAs 46.1, 46.2, 47.1, 48.1, 49.1, 50.1 and 51.1 in Seaforth, Clontarf, Balgowlah, North Balgowlah and Manly Vale, where the assessment outcomes are as follows:

- The highest predicted noise levels occur for receivers directly adjacent to the works or in close proximity in NCAs 46.1, 48.1, 49.1, 50.1 and 51.1 in Seaforth, Clontarf, Balgowlah and North Balgowlah
- During standard construction hours up to 127 receiver buildings for any one of the major works areas are predicted to be noise affected (ie >NML) during typical construction activities. However, this is predicted to increase to 912 noise affected receiver buildings during periods of worst case activities.
- The highest predicted noise levels occur when equipment such as road saws or rock hammers, associated with excavation works or utility modification works, are used in close proximity to receivers. For example, the two Burnt Bridge Creek Deviation southbound and northbound surface works (BCG1 and BCG2) major works areas and the Sydney Road road works (BGC7). For these works some receiver buildings are predicted to be highly noise affected (ie >75 dB(A)) during worst case works, however, this is unlikely to occur during typical works.
- No receiver buildings are predicted to be highly noise affected (ie >75 dB(A)) during typical activities over the entire works stage of the Burnt Bridge Creek Deviation southbound and northbound surface works (BCG1 and BCG2). When worst case activities occur, there is potential for up to 20 and 25 receiver buildings, respectively, to be highly noise affected (ie >75 dB(A)). Receivers are only likely to be highly noise affected when plant and equipment are closest to each receiver building.
- Typical construction noise levels are predicted to be above the standard construction hours NMLs by no more than 20 dB(A) at the closest receiver buildings over the entire works stage, which could be perceived as clearly audible to moderately intrusive, with the exception of one receiver for BGC2.
- During worst case works, construction noise levels are generally predicted to be no more than 25 dB(A) above the standard construction hours NMLs at the closest receiver buildings, which could be perceived as highly intrusive. All receivers except the closest receiver building for BCG5 and BCG7 and up to 24 receiver buildings located in NCA 49.1 and NCA 50.1 for the Burnt Bridge Creek Deviation southbound and northbound surface works (BCG1 and BCG2) are predicted to be within 20 dB(A) of the standard construction hours NMLs. The mitigation

measures installed as part of the Balgowlah Golf Course construction support site (BL10) (see Section 5.9) would assist with mitigating noise impacts to nearby receiver buildings, especially to receiver buildings to the east in NCA 48.1 and NCA 50.1.

Where works outside standard construction hours are required, noise impacts are predicted to be above the NMLs. The number of receiver buildings identified in Table 5-167 and Table 5-168 represent impacts for the entire works stage, based on when plant and equipment are closest to each receiver building. These numbers are much greater than the number of receiver buildings that would be noise affected on any individual night. The assessment indicates:

- The key OOHW noise generating activities are the traffic switching and resurfacing works along Burnt Bridge Creek Deviation (BCG1 and BCG2), support and deliveries for the cut and cover portal construction works (BCG4), and intersection and road works in the areas where the new access road connects at the Burnt Bridge Creek Deviation (BCG6) and Sydney Road (BCG7).
- Outside standard hours, for the major works area with the highest number of potentially noise affected receiver buildings, typical works for the works area are predicted to result in up to 2318 noise affected receiver buildings. This could increase to 4059 noise affected receiver buildings during periods of worst case noise intensive construction activities.
- Due to the length of the Burnt Bridge Creek Deviation southbound and northbound works (BCG1 and BCG2), these works have the highest number of potentially noise affected receiver buildings. The loudest activities would be road resurfacing works, which would move progressively along the extent of the major works area, and so that noise impacts would peak when closest to each receiver and reduce as the works move away.
- During road resurfacing works along the Burnt Bridge Creek Deviation (northbound) (BGC2)
  - Up to nine receivers could be highly noise affected (ie >75 dB(A)). Receivers are only likely to be highly noise affected when plant and equipment are closest to each receiver building.
  - During periods of typical construction works, noise levels could be more than 25 dB(A) above the night NML, at up to 63 receivers at a stage during the works. This could be perceived as highly intrusive.
  - During worst case construction works the number of receivers where construction noise is more than 25 dB(A) above the NML is predicted to increase to 137 receiver buildings. The numbers of noise affected (ie >NML) receiver buildings are for the entire works stage. However, a smaller number would experience these noise levels on any individual night as the works change location.
- For the intersection and road works in the areas where the new access road connects at the Burnt Bridge Creek Deviation (BCG6) and Sydney Road (BCG7), higher noise impacts are predicted for the Sydney Road (BCG7) works due to the proximity of residential receiver buildings and the elevated works location relative to receiver buildings. During the Sydney Road (BCG7) works:

  - Up to six receivers could be highly noise affected (ie >75 dB(A)) outside standard construction hours. Receivers are only likely to be highly noise affected when plant and equipment are closest to each receiver building.
  - During periods of typical utility modification works, construction noise levels could be more than 25 dB(A) above the night NML, which could be perceived as highly intrusive, at up to eight receivers during the works. When worst case construction activities occur, for example works which require the use of either road saws or rock hammers for periods, this number is predicted to increase to 41 receiver buildings. The numbers of receiver buildings for the entire works stage. However, a smaller number would experience more than 25 dB(A) exceedances on any individual night as the works change location.

- For other OOHW, during the cut and cover portal works (BGC4) and access road intersection works at Burnt Bridge Creek Deviation works (BCG6), there are no receivers predicted to be noise affected by more than 25 dB(A) when construction works are at typical intensity. During periods of worst case construction intensity up to two (BGC4) and up to eight (BGC10) residential receiver buildings, could be exposed to construction noise more than 25 dB(A) above the night NML, respectively.
- It is important to note that the highest exceedances are during worst case activities such as concrete sawing or rock hammering, which normally occur sporadically and for short periods of time.

Non-residential receivers

Construction noise levels at non-residential receiver buildings are generally predicted to achieve the NMLs, except for the key receivers identified below. The higher noise levels would only likely occur when works are taking place in close proximity to the receiver and are predicted to be lower when works take place at different locations within the major works area for both typical and worst case activities. The assessment of non-residential receivers found:

- Up to two childcare centres in NCA 47.1 (Peacock Street Long Day Care and Seaforth Infants School) and one childcare receiver in NCA 50.1 (Balgowlah Kinder Haven). Typical activities are predicted to achieve the screening NML for childcare centres. Generally, worst case impacts from Balgowlah surface road works are predicted to be up to 59 dB(A), which is above the external screening NML of 50 dB(A) $L_{Aeq\ 15minute}$ for childcare centres.
- During typical works, noise levels at schools are predicted to comply with NMLs, except for Northern Beaches Secondary College Balgowlah Boys in NCA 48.1 during BGC1, BCG2, BCG5 and BCG7. During worst case works there are other schools predicted to be noise affected. Up to four schools located in NCAs 46.1, 48.1, 49.1 and 50.1 are predicted to be above the NML during various stages of the works, two of which are predicted to more than 10 dB(A) above the NML (Northside Preschool (NCA 46.1) and Northern Beaches Secondary College Balgowlah Boys (NCA 48.1)). It should be noted that both of these receivers currently experience high existing daytime ambient noise levels from traffic on Sydney Road and Manly Road. Multiple school buildings are predicted to be noise affected in some schools.

- Up to 5 dB(A) above the NML is predicted at two places of worship in NCA 47.1 (Seaforth Anglican Church and Seaforth Baptist Church), and one places of worship in NCA 48.1 (The Catholic Community of North Harbour)
- Up to 7 dB(A) above the NML at the Balgowlah Scout HQ when the works are at the closest location
- Up to two commercial receivers on Sydney Road in NCA 46.1 during BCG1 and BCG2, and two commercial receivers on Sydney Road in NCA 48.1 during BCG5 and BCG7 are predicted to be noise affected.

Reasonable temporary acoustic screens, typical for the types of works that would take place in each major works area have been assumed as part of the modelling.

Construction mitigation and management measures are provided in Section 6 to assist in reducing construction noise impacts to other sensitive receivers. Specific details for the surface road works is provided in Section 6.4.

5.10.2.3.2 Minor construction support sites

The Balgowlah surface road works would be supported by two sites: one at Kitchener Street construction support site (BL11) (assessment reference BCG8), and the Balgowlah Golf Course construction support site (BL10) (assessed in Section 5.9). Temporary areas for laydown, offices and toilets would be within individual work areas and would shift with the work.

The key noise impacts for the Kitchener Street construction support site (BL11) on the nearby receivers are as discussed below.

Kitchener Street construction support site (BL11/BCG8)

The Kitchener Street construction support site (BL11) would predominantly operate during standard construction hours but might be used at times to support works outside standard construction hours.

An indicative noise barrier at least two metres high was assumed along the eastern boundary of the site. This should be reviewed during detailed construction planning for the Kitchener Street construction support site (BL11).

During oversized deliveries, worst case predicted noise levels at the nearest receiver buildings to the east in NCA 50.1 are up to 14 dB(A) above NML. When the works are further away within the minor construction support site predicted noise levels are within or marginally within (up to 1 dB(A)) the NML. Similar noise levels would be expected during other activities such as mobilisation and site establishment works.

No residential receiver buildings are predicted to be highly noise affected (ie >75 dB(A)) from activities at the minor construction support site even when all reasonable worst case noise intensive equipment are operating concurrently.

Where feasible and reasonable, use of this construction support site should be limited to standard construction hours.

As the construction support site design is refined, feasible and reasonable mitigation measures, should be implemented considering the construction support site layouts, equipment, construction methods or construction hours which may require specific mitigation and management measures that are different from those outlined in this section. During this process, the arrangement of the site layout should maximise acoustic shielding (ie locations of site sheds, offices and fixed structures) to the residential receivers directly to the east.

5.10.2.3.3 Sleep disturbance

The most likely sources of potential sleep disturbance from night construction works would be the use of rock hammers or road saws or construction equipment high noise events (ie metal on metal bangs or air brake releases). Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from works during the night period.

The predicted noise levels show exceedances of the sleep disturbance screening levels for most of the required night works. The works with the highest number of potential maximum noise levels are associated with the Burnt Bridge Creek Deviation southbound and northbound works (BCG1 and BCG2).

Across the length of BCG1, maximum noise levels at up to 718 receiver buildings are predicted to exceed the L_{Amax} sleep disturbance screening level during typical night works, with up to 97 receiver buildings predicted to experience L_{Amax} noise levels above the awakening reaction level. Up to 1097 receiver buildings are predicted to receive maximum noise levels above the screening level during worst case works; however, only up to 148 receiver buildings are predicted to exceed the awakening reaction level.

For the intersection and road works in the areas where the new access road connects at the Burnt Bridge Creek Deviation (BCG6) and Sydney Road (BCG7), up to around 90 and 148 receiver buildings, respectively, could potentially exceed the sleep disturbance screening level during typical works, and only up to three and 15 receiver buildings predicted to exceed awakening reaction levels during the worst case works, respectively. During worst case works this could increase to around 940 receiver buildings above the sleep disturbance screening level, with only 27 and 85 receiver buildings predicted to experience levels above the awakening reaction level.

Where sources of high noise events (ie metal on metal bangs or air brake releases) are managed or eliminated, this potential for sleep disturbance can be mitigated

5.10.2.3.4 Construction noise assessment outcomes

The Balgowlah surface road works requires limited OOHW; however, there are a number of key high noise generating activities that would require a ROL and so are likely completed during the night period.

Background noise levels in the suburbs surrounding the Burnt Bridge Creek Deviation are relatively low. This combined with the topography of the area, which provides line of site from the major works area to more receivers that if the area topography were flat, results in predicted noise levels at a large number of residential receiver buildings during worst case activities to be above the NML, even with the implementation of feasible and reasonable noise treatments. During other required OOHW typical noise impacts are more limited to around the works area; however, even with the incorporation of feasible and reasonable noise treatments predicted noise levels are above NMLs at some receivers.

Due to the nature of the surface road works, further acoustic mitigation, programming and alternative construction activity locations should be reviewed during design development and construction planning, to further reduce the residual impacts identified in this assessment. These measures are detailed in Section 6, with further surface road works measures included in Section 6.4.

5.10.2.4 Construction noise prediction tables

Table 5-160 provides a key to the cell shading and text formatting used to explain results in the following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-160 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes:
1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are expected to exceed NMLs. The range is of noise impacts throughout all receivers in the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented.

The predicted noise levels for nearby receiver locations are presented in the following tables:

- Table 5-161 to Table 5-162 for residential receivers during works during standard construction hours
- Table 5-163 to Table 5-164 for residential receivers during works outside standard construction hours
- Table 5-165 to Table 5-166 for non-residential receivers.

It is important to note that all results presented in this section represent the noise levels that occur over an entire stage/works area and not an individual activity/night. As such, the number of noise affected (ie >NML) receivers during individual works/activities or on an individual night area less than those presented.

The construction NMLs for all residential receivers nearby are presented in Annexure B.2, and for all other non-residential receivers see Section 3.4.1.2.

Predicted noise levels are intended to be conservative and represent reasonable typical and worst case impacts over the entirety of each stage of the project.

The assessed major works areas are presented in Table 5-172. The highest 'typical' noise levels that have been predicted for all major works areas are presented as noise contour envelopes in Annexure H.2. Maps presenting the predicted exceedance for a sample of scenarios from the major works areas with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

These present the extent of typical predicted noise impacts during standard hours, and for key OOHW periods to give an indication of the likely extent of noise levels from the specific major works areas that make up the Balgowlah surface road works.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different periods.

Table 5-161 – BCG1 to BCG4 predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – standard hours (residential receivers) – Balgowlah surface road works

Major works area/assessment reference				BGC1		BGC2		BGC3[6]		BGC4[6]	
Typical/worst case activity noise intensity				Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver				Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level		Predicted noise levels, $L_{Aeq\ (15\ minute)}$							
		HNA	NML								
Seaforth	39.2	75	47	< 35	≤ 42	< 35	31 / 42	< 35	40 / 41	< 35	41 / 42
	46.2	75	68	42 / 59	54 / 71	42 / 59	54 / 71	46 / 47	55 / 56	48 / 50	57 / 59
	47.1	75	53	39 / 49	51 / 61	41 / 50	53 / 62	45 / 50	54 / 59	47 / 49	56 / 58
	47.2	75	53	34 / 40	46 / 52	≤ 39	30 / 51	41 / 43	50 / 52	42 / 43	51 / 52
	49.1	75	55	41 / 69	53 / **81**	≤ 68	40 / **80**	54 / 65	63 / 74	59 / 66	68 / 75
	53.1	75	58	< 35	37 / 45	< 35	35 / 42	35 / 36	44 / 45	35 / 36	44 / 45
	53.2	75	58	< 35	37 / 46	< 35	37 / 45	35 / 36	44 / 45	35 / 36	44 / 45
	53.3	75	58	≤ 41	32 / 53	≤ 40	32 / 52	43 / 45	52 / 54	41 / 42	50 / 51
	54.1	75	55	< 35	35 / 43	< 35	34 / 41	34 / 35	43 / 44	< 35	43
Clontarf	45.1	75	50	< 35	≤ 45	< 35	≤ 45	35 / 37	44 / 46	34 / 36	43 / 45
	46.1	75	68	44 / 70	56 / **82**	44 / 68	56 / **80**	50 / 53	59 / 62	55 / 57	64 / 66
Balgowlah	48.1	75	65	36 / 52	48 / 64	37 / 52	49 / 64	47 / 50	56 / 59	49 / 51	58 / 60
	50.1	75	57	43 / 67	55 / **79**	44 / 65	56 / **77**	49 / 51	58 / 60	50 / 51	59 / 60
North Balgowlah	51.1	75	53	41 / 70	53 / **82**	34 / 74	46 / **86**	59 / 64	68 / 73	53 / 55	62 / 64
	53.4	75	58	≤ 37	≤ 49	≤ 36	30 / 48	38 / 40	47 / 49	39 / 41	48 / 50
Manly Vale	52.1	75	59	41 / 52	53 / 64	39 / 50	51 / 62	41	50	39 / 40	48 / 49

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-160
5. Table features are explained further in Section 4.2.3.2
6. Reasonable temporary acoustic screens, typical for these types of works, have been assumed erected nearby to the works area as part of the modelling.

Table 5-162 – BCG5 to BCG8 predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – standard hours (residential receivers) – Balgowlah surface road works

Major works area/assessment reference				BGC5		BGC6[6]		BGC7[6]		BGC8	
Typical/worst case activity noise intensity				Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver				Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level		Predicted noise levels, $L_{Aeq\ (15\ minute)}$							
		HNA	NML								
Seaforth	39.2	75	47	< 35	35 / 38	< 35	< 35	< 35	40 / 41	34 / 36	35 / 37
	42.1	75	52	< 35	36 / 38	< 35	< 35	< 35	40 / 41	< 35	< 35
	46.2	75	68	35 / 40	46 / 51	39	49 / 50	38 / 41	49 / 51	42 / 43	43
	47.1	75	53	32 / 47	43 / 58	45 / 46	56	40 / 42	50 / 52	37 / 43	37 / 43
	47.2	75	53	31 / 35	42 / 46	37 / 38	48	38 / 39	48 / 50	39 / 42	40 / 43
	49.1	75	55	48 / 60	59 / 71	50 / 52	60 / 63	50 / 57	60 / 68	42 / 44	43 / 44
	53.1	75	58	< 35	37 / 40	< 35	40	< 35	39 / 40	36 / 37	36 / 37
	53.2	75	58	< 35	39 / 41	< 35	42	< 35	41 / 42	34 / 35	34 / 36
	53.3	75	58	32 / 37	43 / 48	39	49 / 50	35 / 37	45 / 47	39 / 42	40 / 43
	54.1	75	55	< 35	36 / 38	< 35	39	< 35	38 / 39	< 35	34 / 35
Clontarf	45.1	75	50	< 35	38 / 42	< 35	37 / 38	< 35	43 / 45	34 / 37	35 / 38
	46.1	75	68	46 / 54	57 / 65	41 / 42	52	46 / 51	57 / 62	43 / 44	43 / 44
Balgowlah	48.1	75	65	46 / 64	57 / 75	45 / 46	56	50 / **76**	60 / **86**	44 / 46	45 / 47
	50.1	75	57	46 / 58	57 / 69	48	58 / 59	49 / 60	59 / 71	57 / 71	58 / 71
North Balgowlah	51.1	75	53	49 / 64	60 / 75	59 / 62	69 / 73	42 / 44	53 / 55	54 / 66	55 / 66
	53.4	75	58	< 35	39 / 44	< 35	44	< 35	42 / 45	39 / 41	40 / 42
Manly Vale	52.1	75	59	34 / 36	45 / 47	36	46	35 / 36	45 / 46	52 / 56	53 / 56

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-160
5. Table features are explained further in Section 4.2.3.2
6. Reasonable temporary acoustic screens, typical for these types of works, have been assumed erected nearby to the works area as part of the modelling.

Table 5-163 – BCG1 to BCG4 predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – outside standard hours (residential receivers) – Balgowlah surface road works

Major works area/assessment reference						BGC1		BGC2		BGC3[6]		BGC4[7]	
Typical/worst case activity noise intensity						Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver						Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level				Predicted noise levels, $L_{Aeq\ (15\ minute)}$							
		HNA	Day (O)	Eve	Ngt								
Seaforth	39.2	75	42	39	35	< 35	< 35	< 35	≤ 39	-	-	< 35	< 35
	46.2	75	63	59	42	32 / 49	38 / 55	45 / 62	51 / 68	-	-	45 / 47	46 / 48
	47.1	75	48	44	35	≤ 39	35 / 45	44 / 53	50 / 59	-	-	44 / 46	44 / 47
	47.2	75	48	44	35	< 35	30 / 36	≤ 42	≤ 48	-	-	39 / 40	40 / 41
	49.1	75	50	47	36	31 / 59	37 / 65	31 / 71	37 / **77**	-	-	56 / 63	56 / 64
	53.1	75	53	44	35	< 35	< 35	< 35	32 / 39	-	-	< 35	< 35
	53.2	75	53	44	35	< 35	< 35	28 / 36	34 / 42	-	-	< 35	< 35
	53.3	75	53	44	35	< 35	≤ 37	≤ 43	≤ 49	-	-	38 / 39	39 / 40
	54.1	75	50	44	35	< 35	< 35	< 35	31 / 38	-	-	< 35	< 35
Clontarf	45.1	75	45	43	38	< 35	< 35	≤ 36	≤ 42	-	-	< 35	< 35
	46.1	75	63	59	42	34 / 60	40 / 66	47 / 71	53 / **77**	-	-	52 / 54	52 / 54
Balgowlah	48.1	75	60	55	37	≤ 42	32 / 48	40 / 55	46 / 61	-	-	46 / 48	47 / 49
	50.1	75	52	50	40	33 / 57	39 / 63	47 / 68	53 / 74	-	-	47 / 48	47 / 49
North Balgowlah	51.1	75	48	45	38	31 / 60	37 / 66	37 / **77**	43 / **83**	-	-	50 / 52	51 / 53
	53.4	75	53	44	35	< 35	< 35	≤ 39	≤ 45	-	-	36 / 38	37 / 38
Manly Vale	52.1	75	54	50	41	31 / 42	37 / 48	42 / 53	48 / 59	-	-	36 / 37	37

Notes:

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-160
5. Table features are explained further in Section 4.2.3.2
6. No work is proposed outside standard construction hours
7. Reasonable temporary acoustic screens, typical for these types of works, have been assumed erected nearby to the works area as part of the modelling.

Table 5-164 – BCG5 to BCG8 predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – outside standard hours (residential receivers) – Balgowlah surface road works

Major works area/assessment reference						BGC5[6]		BGC6[7]		BGC7[7]		BGC8[6]	
Typical/worst case activity noise intensity						Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver						Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level				Predicted noise levels, $L_{Aeq\ (15\ minute)}$							
		HNA	Day (O)	Eve	Ngt								
Seaforth	39.2	75	42	39	35	-	-	< 35	< 35	< 35	40 / 41	-	-
	42.1	75	47	43	41	-	-	< 35	< 35	< 35	40 / 41	-	-
	46.2	75	63	59	42	-	-	39	49 / 50	38 / 41	49 / 51	-	-
	47.1	75	48	44	35	-	-	45 / 46	56	40 / 42	50 / 52	-	-
	47.2	75	48	44	35	-	-	37 / 38	48	38 / 39	48 / 50	-	-
	49.1	75	50	47	36	-	-	50 / 52	60 / 63	50 / 57	60 / 68	-	-
	53.1	75	53	44	35	-	-	< 35	40	< 35	39 / 40	-	-
	53.2	75	53	44	35	-	-	< 35	42	< 35	41 / 42	-	-
	53.3	75	53	44	35	-	-	39	49 / 50	35 / 37	45 / 47	-	-
	54.1	75	50	44	35	-	-	< 35	39	< 35	38 / 39	-	-
Clontarf	45.1	75	45	43	38	-	-	< 35	37 / 38	< 35	43 / 45	-	-
	46.1	75	63	59	42	-	-	41 / 42	52	46 / 51	57 / 62	-	-
Balgowlah	48.1	75	60	55	37	-	-	45 / 46	56	50 / **76**	60 / **86**	-	-
	50.1	75	52	50	40	-	-	48	58 / 59	49 / 60	59 / 71	-	-
North Balgowlah	51.1	75	48	45	38	-	-	59 / 62	69 / 73	42 / 44	53 / 55	-	-
	53.4	75	53	44	35	-	-	< 35	44	< 35	42 / 45	-	-
Manly Vale	52.1	75	54	50	41	-	-	36	46	35 / 36	45 / 46	-	-

Notes:

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-160
5. Table features are explained further in Section 4.2.3.2
6. No work is proposed outside standard construction hours
7. Reasonable temporary acoustic screens, typical for these types of works, have been assumed erected nearby to the works area as part of the modelling.

Table 5-165 – BCG1 to BCG4 predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – non-residential receivers – Balgowlah surface road works

Major works area/assessment reference			BGC1		BGC2		BGC3[6]		BGC4[6]	
Typical/worst case activity noise intensity			Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver			Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
OSR type	NCA	NML[6]	Predicted noise levels, $L_{Aeq\ (15\ minute)}$							
Commercial	46.1	70	42 / 68	54 / 80	42 / 65	54 / 77	50 / 53	59 / 62	55 / 57	64 / 66
	46.2	70	39 / 55	51 / 67	39 / 56	51 / 68	47 / 49	56 / 58	50 / 51	59 / 60
Childcare	47.1	50	33 / 43	45 / 55	33 / 43	45 / 55	41 / 46	50 / 55	44 / 46	53 / 55
	50.1	50	≤ 46	34 / 58	≤ 47	38 / 59	47 / 50	56 / 59	48 / 49	57 / 58
	53.3	50	≤ 36	≤ 48	≤ 36	≤ 48	38 / 40	47 / 49	38 / 40	47 / 49
Educational	46.1	55	≤ 52	38 / 64	30 / 54	42 / 66	44 / 47	53 / 56	48 / 50	57 / 59
	48.1	55	41 / 57	53 / 69	42 / 57	54 / 69	48 / 50	57 / 59	51 / 53	60 / 62
	49.1	55	≤ 49	33 / 61	≤ 48	≤ 60	41 / 52	50 / 61	45 / 52	54 / 61
	50.1	55	≤ 49	37 / 61	≤ 50	41 / 62	41 / 43	50 / 52	40 / 41	49 / 50
	52.1	55	30 / 41	42 / 53	29 / 40	41 / 52	38 / 39	47 / 48	37	46
Other sensitive receiver	50.1	65	≤ 52	41 / 64	32 / 53	44 / 65	49 / 52	58 / 61	48 / 50	57 / 59
Place of worship	47.1	55	37 / 47	49 / 59	34 / 44	46 / 56	44 / 49	53 / 58	47 / 50	56 / 59
	48.1	55	≤ 45	41 / 57	30 / 45	42 / 57	41 / 44	50 / 53	45 / 46	54 / 55
Recreational	50.1	60	31 / 55	43 / 67	35 / 56	47 / 68	49 / 52	58 / 61	49 / 51	58 / 60
	51.1	60	≤ 46	≤ 58	≤ 43	≤ 55	35 / 41	44 / 50	41 / 42	50 / 51

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML. A full key is presented in Table 5-160
5. Table features are explained further in Section 4.2.3.2
6. Other sensitive receivers have a range of NMLs based upon the receiver classification as outlined in Section 3.4.1.2.The exceedances are based upon the respective receiver NML
7. Reasonable temporary acoustic screens, typical for these types of works, have been assumed erected nearby to the works area as part of the modelling.

Table 5-166 – BCG5 to BCG8 predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – non-residential receivers – Balgowlah surface road works

Major works area/assessment reference			BGC5		BGC6[7]		BGC7[7]		BGC8	
Typical/worst case activity noise intensity			Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver			Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
OSR type	NCA	NML[6]	Predicted noise levels, $L_{Aeq\ (15\ minute)}$							
Commercial	46.1	70	44 / 51	55 / 62	42	52	45 / 50	55 / 60	41 / 42	42 / 43
	48.1	70	51 / 68	62 / 79	42 / 43	53	44 / 70	55 / 81	42 / 43	43 / 44
	50.1	70	42 / 54	53 / 65	45 / 46	55 / 56	47 / 59	57 / 69	34 / 47	34 / 48
Childcare	47.1	50	26 / 40	37 / 51	40	50 / 51	38 / 40	48 / 51	35 / 41	35 / 41
	50.1	50	46 / 58	57 / 69	44 / 45	54 / 55	51 / 63	61 / 73	29 / 43	30 / 43
	53.3	50	< 35	39 / 44	35	45 / 46	< 35	42 / 44	35 / 38	36 / 39
Educational	46.1	55	32 / 39	43 / 50	38	48 / 49	31 / 36	41 / 46	41 / 42	42 / 43
	48.1	55	44 / 62	55 / 73	41	51 / 52	36 / 62	46 / 72	44 / 45	44 / 46
	49.1	55	33 / 45	44 / 56	43 / 46	54 / 56	34 / 42	45 / 52	42 / 43	42 / 44
	50.1	55	27 / 40	38 / 51	38 / 39	48 / 49	25 / 36	35 / 47	40 / 54	41 / 55
Other sensitive receiver[6]	50.1	65	48 / 61	59 / 72	48 / 49	58 / 59	38 / 50	49 / 60	39 / 52	39 / 53
Place of worship	47.1	55	27 / 41	38 / 52	41 / 42	51 / 52	39 / 42	50 / 52	36 / 42	37 / 43
	47.2	55	< 35	39 / 44	< 35	35 / 36	35 / 37	46 / 47	33 / 36	33 / 36
	48.1	55	30 / 47	41 / 58	41	51 / 52	24 / 50	34 / 60	41 / 43	42 / 43
Recreational[6]	50.1	65	51 / 63	62 / 74	47 / 48	58	41 / 53	51 / 63	43 / 57	44 / 57

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML. A full key is presented in Table 5-160
5. Table features are explained further in Section 4.2.3.2
6. Other sensitive receivers have a range of NMLs based upon the receiver classification as outlined in Section 3.4.1.2.The exceedances are based upon the respective receiver NML
7. Reasonable temporary acoustic screens, typical for these types of works, have been assumed erected nearby to the works area as part of the modelling.

Table 5-167 – Number of residential receiver buildings over the noise management level (major works areas) – All NCAs – Balgowlah surface road works

Works area	Assessment reference	Typical/worst case activity noise intensity	Highly noise affected > 75 dB(A)		Day (standard hours)			Day (outside standard hours)				Evening				Night				Sleep disturbance	
			Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening level (L_{Amax})	Awakening (L_{Amax})
Burnt Bridge Creek Deviation surface works (southbound)	BGC1	Typical	0	0	116	11	0	35	11	0	0	49	31	0	0	259	147	24	0	718	97
		Worst case	**20**	0	730	158	24	97	57	1	0	163	88	6	0	573	450	79	5	1097	148
Burnt Bridge Creek Deviation surface works (northbound)	BGC2	Typical	0	**1**	104	15	1	218	161	32	1	364	251	64	3	984	1059	212	63	654	99
		Worst case	**25**	**9**	624	148	24	604	376	89	14	762	642	139	24	1458	1807	657	137	994	153
Trough works[1]	BGC3	Typical	0	0	52	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	0	464	45	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cut and cover portal works	BGC4	Typical	0	0	37	1	0	43	22	0	0	99	37	1	0	780	434	30	1	196	7
		Worst case	0	0	401	29	0	54	24	0	0	134	42	1	0	857	509	37	2	455	22
Access road within Balgowlah Golf Course [1]	BGC5	Typical	0	0	11	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	0	225	17	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Access road intersection works at Burnt Bridge Creek Deviation	BGC6	Typical	0	0	5	0	0	22	5	0	0	50	14	1	0	622	191	8	0	90	3
		Worst case	0	0	99	5	0	449	99	5	0	682	282	15	1	1217	1590	220	8	939	27
Sydney Road roadworks	BGC7	Typical	**1**	**1**	8	1	0	11	8	1	0	25	12	4	0	534	230	31	8	148	15
		Worst case	**6**	**6**	53	8	1	394	53	8	1	797	217	13	4	1523	1940	264	41	935	85
Kitchener Street minor construction support site (BL11)[1]	BGC8	Typical	0	0	94	6	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	0	109	8	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:
1. No typical work is proposed outside standard construction hours
2. 'Typical' and 'Worst case' case noise assessment scenarios are explained in Section 4.2.3.2.2, and demonstrated in Figure 4-8
3. Refer to the "Required out of hours work" table in the section "Construction hours and durations" of this assessment section for an indication of the duration and how often these noise impacts are expected to occur
4. An indicative program and timeline in provided at the beginning of this section to provide an indication of the duration of these construction works and the associated construction noise impacts.

Table 5-168 – Number of non-residential receivers over the noise management level (major works areas) (All NCAs) – Balgowlah surface road works

Works area	Assessment reference	Typical/worst case activity noise intensity	Commercial[2]			Childcare			Educational[6]			Recreational[2]			Places of worship			Other sensitive receivers[2]		
			1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
Burnt Bridge Creek Deviation surface works (southbound)	BGC1	Typical	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Worst case	2	0	0	3	0	0	20	1	0	1	0	0	5	0	0	0	0	0
Burnt Bridge Creek Deviation surface works (northbound)	BGC2	Typical	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Worst case	2	0	0	3	0	0	18	2	0	1	0	0	3	0	0	0	0	0
Trough works[1]	BGC3	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	3	0	0	17	0	0	0	0	0	2	0	0	0	0	0
Cut and cover portal works	BGC4	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	3	0	0	18	0	0	0	0	0	2	0	0	0	0	0
Access road within Balgowlah Golf Course [1]	BGC5	Typical	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Worst case	2	0	0	3	0	0	20	1	0	1	0	0	5	0	0	0	0	0
Access road intersection works at Burnt Bridge Creek Deviation	BGC6	Typical	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Worst case	2	0	0	3	0	0	18	2	0	1	0	0	3	0	0	0	0	0
Sydney Road roadworks	BGC7	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	3	0	0	17	0	0	0	0	0	2	0	0	0	0	0
Kitchener Street minor construction support site (BL11)[1]	BGC8	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	3	0	0	18	0	0	0	0	0	2	0	0	0	0	0

Notes:
1. No typical work is proposed outside standard construction hours
2. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table
3. 'Typical' and 'Worst case' case noise assessment scenarios are explained in Section 4.2.3.2.2, and demonstrated in Figure 4-8
4. Refer to the "Required out of hours work" table in the section "Construction hours and durations" of this assessment section for an indication of the duration and how often these noise impacts are expected to occur
5. An indicative program and timeline in provided at the beginning of this section to provide an indication of the duration of these construction works and the associated construction noise impacts
6. Multiple buildings at Northern Beaches Secondary College Balgowlah Boys (NCA 48.1), Seaforth Public School (NCA 49.1) are identified as potentially noise affected. All school buildings are included in the count.

5.10.2.5 Cumulative construction noise impacts

Currently, there are no other known major construction projects that are likely to result in cumulative noise impacts on the receivers nearby to the Balgowlah surface road works areas.

However, there is the potential for cumulative noise impacts from other construction activities associated with the project, as noted in Section 5.10.1.6.

For the Balgowlah surface road works, the proposed staging of concurrent construction works associated with the project and other nearby major infrastructure projects that are considered for cumulative construction impacts are presented in Table 5-169.

Table 5-169 – Concurrent construction works near the Balgowlah surface road works areas

Project component	2023				2024				2025				2026				2027				2028			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Balgowlah surface road works (BCG)																								
Balgowlah Golf Course construction support site (BAL)																								

Table 5-170 and Table 5-171 presents all the major works areas and nearby major construction projects, and indicates if the predicted noise levels during typical construction activities are predicted to exceed the NML in each NCA.

When construction is carried out in more than one major works area at the same time and if both are predicted to exceed the NML in the same NCA then there this is the potential for an increase in construction noise levels in that NCA due to cumulative noise impacts.

Worst case noise activities have not been included in the cumulative noise assessment, as they are likely to be infrequent and sporadic. It is unlikely that they would occur simultaneously in more than one works area. Worst case impacts have the potential to impact a larger number of NCAs than presented in Table 5-170 and Table 5-171. For worst case works there is greater chance that the same NCAs may be impacted over consecutive nights and so could result in consecutive impacts. This is because the worst case activities are more noise intensive and affect a large range of receivers than for typical activities. Depending upon when they are to occur, both typical and worst case activities may require consideration when determining respite provisions.

Table 5-170 and Table 5-171 shows that similar NCAs could be impacted by both the Balgowlah surface road works (BCG) and the Balgowlah Golf Course construction support site (BAL) during both standard hours and when OOHW are proposed to occur.

During standard construction hours, there is potential for cumulative construction noise levels over the NMLs for NCAs 48.1, 49.1, 50.1 and 51.1. Outside standard construction hours the key points for cumulative construction noise are as follows:

- For cumulative impacts with the Balgowlah Golf Course construction support site (BAL) construction works, as the long term tunnelling and tunnel fitout works are predicted to achieve

the night period NML, cumulative increases that could result in receivers being noise affected would be limited to receivers nearby the construction support site. Cumulative increase could occur during key OOHW noise generating activities associated with the Balgowlah surface road works, which are traffic switching and resurfacing works along Burnt Bridge Creek Deviation (BCG1 and BCG2), support and deliveries for the cut and cover portal construction works (BCG4), and intersection and road works in the areas where the new access road connects at the Burnt Bridge Creek Deviation (BCG6) and Sydney Road (BCG7).

- The potential for cumulative noise levels over the NMLs vary for each of the Balgowlah surface road works (BCG) major works areas, but there are potential cumulative increases for receivers in NCAs 47.1, 48.1. 49.1, 50.1 and 51.1 at stages during the works.
- For cumulative impacts between the various Balgowlah surface road works (BCG), there is the potential for cumulative noise levels over the NMLs. For most of the major works areas where OOHW could occur noise levels are predicted to be over the NMLs for similar NCAs.

As such, the staging, coordination and management of potential cumulative noise levels for these NCAs should be considered during detailed construction planning where feasible and reasonable. Construction works where cumulative noise levels are predicted should be scheduled to provide respite to noise affected (ie >NML) receivers as outlined and recommended the CNVG (see Annexure G) and further detailed in Section 6.4.3. Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5.

Table 5-170 – Noise affected (ie >NML) NCAs for each major works area – typical activities (standard hours) – Balgowlah surface road works

Suburb	NCA	Daytime NML	BGC1	BGC2	BGC3	BGC4	BGC5	BGC6	BGC7	BGC8	BAL[2]
Seaforth	39.2	47									
	42.1	52									
	46.2	68									
	47.1	53									♦
	47.2	53									
	49.1	55	♦	♦	♦	♦	♦		♦		♦
	53.1	58									
	53.2	58									
	53.3	58									
	54.1	55									
Clontarf	45.1	50									
	46.1	68	♦								
Balgowlah	48.1	65							♦		♦
	50.1	57	♦	♦			♦		♦	♦	♦
North Balgowlah	51.1	53	♦	♦	♦	♦	♦	♦		♦	♦
	53.4	58									
Manly Vale	52.1	59									

Notes:
1. ♦ and (blue) shading indicates 'typical' construction activities are predicted to exceed the Daytime NML receivers in that NCA are considered 'noise affected'
2. Balgowlah Golf Course construction support site (BAL). See Section 5.9. Potential for 'noise affected' based upon the highest prediction across all stages.

Table 5-171 – Noise affected (ie >NML) NCAs for each major works area – typical activities (OOHW) – Balgowlah surface road works

Suburb	NCA	Night NML	BGC1	BGC2	BGC3	BGC4	BGC5	BGC6	BGC7	BGC8	BAL[2]
Seaforth	39.2	35									
	42.1	41									
	46.2	42	♦	♦		♦					
	47.1	35	♦	♦		♦		♦	♦		♦
	47.2	35		♦		♦		♦	♦		
	49.1	36	♦	♦		♦		♦	♦		♦
	53.1	35									
	53.2	35		♦							
	53.3	35		♦		♦		♦	♦		
	54.1	35									
Clontarf	45.1	38									
	46.1	42	♦	♦		♦			♦		♦
Balgowlah	48.1	37	♦	♦		♦		♦	♦		♦
	50.1	40	♦	♦		♦		♦	♦		♦
North Balgowlah	51.1	38	♦	♦		♦		♦	♦		♦
	53.4	35		♦		♦					
Manly Vale	52.1	41	♦	♦							

Notes: 1. ♦ and (**orange**) shading indicates 'typical' construction activities are predicted to exceed the Night NML receivers in that NCA are considered 'noise affected'

2. Balgowlah Golf Course construction support site (BAL). See Section 5.9. Potential for 'noise affected' based upon the highest prediction across all stages.

5.10.3 Construction road traffic noise

5.10.3.1 Traffic switching

A number of traffic switching arrangements along the Burnt Bridge Creek Deviation would be used during the construction of the Balgowlah surface road works. Traffic switching is to create the safe working space required to enable the construction of the cut and cover tunnel entry and exit points. Proposed traffic switching arrangements have been planned to minimise disruption to traffic by reducing the required traffic changes to only three major traffic stages.

As part of traffic switching, once the new lane has been constructed along the Burnt Bridge Creek Deviation, southbound traffic would be relocated onto that lane. This would result in the southbound lane being further from receivers to the west of the Burnt Bridge Creek Deviation, shifting up to 15 metres east of the current location, further reducing road traffic noise impacts. For construction works along the northbound lanes of the Burnt Bridge Creek Deviation, northbound traffic would be relocated onto the existing southbound traffic lanes. In addition to this, there would likely be periods of localised switching along both the existing southbound and northbound. Each of these construction stages for the Balgowlah surface road works, along with the associated traffic stage, would take around 18 months to complete and would require some out of hours work, mostly for short periods when traffic is switched between stages.

During the construction of the Balgowlah surface road works, traffic speeds along the Burnt Bridge Creek Deviation would decrease from current posted speeds of 80 kilometres per hour down to either

60 kilometres per hour during the construction period, or where required 40 kilometres per hour when works are taking place adjacent to live traffic, road traffic noise levels would also reduce.

In all cases for receivers along the west of Burnt Bridge Creek Deviation (NCA 49.1), the traffic following the switch would be further away than the current situation. For the receivers along the east of the Balgowlah Golf course (NCA 50.1) the relative change in distance from the existing traffic lanes to where the traffic would be following the traffic switch, would result in a negligible difference (less than 0.5 dB(A)) in road traffic noise, when considering the distance change alone.

Further to the above, for the receivers to the east of Burnt Bridge Creek Deviation on Dudley Street, the existing noise wall along the eastern side of Burnt Bridge Creek Deviation would be removed as part of the construction works, along with the noise reduction benefits from this wall. While almost all residential properties along Dudley Street would be acquired and demolished as part of the project, it is recommended that as part of further design development, feasible and reasonable mitigation measures for road traffic noise impacts, such as installation of temporary noise barriers, be further investigated and implemented were feasible and reasonable to attenuate increases in road traffic noise at any remaining residences.

There would likely be an overall decrease in road traffic noise level at all receivers nearby to the Burnt Bridge Creek Deviation, with the potential exception of the receivers to the east of Burnt Bridge Creek Deviation on Dudley Street, as a result of the planned traffic switching arrangements during the construction period.

5.10.3.2 Heavy vehicle operations associated with the surface road works.

Heavy vehicles would mostly travel between work areas via the Burnt Bridge Creek Deviation, Sydney Road or from the Balgowlah Golf Course construction support site. These vehicles would travel to and from the Balgowlah surface road works via these and other major arterial roads in the area, moving directly to the work sites.

The predicted increase in road traffic noise levels from construction vehicles as part of the Balgowlah surface road works indicates that construction traffic would have minimal impact on the surrounding road network, as overall road traffic noise levels are unlikely to increase by more than 2 dB(A).

Mitigation and management measures detailed in Section 6.7 should be considered during further design development and construction planning and, where feasible and reasonable, adopted to minimise construction traffic noise impacts associated with the project.

5.10.4 Ground-borne construction noise

Ground-borne noise levels have the potential to be generated by vibration intensive works at the surface road works and associated construction support sites. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers. Section 4.3.2 outlines the potential impacts from ground-borne noise generated by surface construction works such as these.

5.10.5 Construction vibration

Across the Balgowlah surface road works, vibration intensive activities such as rock hammering could be required as part of the road works. These activities have been assessed for potential vibration impacts using minimum working distances of 22 metres for sound structures, 30 metres for unsound structures and 73 metres for adverse human response.

Vibration levels generated from construction works would vary depending on the level and type of activity carried out at each site during each stage. The minimum working distances for a range of plant are presented in Table 4-11, and the works area specific minimum working distances for each of the major works area are presented in Annexure L. The major works areas that have been assessed are identified in Table 5-172.

The number of properties that are within the minimum working distances for various works areas, which have been grouped into similar types and locations, is presented in Table 5-172. Potential vibration impacts to receivers would depend on vibration source levels, the separation distance, the intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. When construction works occur within the minimum working distance of nearby sensitive structures they should be assessed during further design development and construction planning, as recommended in Section 6.8.

Table 5-172 – Number of structures within nominated minimum working distance for vibration impacts – Balgowlah surface road works

Major works area reference (Figure 5-19)	Major works area	NCA	Number of receivers within minimum working distance		
			Cosmetic damage		Human response
			Sound structure	Unsound structure	
BGC1	Burnt Bridge Creek Deviation surface works (southbound)	46.1	-	-	8
		49.1	1	-	40
		50.1	-	-	7
		51.1	1	-	50
BGC2	Burnt Bridge Creek Deviation surface works (northbound)	46.1	-	-	6
		49.1	19	-	51
		50.1	-	-	3
		51.1	17	-	75
BGC3	Trough works	49.1	-	-	16
BGC4	Cut and cover portal works	49.1	-	-	16
BGC5	Access road within Balgowlah Golf Course	48.1	-	-	7
		49.1	-	-	2
		50.1	-	-	2
		51.1	-	-	3
BGC6	Access road intersection works at Burnt Bridge Creek Deviation	49.1	-	-	3
		51.1	-	-	4

Major works area reference (Figure 5-19)	Major works area	NCA	Number of receivers within minimum working distance		
			Cosmetic damage		Human response
			Sound structure	Unsound structure	
BGC7	Sydney Road roadworks	48.1	8	-	31
		49.1	-	-	3
		50.1	-	-	5

Cosmetic damage

Up to 44 non-heritage receiver buildings would be within minimum working distances for cosmetic damage, as presented in Table 5-172 and Annexure L.

Burnt Bridge Creek Deviation surface works (northbound) (BGC2) has the highest number of non-heritage receiver buildings located within the minimum working distance for light framed structures for any one major works area, assuming the use of large rock hammers as part of the works, for which 36 receiver buildings are identified. This is due to the proximity of the works area to the buildings to the west of Burnt Bridge Creek Deviation along Hope Street. Receiver buildings are also identified within this minimum working distance for Burnt Bridge Creek Deviation surface works (southbound) (BGC1) and Sydney Road roadworks (BGC7).

These estimates are conservative, and so during detailed construction planning when the vibration generating plant and the locations that it would be used are known, the number of structures that are within minimum working distances should be reviewed.

Human response

Up to 197 non-heritage receiver buildings would be within minimum working distance for adverse human response.

Up to 135 various types of sensitive receiver buildings are within the minimum working distance for adverse human response during works for Burnt Bridge Creek Deviation surface works (northbound) (BGC2), with less for other major works areas.

For these receivers there is the potential to perceive vibration impacts during activities that require vibration intensive plant items such as large rock hammers, but less receivers would be impacted during individual activities.

This is a conservative screening assessment and where less vibration intensive plant are used, vibration is attenuated or there are discontinuity in the ground between the plant and receiver, the chance of perceived vibration reduces.

5.10.5.1 Heritage listed structures

The figures in Annexure L show the relative locations of heritage items nearby to all the assessed major works areas, along with the minimum working distances for vibration impacts.

No heritage items have been identified to fall within the minimum working distance for unsound structures across the construction works required for the Balgowlah surface road works.

5.10.5.2 Vibration mitigation and management

Further analysis and assessment of potential vibration impact should be carried out during further design development and construction planning, when likely plant and equipment, timing and location of works are known.

Due to the varying nature of vibration intensive activities, cumulative vibration impacts are unlikely to result in increased vibration levels at sensitive receivers. However, all vibration generating activities should be considered during detailed construction planning, and individual activities would not only be considered in isolation.

Vibration mitigation and management measures would be used to minimise any possible impacts. The measures adopted for this project are outlined in Section 6 and should be included in a CNVMP.

5.11 Wakehurst Parkway south construction support site (BL12)

This section assesses the potential construction noise and vibration impacts, and the reasonable and feasible measures that would be considered to control impacts on noise and vibration sensitive receivers near the Wakehurst Parkway south construction support site (BL12).

5.11.1 Construction support site overview

5.11.1.1 Construction support site description

Work at the site would occur in stages as presented in Table 5-173.

Table 5-173 –Wakehurst Parkway south construction support site (BL12) – stage overview

Stage	Representative activity	Major stage activities/description
Site establishment	1. Early works	Connect and relocate services at the site such as electricity, sewerage and water
	2. Establish site	Install environmental controls, clearing and grubbing, road and intersection modifications and installation of traffic controls, establish facilities
Surface road works support	3. Support surface road works	General activities and deliveries to/from the site to support the Wakehurst Parkway surface road works Support the construction of the cut and cover portal
Motorway facilities support	4. Support ventilation outlet and motorway facilities construction	General activities and deliveries to/from the site to support construction of the ventilation outlet and motorway facilities at the Wakehurst Parkway
Commissioning and site rehabilitation	5. Site rehabilitation	Decommission and rehabilitate site

As part of early works, there may be additional minor construction activities required adjacent to the construction support site, such as local area road works associated with ensuring access for residents. These

works would take place for relatively short periods (less than one month). They would occur during standard hours where practicable; however, OOHW may be required due to road congestion and road safety issues. Impacts from these types of works have been assessed separately and are presented in Section 5.15.1.

5.11.1.2 Construction works program

An approximate timeframe for the operation of the site is presented in Table 5-174, subject to project approval. This site is planned to operate from the start of 2023 until the third quarter of 2027. The longest duration activity at this site would be support for Wakehurst Parkway surface road works.

Table 5-174 – Wakehurst Parkway south construction support site (BL12) – indicative program and timeline

Stage	Representative activity	Reference	Indicative construction timeframe																	
			2023				2024				2025				2026				2027			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Site establishment	1. Early works	WPS_01																				
	2. Establish site	WPS_02																				
Surface road works support	3. Support surface work	WPS_03																				
Motorway facilities support	4. Support motorway facilities construction	WPS_04																				
Commissioning and site rehabilitation	5. Site rehabilitation	WPS_05																				

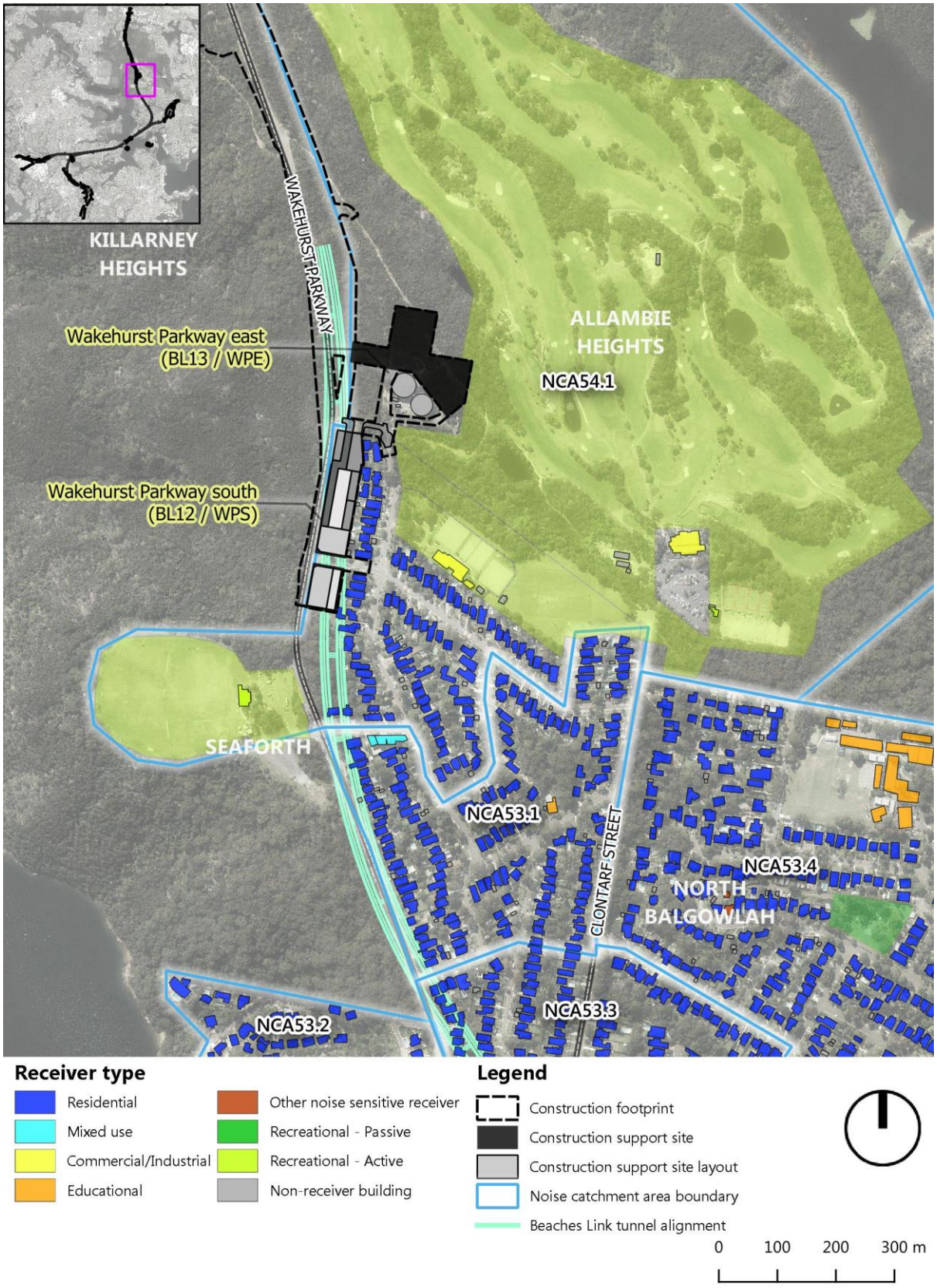
5.11.1.3 Nearby noise and vibration sensitive receivers

The site is located at the adjacent to Wakehurst Parkway. Part of the site is located from Kirkwood Street to just south of Judith Street. The site is mostly surrounded by residential and recreational receivers.

Residential receivers adjoin the site to the east, while recreational receivers are further east and to the southwest of the site.

The location of the site, nearby NCAs and receiver locations are shown in Figure 5-20.

Figure 5-20 – Location of Wakehurst Parkway south construction support site (BL12)



5.11.1.4 Construction duration and working hours

Table 5-175 presents each of the major stages and each of the assessed activities for the Wakehurst Parkway south construction support site (BL12), along with the duration and proposed periods of works for each activity.

During the operation of the Wakehurst Parkway south construction support site (BL12), work would typically take place during the standard construction hours, presented in Table 3-2 (Section 3).

No work typical works would take place outside standard hours, except for office activities and occasional vehicle arrivals and departures.

Table 5-175 – Wakehurst Parkway south construction support site (BL12) – construction hours

Stage	Representative activity		Reference	Assessed activities[1]	Work hours[2]			
					Day (Standard)	Day (OOHW)	Evening	Night
Site establishment	1.	Early works	WPS_01	Utilities works (within construction support site)	♦			
				Demolition of existing structures (non-rock hammering)	♦			
	2.	Establish site	WPS_02	Installation of environmental controls	♦			
				Clearing and grubbing	♦			
				Road and intersection modifications and installation of traffic controls	♦			
				Establishment of construction facilities	♦			
Surface road works support	3.	Support surface work	WPS_03	Construction support site general activities	♦			
				Deliveries to site	♦			
Motorway facilities support	4.	Support motorway facilities construction	WPS_04	Construction support site general activities	♦			
				Deliveries to site	♦			
Commissioning and site rehabilitation	5.	Site rehabilitation	WPS_05	Decommissioning and rehabilitation of site	♦			

Notes: 1. Annexure E describes the modelled plant for each activity

2. Day (Standard) is 7.00am to 6.00pm Monday to Friday and 8.00am to 1.00pm Saturday
Day Out-of-Hours Work is 1.00pm to 6.00pm Saturday and 8.00am to 6.00pm Sunday/Public holiday
Evening is 6.00pm to 10.00pm Monday to Friday and 6.00pm to 10.00pm Saturday/Sunday/Public holiday
Night is 10.00pm to 7.00am Monday to Friday and 10.00pm to 8.00am Saturday/ Sunday/Public holiday.

5.11.1.5 Concurrent construction projects

The nearest construction work associated with this project would be the Wakehurst Parkway surface road works along the Wakehurst Parkway adjacent to the construction support site and the Wakehurst Parkway east construction support site (BL13) approximately 100 metres directly north.

The nearest other construction works areas associated with the project would be the Balgowlah surface road works and Balgowlah Golf Course construction support site (BL10), located about 2 kilometres southeast of this construction support site. At this distance, it is unlikely there would be a substantial cumulative construction noise impact on any receiver.

There are no nearby construction sites associated with other major infrastructure projects that could result in cumulative noise impacts.

5.11.1.6 Construction assessment scenarios

The airborne noise assessment for the Wakehurst Parkway south construction support site (BL12) was separated into five stages. Each stage was assessed against the work periods proposed in Table 5-175. The details of modelled construction plant items and corresponding sound power levels are presented in Annexure E. The equipment/plant listed in Annexure E represent the reasonable worst case equipment/plant operating simultaneously in any 15 minute period (refer to Section 4.2.2 for further explanation of assessment scenarios). Multiple activities would sometimes occur concurrently within the one construction support site and were captured in the assessment as shown in Table 5-175.

5.11.1.7 Summary of assumed noise treatment and management measures

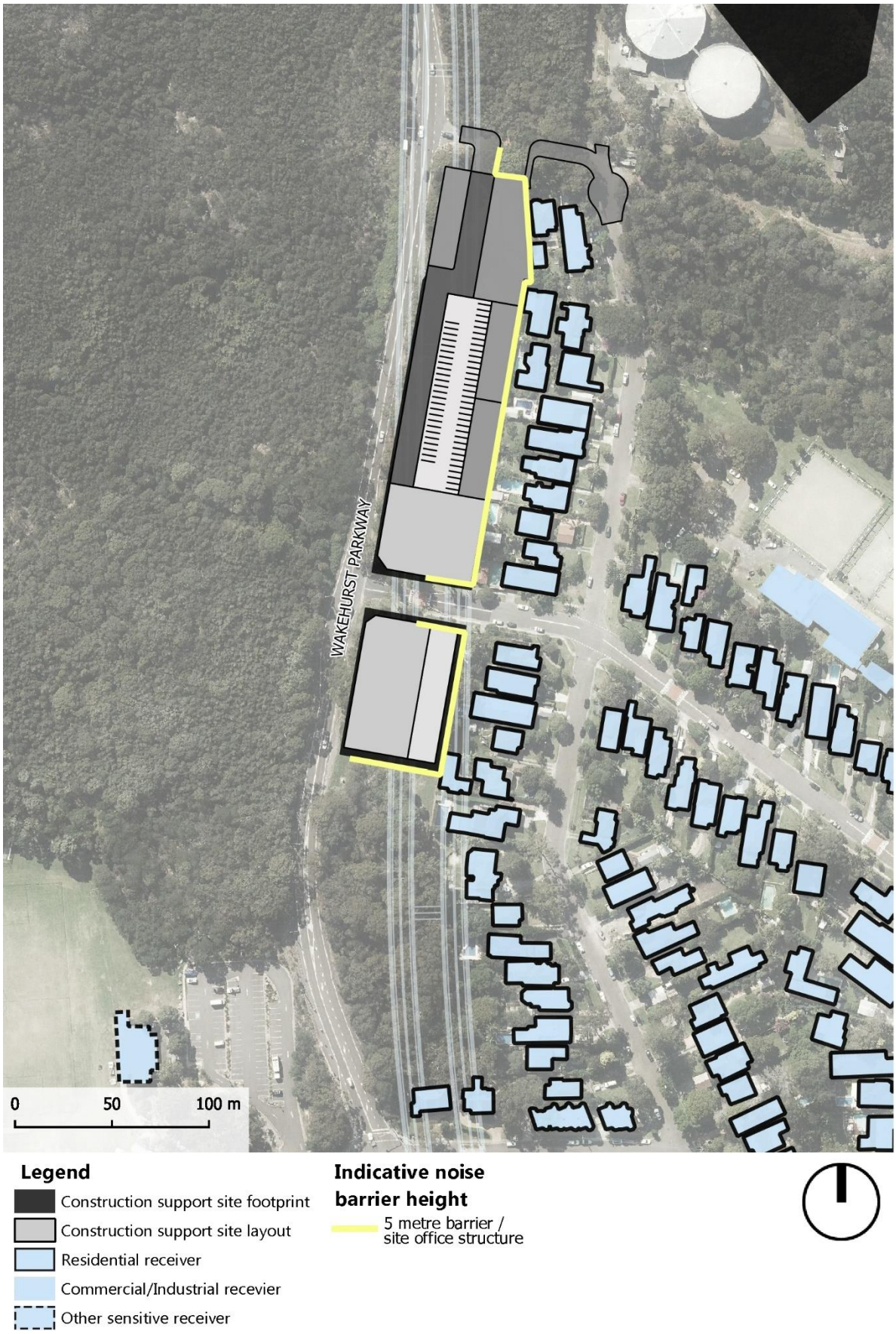
As part of the assessment process, feasible and reasonable noise treatment measures and management methods have been identified based on the preliminary site layout and the reasonable worst case plant/equipment operating, to assist in attenuating and managing noise emissions from the construction activities. Identified feasible and reasonable noise treatment measures have been included in the noise model and are presented in Table 5-176. The results presented in this assessment are based on those noise treatments and management measures being implemented. The locations of physical treatment measures are shown on Figure 5-24.

Table 5-176 – Assumed noise treatment and management measures – Wakehurst Parkway south construction support site (BL12)

Activity or plant/equipment	Description of management and mitigation measures
Work outside standard hours	Once this site is established, work would only occur in standard hours, except for office activities, occasional vehicle arrivals and potentially other quiet activities.
Surface road work and ventilation outlet and motorway facilities construction support	Temporary barriers would be used to reduce noise levels at receivers during site intersection modifications and installation of traffic controls outside standard hours (WPS_02). An indicative five metre high noise barrier would be built along the eastern boundary of the site during stage WPS_02. Site offices placed along the eastern boundary could be integrated to form part of the 5m barrier.

Further design development and construction planning refinements to the construction support site layouts, equipment, construction methods or construction hours may require specific mitigation and management measures that are different from those outlined in this section. Final details for noise treatments and management measures will be confirmed during further design development and construction planning to determine what is feasible and reasonable, with consideration of cumulative construction impacts.

Figure 5-21 – Wakehurst Parkway south construction support site (BL12) with indicative acoustic treatment measures



5.11.2 Construction airborne noise

The methodology used for assessing airborne noise impacts from construction support sites is outlined in Section 4.2.2.

5.11.2.1 Nearby receiver summary and objectives

Table 5-177 presents NMLs and the screening levels for the assessment of sleep disturbance for the nearest residential receivers surrounding the Wakehurst Parkway south construction support site (BL12). Noise management levels for other (non-residential) noise sensitive receivers are presented in in Section 3.4.1. The locations of the NCAs surrounding the construction support site are shown in Figure 5-20.

Table 5-177 – Construction noise management levels and screening levels for residential receivers

NCA ID	Noise management levels (NML) $L_{Aeq(15\ minute)}$				Sleep disturbance screening levels
	Standard hours (RBL + 10dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL + 5dB)			L_{Amax} (RBL + 15dB)
	Day	Day	Evening	Night	Night
47.1	53	48	44	35	45
53.1	58	53	44	35	45
53.2	58	53	44	35	45
53.3	58	53	44	35	45
53.4	58	53	44	35	45
54.1	55	50	44	35	45

5.11.2.2 Predicted noise impacts

Table 5-178 provides a key to the cell shading and text formatting used to explain results in the following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-178 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep Disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes: 1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are expected to exceed NMLs. The range is of noise impacts throughout all receivers in the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented. It is noted that the noise predictions include adjustments for annoying activities, in accordance with the ICNG.

Noise contours for the loudest early works, site establishment, and longer term tunnelling stages are shown in Annexure H.1. Maps presenting the predicted exceedance for a sample of scenarios at the construction support site with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different periods.

5.11.2.3 Residential

The predicted noise levels for residential receivers is presented in the following table:

- Table 5-179: for standard construction hours.

The number of receiver buildings predicted to exceed NMLs during each stage are summarised in Table 5-180.

The predicted impacts would only occur during the reasonably worst case noise intensive works and are intended to be conservative. When works are less noise intensive or occur at various locations, noise levels would be less than those predicted.

Table 5-179 – Predicted construction noise levels during standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Wakehurst Parkway south construction support site (BL12)

NCA	Noise Management Level		Predicted noise levels at each construction stage[1,2]				
	HNA	NML	WPS_01	WPS_02	WPS_03	WPS_04	WPS_05
47.1	75	53	≤ 40	≤ 41	< 35	< 35	< 35
53.1	75	58	≤ 56	≤ 59	< 35	< 35	≤ 47
53.2	75	58	≤ 46	≤ 49	< 35	< 35	≤ 40
53.3	75	58	≤ 47	≤ 48	< 35	< 35	≤ 39
53.4	75	58	≤ 48	≤ 46	< 35	< 35	≤ 38
54.1	75	55	41 - **85**	44 - **84**	≤ 53	≤ 53	≤ 72

Notes: 1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))

2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

As detailed in Section 5.11.1.4, during the operation of the Wakehurst Parkway south construction support site (BL12), construction work would typically take place during the standard construction hours, presented in Table 3-2 (Section 3). No work would take place outside standard hours, except for office activities and occasional vehicle arrivals and departures.

Table 5-180 – Number of receiver buildings over the noise management level (all NCAs) – residential receivers – Wakehurst Parkway south construction support site (BL12)

Modelled representative activity	Assessment reference	Highly noise affected > 75 dB(A) L_{Aeq}		Day (standard hours) L_{Aeq}			Day (outside standard hours) L_{Aeq}				Evening L_{Aeq}				Night L_{Aeq}				Sleep disturbance L_{Amax}	
		Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening	Awakening
Early works	WPS_01[1]	**9**	-	15	19	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Establish site	WPS_02[1]	**18**	-	30	6	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Support surface road works	WPS_03[1]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Support motorway facilities construction	WPS_04[1]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site rehabilitation	WPS_05[1]	0	-	6	17	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes: 1. No typical work is proposed outside standard construction hours

2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period in accordance with the key presented in Table 5-178.

5.11.2.4 Residential – summary of airborne noise assessment

Standard construction hours

The highest predicted levels occur during early works and site establishment (WPS_01, WPS_02 and WPS_05). During these stages, up to 54 receiver buildings are predicted to be noise affected (ie >NML) including:

- Up to 30 receiver buildings in NCAs 53.1 and 54.1 where noise levels could be up to 10 dB(A) above the NML
- Up to 19 receiver buildings in NCA 54.1 where noise levels could be 11 to 20 dB(A) above the NML
- Up to 18 residential receiver buildings in NCA 54.1 could be highly noise affected (>75 dB(A)).

Respite should be provided for any activities resulting in highly noise affected receivers.

The highest predicted noise levels would be caused by utilities relocations, vegetation clearing and installation of environmental controls such as noise barriers. The short term noise impact of noise barrier installations would be offset by the noise benefits for receivers during later stages of the site's operation.

Work outside standard construction hours

There are no proposed works outside standard construction hours, except for office activities and occasional light vehicle arrivals.

5.11.2.5 Non-residential

The predicted noise levels for non-residential receivers are presented in Table 5-181. The number of receiver buildings predicted to exceed the NMLs are summarised in Table 5-182. The predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-181 – Predicted noise levels at other sensitive receivers – $L_{Aeq(15\ minute)}$, dB(A) – Wakehurst Parkway south construction support site (BL12)

Receiver type	NCA	NML	Predicted noise levels at each construction stage[1, 2]				
			WPS_01	WPS_02	WPS_03	WPS_04	WPS_05
Commercial	54.1	70	≤ 51	≤ 51	< 35	< 35	42 - 42
Childcare	53.3	50	≤ 43	38 - 44	< 35	< 35	≤ 35
Educational	53.1	55	≤ 39	≤ 42	< 35	< 35	< 35
Other sensitive receiver	53.2	55	≤ 41	≤ 42	< 35	< 35	< 35
	53.4	70	< 35	38 - 39	< 35	< 35	< 35
Recreational	53.3	60	38 - 41	41 - 43	< 35	< 35	< 35
	53.4	65	< 35	≤ 36	< 35	< 35	< 35
	54.1	60	39 - 65	42 - 71	43 - 46	43 - 47	38 - 55

Notes: 1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML

2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-182 – Number of other sensitive receivers over the noise management levels (all NCAs) – Wakehurst Parkway south construction support site (BL12)

Modelled representative activity	Assessment reference	Commercial[1]			Childcare			Educational			Recreational[1]			Other sensitive receivers[1]		
		1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
Early works	WPS_01	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Establish site	WPS_02	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Support surface road works	WPS_03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Support motorway facilities construction	WPS_04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site rehabilitation	WPS_05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table.

Two non-residential receivers are predicted to be noise affected (ie >NML) during Stage 1 (WPS_01 early works) and Stage 2 (WPS_02 establish site). Both receivers are recreational areas in NCA 54.1 and would experience noise levels up to 11 dB(A) above the NML.

5.11.2.6 Cumulative construction noise impacts

As outlined in Section 4.2.4, potential cumulative noise impacts from other major construction projects around the Wakehurst Parkway south construction support site would be considered when assessing the site and determining feasible and reasonable mitigation and management measures.

No other major projects are in close proximity to the site; however, there are a number of project related construction work areas and construction support sites located nearby. Proposed staging of concurrent construction works associated with the project that are considered for cumulative construction impacts are presented in Table 5-183.

Table 5-183 – Concurrent construction works near the Wakehurst Parkway south construction support site

Project	2022	2023	2024	2025	2026	2027
Wakehurst Parkway south (WPS) construction support site						
Wakehurst Parkway east (WPE) construction support site						
Wakehurst Parkway surface road works (WKP)						

Proposed staging of concurrent work has been reviewed for the closest receivers to the site at Wakehurst Parkway south. The loudest stages for both standard construction hours and out of hours works have been used to calculate potential cumulative noise impacts.

If noise from one site dominates noise levels at the receiver (ie > 5-10 dB(A) above noise from other sites), that site would typically control construction noise levels at the receiver. As such, it is not likely to increase the overall $L_{Aeq,\ 15\ minute}$ construction noise level at these receivers.

If noise levels from each site are similar at a receiver, a total construction noise increase of up to 3 dB(A) is expected. Two representative NCAs adjacent to the works have been assessed in Table 5-184 for standard hours only, as no typical construction work outside standard construction hours is proposed.

Table 5-184 – Potential cumulative noise impacts from construction projects near the Wakehurst Parkway south construction support site

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 53.1	Standard hours NML= 58 dB(A)	WPS	1. Establish site 2. Support surface road works / motorway facilities construction	≤ 59 < 35	1. (WPS - Establish site) Potential cumulative increase of up to 3 dB(A) at nearest receivers to Wakehurst Parkway south (WPS): combining up to 4 dB(A) over the NML. At receivers closer to Wakehurst Parkway east (WPE) this site dominates and cumulative
		WPE	Early works	38 - 77	

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 53.1		WKP	WKP3_E Concrete pours (cut and cover / portals)	≤ 42	increases are unlikely during noise intensive works. 2. (WPS – Support surface road works) Negligible cumulative increase as Wakehurst Parkway East or Wakehurst Parkway surface road works (WKP) dominates during noise intensive works. Wakehurst Parkway south construction noise level predicted to be well below the NML.
NCA 54.1	Standard hours NML= 55 dB(A)	WPS	1. Establish site 2. Support surface road works / motorway facilities construction	41 – 85 ≤ 53	1. (WPS - Establish site) Potential 5 dB(A) increase at some receivers if Wakehurst Parkway south, Wakehurst Parkway east and Wakehurst Parkway surface road works occur concurrently and contribute similar noise levels. The combined level would be 46 – 85 dB(A). Some receivers would be highly noise affected by one site alone, and respite would be provided. 2. (WPS – Support surface road works) Negligible cumulative increase as Wakehurst Parkway east or Wakehurst Parkway surface road works dominates during the activity, Wakehurst Parkway south construction noise is predicted to be below NML.
		WPE	Early works	43 - 76	
		WKP	WKP3_E Concrete pours (cut and cover / portals)	44 - 73	

At receivers not directly adjacent to the Wakehurst Parkway south construction support site, there is potential for cumulative increases of construction noise from concurrent works with the site at Wakehurst Parkway east, the Wakehurst Parkway surface road works.

At some receiver locations, when an individual site does not dominate construction noise levels at the receiver (ie it does not contribute more than 5 dB(A) more noise than other sites), cumulative construction noise levels could be up to 3 dB(A) higher than the noise levels predicted for any one activity.

Any increase due to cumulative noise is unlikely as noise generating activities would need to occur simultaneously. However, even where a cumulative construction noise increase is predicted, the total construction noise level at that receiver is expected to be below the NML.

Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5.

5.11.3 Construction related road traffic noise assessment

Vehicles would access the site directly from Wakehurst Parkway via access points at Judith Street and Kirkwood Street. Table 5-185 presents the forecasted number of vehicles accessing the construction support site during the peak construction period. A maximum of one truck would access the site each hour during the daytime period (7.00am to 10.00pm) and no trucks would access the site in the night time period (10.00pm to 7.00am).

Table 5-185 – Number of construction vehicles accessing the Wakehurst Parkway south construction support site (BL12)

Type of vehicle	Per day[1] over 15 hours[3,4]	Per night[2] over nine hours[3]
Heavy vehicle (deliveries, spoil haulage and concrete deliveries)	8	0
Light vehicle	116	52[5]

Notes:
1. Day is 7.00am to 10.00pm
2. Night is 10.00pm to 7.00am
3. Numbers presented are individual vehicles, not vehicle movements
4. Vehicle numbers has been distributed onto the local road network based upon the proposed access roads. Where a vehicle accesses the site by one road and leaves by another, one vehicle movement is counted along each road once. Where a vehicle accesses and leaves the site by the same road, two vehicle movements are counted on that road
5. These vehicle movements would occur in the early morning peak period between 6.00am to 7.00am.

This assessment is based on predicted non-project traffic volumes. Table 5-210 presents the predicted increases in road traffic noise from the additional construction traffic.

Table 5-186 – Road traffic noise impacts from the Wakehurst Parkway south construction support site (BL12)

Construction vehicle access road	Road type	Time of day	Predicted road traffic noise increase, dB(A)[1, 2]	Exceedance of the RNP criteria	Exceedance of sleep disturbance screening level
Wakehurst Parkway	Arterial	Day $L_{Aeq(15hr)}$	0.5	No	N/A
		Night $L_{Aeq(9hr)}$	<0.5	No	Yes

Notes:
1. Predicted road traffic noise levels are based upon a loudest heavy vehicle
2. Predicted road traffic noise levels are based upon the nearest residential receiver to the road. Receivers at further distances are expected to experience lower noise levels than those predicted.

The predicted road traffic noise increase due to the Wakehurst Parkway south construction support site (BL12) is less than 2 dB(A) during the day and night time periods. Therefore, predicted noise levels on those roads comply with the RNP criteria identified in Section 3.4.2.

Maximum noise levels (L_{Amax}) from night period light vehicle movements are predicted to exceed the sleep disturbance screening level, but not the adopted awakening reaction level.

As all 52 night time light vehicles to this site would be in the peak hour 6.00am to 7.00am and would be distributed between the access points, they are not likely to noticeably increase the number of maximum noise events experienced by nearby receivers from existing vehicle movements on Wakehurst Parkway. This is due to the number of movements generated by the site not being substantial when compared to existing traffic along Wakehurst Parkway.

Mitigation and management measures detailed in Section 6.7 should be considered during further design development and construction planning and, where feasible and reasonable, adopted to minimise construction traffic noise impacts associated with the project.

5.11.3.1 Cumulative construction road traffic assessment

As there is a number of construction support sites and surface road construction works occurring concurrently as part of the project, there is the potential for cumulative noise impacts from the combined construction road traffic along the Wakehurst Parkway.

Refer to Section 5.12.3.1 for an assessment of cumulative construction road traffic operating along the Wakehurst Parkway.

5.11.4 Ground-borne construction noise

Ground-borne noise may be generated by vibration intensive works within the construction support site. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers. Section 4.3.2 outlines the potential impacts from ground-borne noise generated by surface construction works such as these.

Ground-borne noise impacts from the construction of the mainline and ramp tunnel are assessed through ground-borne vibration impacts presented in Section 5.16.1.

5.11.5 Construction vibration

The vibration generated from construction works would vary depending on the level and type of activity carried out. For the Wakehurst Parkway south construction support site (BL12), the only stage which may include vibration intensive works is early works (WPS_01), where rock hammering may be needed for utilities adjustments. The location and extent of these works and where vibration intensive activities may be required within the site boundary would be finalised during detailed construction planning.

Proposed vibration intensive plant items are identified in Annexure E. Minimum working distances for a range of construction plant items are presented in in Table 4-11. Presented in Annexure L are the estimated minimum working distances from the minor construction support site for both structural damage and adverse human response to vibration for the most vibration intensive activity proposed.

The number of receiver buildings within the minimum working distances for rock hammering is presented in Table 5-187.Potential vibration generated to receivers depends on the vibration source levels, separation distance, intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. This assessment considers a worst case scenario that the proposed vibration intensive plant items could be used anywhere within the boundaries of the site. However, this is unlikely to occur and the location of the vibration intensive equipment should be reviewed during detailed construction planning, as recommended in Section 6.8.

Table 5-187 – Number of structures within nominated minimum working distance for vibration impacts – Wakehurst Parkway south construction support site (BL12)

NCA	Number of structures within minimum working distances		
	Cosmetic damage		Human response
	Sound structure	Unsound structure	
Early works			
54.1	21	2	27

5.11.5.1 Cosmetic damage

One heritage item has been identified within the unsound structure minimum working distance, and 21 residences have been identified within the sound structure minimum working distance established for cosmetic damage, as presented in Table 5-187.

The identified buildings are based on the possibility of rock hammering occurring at any point on the site. Rock hammering is likely to take place within a small part of the site and so the actual number of buildings that would be within the minimum working distance is likely to be much smaller than presented in Table 5-187.

5.11.5.2 Heritage listed structures

Two identified heritage items are within the unsound structure cosmetic damage minimum working distances as shown in Annexure L and identified in Table 5-188.

Refer to the Technical working paper: Non-Aboriginal heritage (Appendix J of the environmental impact statement) for the assessment of impacts to heritage items.

Table 5-188 – Heritage receivers within the cosmetic damage minimum working distance –Wakehurst Parkway south construction support site (BL12)

Place/item name	Register	Type/classification[1]	Listing number	NCA
Bantry Bay Water Pumping Station (WPS 122)	Local Environmental Plan Section 170 heritage and conservation register	Item – General -	I148 -	54.1
Bantry Bay Reservoir (WS 0008)	Local Environmental Plan Section 170 heritage and conservation register	Item – General -	I147 -	54.1

Notes: 1. Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

Before starting work with the potential to impact on heritage items, all nearby heritage items would be reviewed, structural surveys carried out where required and appropriate management strategies developed and implemented to prevent cosmetic damage to the items, further detailed Section 6.8.

5.11.5.3 Human response

Rock hammering would occur for limited duration only at this site; therefore, the risk of substantial annoyance is considered low. However, occupants of up to 27 receiver buildings may be exposed to vibration above the human response screening level during early works (ie residents may feel vibration from rock hammering), as presented in Table 5-187.

The extent of mitigation and management required to limit potential impacts to receivers would be determined by looking not only at the level of vibration, but also the duration that receivers are likely to be exposed to vibration above the human response screening level.

After applying feasible and reasonable vibration mitigation measures, if vibration monitoring still identifies that measured vibration levels exceed the human response screening level, appropriate additional mitigation measures should be provided (see Section 6.10.3).

5.12 Wakehurst Parkway east construction support site (BL13)

This section assesses the potential construction noise and vibration impacts, and the reasonable and feasible treatment measures that would be considered to control impacts on noise and vibration sensitive receivers near the Wakehurst Parkway east construction support site (BL13).

5.12.1 Construction support site overview

5.12.1.1 Construction support site description

Work at the site would occur in stages as presented in Table 5-189.

Table 5-189 – Wakehurst Parkway east construction support site (BL13) – major stage overview

Stage	Representative activity	Major stage activities/description
Site establishment	1. Early works	Connect and relocate services at the site such as electricity, sewerage and water
	2. Establish site	Install environmental controls, clearing and grubbing, road and intersection modifications and installation of traffic controls
	3. Establish facilities	Establish site offices and workshops
Acoustic shed and surface level tunnel access construction	4. Piling for access decline and acoustic shed	Piling for access decline and acoustic shed foundations
	5. Build acoustic shed	Erect acoustic shed elements
Tunnel construction (access decline and mainline and ramp tunnels)	6. Tunnelling	Tunnel spoil handling and haulage, tunnel support, tunnel lining and associated deliveries
Tunnel fitout	7. Tunnel fitout	Install mechanical and utilities services to the tunnel
Tunnel commission and site rehabilitation	8. Remove acoustic shed	Remove acoustic shed
	9. Site rehabilitation	Commission tunnel, decommission site and site rehabilitation

As part of the major activities presented above, the Wakehurst Parkway east construction support site (BL13) would support three roadheaders constructing the mainline and ramp tunnels operating as follows:

- Two digging ramp tunnels towards the mainline
- One digging cross passages.

The construction of the mainline and ramp tunnels are assessed in Section 5.16.

5.12.1.2 Construction works program

An approximate timeframe for the operation of the site is presented in Table 5-190, subject to project approval. This minor construction support site is planned to operate from the start of 2023 until the middle of 2027. The longest duration activity at this construction support site would be tunnelling works.

Table 5-190 – Wakehurst Parkway east construction support site (BL13) – indicative program and timeline

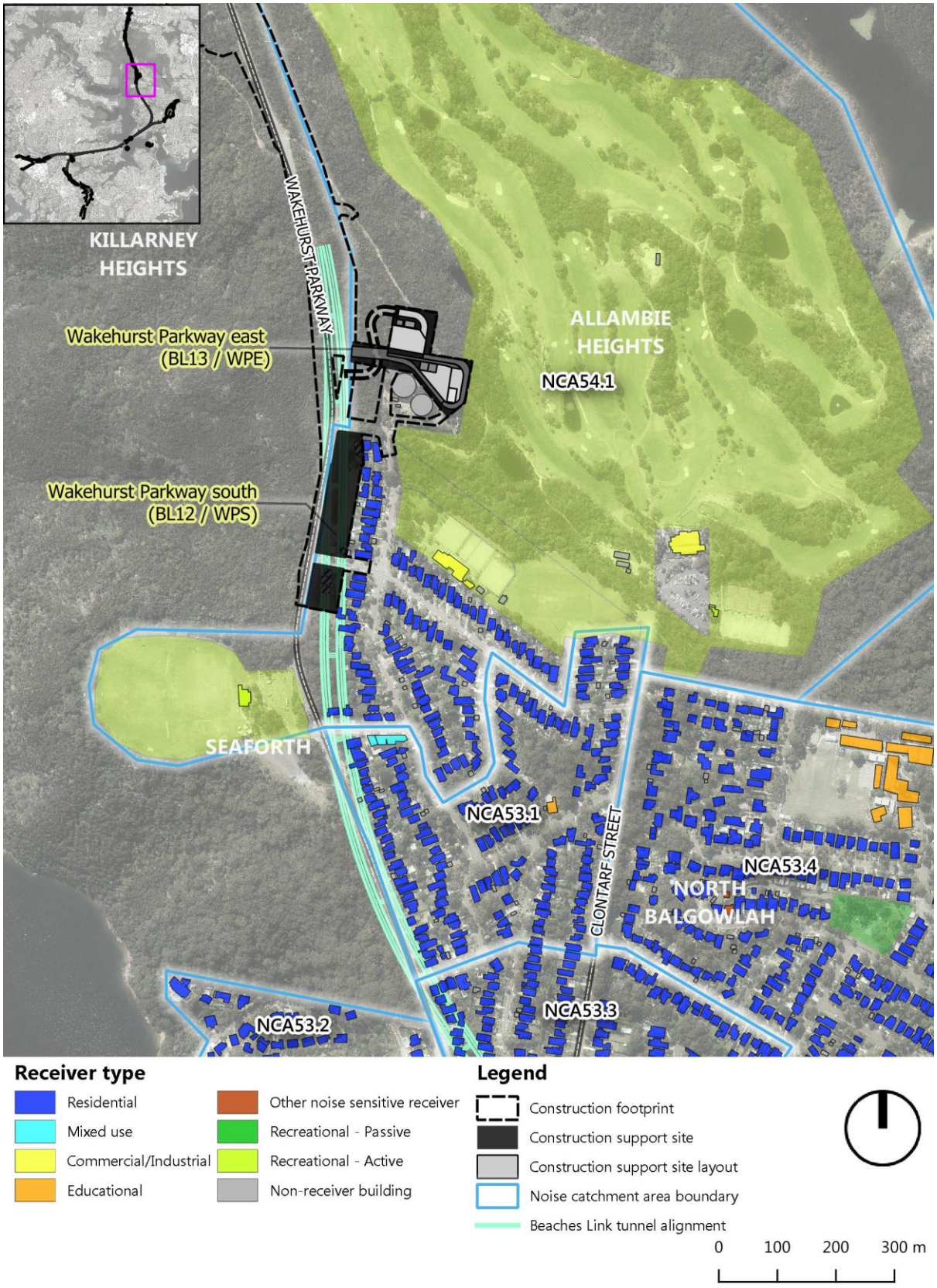
Stage	Representative activity		Reference	Indicative construction timeframe															
				2023				2024				2025				2026				2027			
				1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Site establishment	1.	Early works	WPE_01																				
	2.	Establish site	WPE_02																				
	3.	Establish facilities	WPE_03																				
Acoustic shed and surface level tunnel access construction	4.	Piling for access decline and acoustic shed	WPE_04																				
	5.	Build acoustic shed	WPE_05																				
Tunnel construction (access decline and mainline and ramp tunnels)	6.	Tunnelling	WPE_06																				
Tunnel fitout	7.	Tunnel fitout	WPE_07																				
Tunnel commission and site rehabilitation	8.	Remove acoustic shed	WPE_08																				
	9.	Site rehabilitation	WPE_09																				

5.12.1.3 Nearby noise and vibration sensitive receivers

The site is located on Wakehurst Parkway at Killarney Heights as part of the existing site of Bantry Bay Reservoir owned by Sydney Water. It is mostly surrounded by residential and active recreational receivers. Residential receivers are located to the south of the site, and recreation areas (golf course) are east of the site.

The location of the site, nearby NCAs and receiver locations are shown in Figure 5-22.

Figure 5-22 – Location of Wakehurst Parkway east construction support site (BL13)



5.12.1.4 Construction duration and working hours

Table 5-191 presents each of the major stages and each of the assessed activities for the Wakehurst Parkway east construction support site (BL13), along with the duration and proposed periods of works for each activity.

During the operation of the Wakehurst Parkway east construction support site (BL13), work would typically take place during the ICNG standard construction hours, presented in Table 3-2 (Section 3). However, some works would take place outside standard hours, as presented in Table 5-191.

Table 5-191 – Wakehurst Parkway east construction support site (BL13) – construction hours

Stage	Representative activity		Reference	Assessed activities[1]	Work hours[2]			
					Day (Standard)	Day (OOHW)	Evening	Night
Site establishment	1.	Early works	WPE_01	Utility works	♦			
	2.	Establish site	WPE_02	Install environmental controls	♦			
				Clearing and grubbing	♦			
				Road and intersection modifications and installation	♦	♦	♦	♦
	3.	Establish facilities	WPE_03	Establish construction facilities (site offices and workshops)	♦			
Acoustic shed and surface level tunnel access construction	4.	Piling for access decline and acoustic shed	WPE_04	Piling for access decline and acoustic shed	♦			
	5.	Build acoustic shed	WPE_05	Erect shed elements	♦			
Tunnel construction (access decline and ramp tunnels)	6.	Tunnelling	WPE_06	General site activities[4]	♦	♦	♦	♦
				Deliveries	♦			
				Tunnelling and support[4]	♦	♦	♦	♦
				Tunnel lining (concreting) deliveries[4]	♦	♦	♦	♦
				Spoil handling in acoustic shed	♦	♦[3]	♦[3]	♦[3]
				Spoil haulage	♦			
Tunnel fitout	7.	Tunnel fitout	WPE_07	Deliveries[4]	♦	♦	♦	♦
				Laydown areas	♦			
Tunnel commission and site rehabilitation	8.	Remove acoustic shed	WPE_08	Remove acoustic shed	♦			
	9.	Site rehabilitation	WPE_09	Decommission site and site rehabilitation	♦			

Notes:
1. Annexure E describes the modelled plant for each activity
2. Day Standard is 7.00am to 6.00pm Monday to Friday and 8.00am to 1.00pm Saturday
   Day Out-of-Hours Work is 1.00pm to 6.00pm Saturday and 8.00am to 6.00pm Sunday/Public holiday
   Evening is 6.00pm to 10.00pm Monday to Friday and 6.00pm to 10.00pm Saturday/Sunday/Public holiday
   Night is 10.00pm to 7.00am Monday to Friday and 10.00pm to 8.00am Saturday/ Sunday/Public holiday
3. Spoil haulage off the construction support site would occur during standard construction hours. OOHW spoil handling would occur inside acoustic shed
4. Activities typically within acoustic shed during OOHW periods.

5.12.1.5 Concurrent construction projects

The nearest construction works associated with this project would be the Wakehurst Parkway south construction support site (BL12), to the south of the site, the Wakehurst Parkway surface road works directly adjacent to the east. The Wakehurst Parkway north construction support site (BL14) is located approximately three kilometres north of the Wakehurst Parkway east construction support site (BL13) and unlikely to contribute to cumulative noise impacts.

The nearest other construction works areas associated with the project would be the Balgowlah surface road works and Balgowlah Golf Course construction support site (BL10), located about two kilometres southeast of this construction support site. At this distance, it is unlikely there would be a substantial cumulative construction noise impacts on any receiver.

There are no other nearby construction sites associated with another major infrastructure project that could result in cumulative noise impacts.

5.12.1.6 Construction assessment scenarios

The airborne noise assessment of the Wakehurst Parkway east construction support site (BL13) was separated into nine stages. Each stage was assessed against the works periods proposed in Table 5-191. The details of modelled construction plant items and corresponding sound power levels are presented in Annexure E.

The equipment/plant listed in Annexure E represent the reasonable worst case equipment/plant operating simultaneously in any 15 minute period (refer to Section 4.2.2 for further explanation of assessment scenarios).

Multiple activities would sometimes occur concurrently within the one construction support site and were captured in the assessment as shown in Table 5-191. The access decline to the tunnel is to be built within the acoustic shed once it has been erected. It is generally expected that noise levels would be similar to that of the tunnel construction stage. There may be a minor increase in noise levels while the roadheader is in the access decline; however, this would be temporary before the roadheader progresses into the tunnel.

5.12.1.7 Summary of assumed noise treatment and management measures

As part of the assessment process, feasible and reasonable noise treatment measures and management methods have been identified based on the preliminary site layout and the reasonable worst case plant/equipment operating, to assist in attenuating and managing noise emissions from the construction activities.

Identified feasible and reasonable noise treatment measures have been included in the noise model and are presented in Table 5-192. The results presented in this assessment are based on those noise treatments and management measures being implemented. The locations of physical treatment measures are shown on Figure 5-23.

Table 5-192 – Assumed noise treatment and management measures – Wakehurst Parkway east construction support site (BL13)

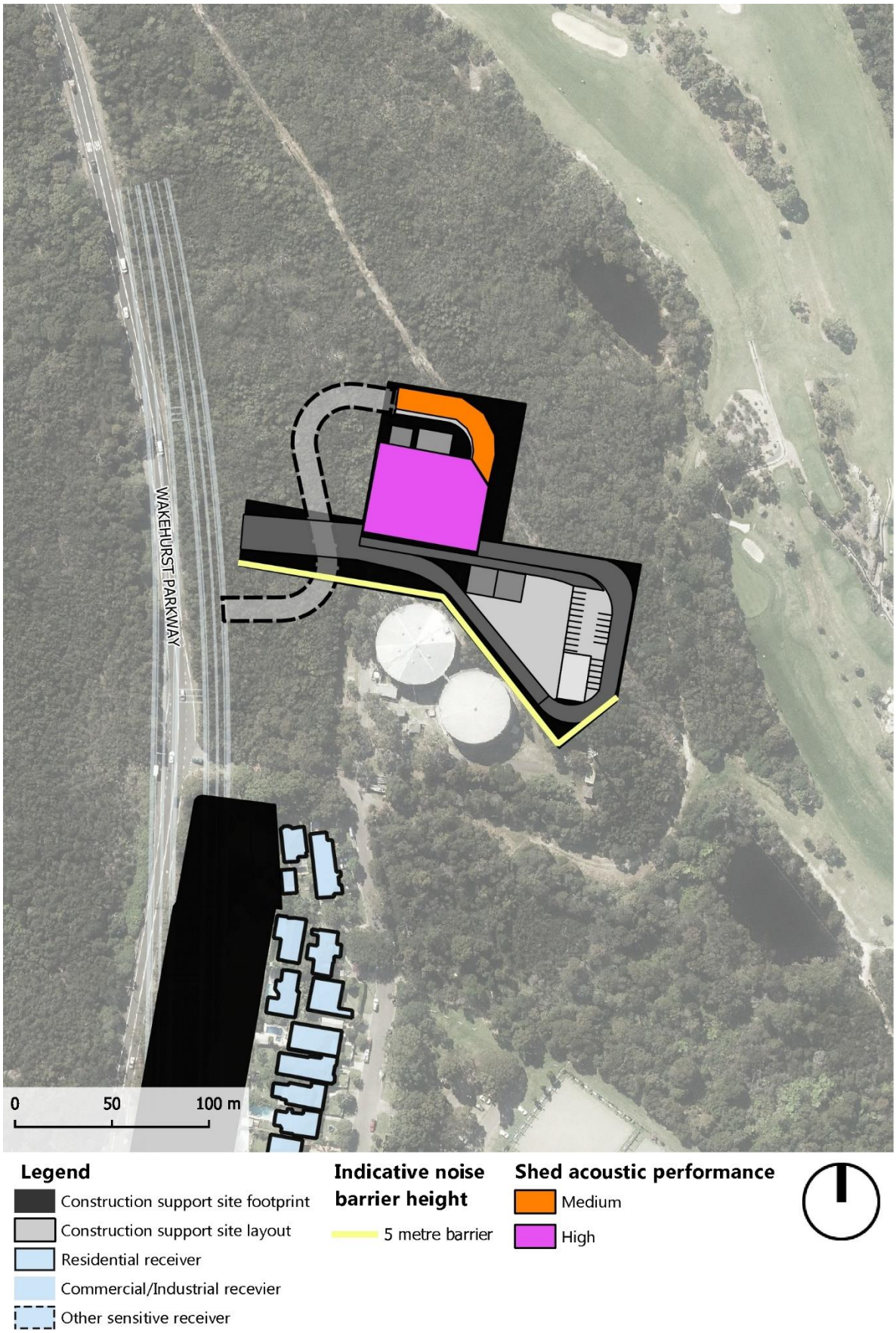
Activity or plant/equipment	Management and treatment measures applied
Work outside standard hours	Work would only occur outside standard hours where it: • Meets the relevant NMLs • Occurs in an acoustic enclosure • Is required for safety reasons • Needs to occur outside standard hours to maintain the operational integrity of the road network. The following indicative noise barrier would be installed on the site to manage noise emissions: • Five metre high barrier along the southern boundary adjacent to the existing water tanks. Further design development and construction planning will likely take into account the existing water tanks as part of site noise barrier
Tunnelling, support and fitout: acoustic shed: acoustic shed	An acoustic shed would be built to reduce noise from tunnelling, support and fitout work outside standard hours. Indicative elements and performance requirements are presented in Table 5-193.
Tunnelling, support and fitout: acoustic shed: covered access decline	The access decline would be covered to reduce noise from tunnelling, support and fitout works outside standard hours. Indicative material and performance requirements are presented in Table 5-193.
Wastewater treatment plant	Plant would achieve a total sound power level of 98 dB(A), which may require acoustic treatment or the use of an acoustic enclosure.
Substation	The substation is to achieve a total sound power level of 90 dB(A), which may require acoustic treatment or the use of an acoustic enclosure.
Ventilation plant	Plant would be acoustically treated to achieve a maximum total sound power level of 98 dB(A). Three ventilation plants were assumed.

Table 5-193 – Indicative acoustic shed construction and acoustic performance – Wakehurst Parkway east construction support site

Shed / access decline element (Indicative example constructions are shown in Table 4-1)	Octave band frequency transmission loss, dB						
	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Acoustic shed (high performance)							
East/North/West walls – Medium performance	8	9	23	37	47	44	46
South walls – High performance	10	29	35	42	46	51	57
Roof – High performance	20	27	36	45	51	56	62
Access decline cover (medium performance)							
Walls – Medium performance	8	9	23	37	47	44	46
Roof – Medium performance	8	9	23	37	47	44	46

Further design development and construction planning refinements to the construction support site layouts, equipment, construction methods or construction hours may require specific mitigation and management measures that are different from those outlined in this section. Final details for noise treatments and management measures will be confirmed during further design development and construction planning to determine what is feasible and reasonable, with consideration of cumulative construction impacts.

Figure 5-23 – Construction support site layout with indicative acoustic treatment measures at Wakehurst Parkway east construction support site (BL13)



5.12.2 Construction airborne noise

The methodology used for assessing airborne noise impacts from construction support sites is outlined in Section 4.2.2.

5.12.2.1 Nearby receiver summary and objectives

Table 5-194 presents NMLs and the screening levels for the assessment of sleep disturbance for the nearest residential receivers surrounding the Wakehurst Parkway east construction support site (BL13). Noise management levels for other (non-residential) noise sensitive receivers are presented in Section 3.4.1. The locations of the NCAs surrounding the construction support site are shown in Figure 5-22.

Table 5-194 – Construction noise management levels and screening levels for residential receivers

NCA ID	Noise management levels (NML) $L_{Aeq(15\ minute)}$				Sleep disturbance screening levels
	Standard Hours (RBL + 10dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL + 5dB)			L_{Amax} (RBL + 15dB)
	Day	Day	Evening	Night	Night
47.1	53	48	44	35	45
53.1	58	53	44	35	45
53.2	58	53	44	35	45
53.3	58	53	44	35	45
53.4	58	53	44	35	45
54.1	55	50	44	35	45

5.12.2.2 Predicted noise impacts

Table 5-195 provides a key to the cell shading and text formatting used to explain results in following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-195 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes:
1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are expected to exceed NMLs. The range is of noise impacts throughout all receivers in the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented. It is noted that the noise predictions include adjustments for annoying activities, in accordance with the ICNG.

Noise contours for the loudest early works, site establishment, and longer term tunnelling stages are shown in Annexure H.1. Maps presenting the predicted exceedance for a sample of scenarios at the construction support site with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different periods.

5.12.2.3 Residential

The predicted noise levels for residential receivers are presented in the following tables:

- Table 5-196: standard hours
- Table 5-197: for works outside standard construction hours.

The number of receiver buildings predicted to exceed NMLs during each stage and time period are summarised in Table 5-198. Predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-196 – Predicted construction noise levels during standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Wakehurst Parkway east construction support site (BL13)

NCA	Noise Management Level		Predicted noise levels at each construction stage[1, 2]								
	HNA	NML	WPE_01	WPE_02	WPE_03	WPE_04	WPE_05	WPE_06	WPE_07	WPE_08	WPE_09
47.1	75	53	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
53.1	75	58	≤ 54	≤ 49	≤ 44	≤ 44	≤ 43	≤ 37	< 35	≤ 38	≤ 42
53.2	75	58	< 35	≤ 36	< 35	< 35	< 35	< 35	< 35	< 35	< 35
53.3	75	58	≤ 35	≤ 36	< 35	< 35	< 35	< 35	< 35	< 35	< 35
53.4	75	58	≤ 47	≤ 43	≤ 39	≤ 39	≤ 37	< 35	< 35	< 35	≤ 37
54.1	75	55	≤ 66	≤ 62	≤ 47	≤ 50	≤ 49	≤ 40	≤ 39	≤ 43	≤ 43

Notes: 1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))

2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-197 – Predicted construction noise levels outside standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Wakehurst Parkway east construction support site (BL13)

NCA	Noise Management Level				Predicted noise levels at each construction stage[3]								
	HNA	Day (O)	Eve	Night	WPE_01[1]	WPE_02	WPE_03[1]	WPE_04[1]	WPE_05[1]	WPE_06	WPE_07	WPE_08[1]	WPE_09[1]
47.1	75	48	44	35	-	< 35	-	-	-	< 35	< 35	-	-
53.1	75	53	44	35	-	≤ 36	-	-	-	< 35	< 35	-	-
53.2	75	53	44	35	-	< 35	-	-	-	< 35	< 35	-	-
53.3	75	53	44	35	-	< 35	-	-	-	< 35	< 35	-	-
53.4	75	53	44	35	-	< 35	-	-	-	< 35	< 35	-	-
54.1	75	50	44	35	-	≤ 56	-	-	-	≤ 37	< 37	-	-

Notes: 1. No typical work is proposed outside standard construction hours

2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))

3. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-198 – Number of receiver buildings over the noise management level (all NCAs) – residential receivers – Wakehurst Parkway east construction support site (BL13)

Modelled representative activity	Assessment reference	Highly noise affected > 75 dB(A) L_{Aeq}		Day (standard hours) L_{Aeq}			Day (outside standard hours) L_{Aeq}				Evening L_{Aeq}				Night L_{Aeq}				Sleep disturbance L_{Amax}	
		Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	> 75 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening	Awakening
Early works	WPE_01[1]	0	-	1	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Establish site	WPE_02	0	0	2	0	0	1	1	0	0	8	2	0	0	42	19	2	0	35	0
Establish facilities	WPE_03[1]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Piling for access decline and acoustic shed	WPE_04[1]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Build acoustic shed	WPE_05[1]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunnelling	WPE_06	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	8	0
Tunnel fitout	WPE_07	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	8	0
Remove acoustic shed	WPE_08[1]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site rehabilitation	WPE_09[1]	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes: 1. No typical work is proposed outside standard construction hours

2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period in accordance with the key presented in Table 5-195.

5.12.2.4 Residential – summary of airborne noise assessment

Standard construction hours

The highest predicted noise levels occur during early works (Stage 1, WPE_01). Two receiver buildings in NCA 54.1 located at 92 and 94 Kirkwood Street are predicted to be noise affected (ie > NML) during this stage due to excavators with rock hammers. These receiver buildings are directly across Kirkwood Street from the site.

The same two receiver buildings are also predicted to be noise affected (ie >NML) from short term site establishment works (Stage 2, WPE_02) during standard hours. The noise impact is caused by the use of mulchers, chainsaws and excavators with rock hammers.

For the remaining stages, construction noise levels are predicted to be below the NML.

Work outside standard construction hours

Due to road operation, worker safety and 24 hour tunnelling requirements, some works are likely to be completed outside standard construction hours as presented in Table 5-87. At the Wakehurst Parkway east construction support site (BL13), the key stages requiring OOHW are during:

- Road and intersection modifications (WPE_02)
- Tunnelling and tunnel support (WPE_06)
- Tunnel fitout (WPE_07).

During site establishment works at night (road and intersection modification, WPE_02), road modification works on Wakehurst Parkway are expected to result in 63 noise affected (>NML) receiver buildings in NCAs 53.1 and 54.1. This is due to short term intersection works under a road occupancy licence, which need to take place outside standard hours to minimise disruption to the road network and protect the safety of road users and workers.

During longer term tunnelling and tunnel support (WPE_06) and tunnel fitout (WPE_07), two residential receiver buildings in NCA 54.1 located at 92 and 94 Kirkwood Street are predicted to be noise affected by up to 2 dB(A).

The predicted noise levels are based on all plant operating concurrently during each assessed activity. However, in practice not all plant would typically operate all the time, meaning that for a substantial part of the time construction noise levels would be less than the predicted noise levels.

The site layout and proposed feasible and reasonable mitigation measures should be reviewed by the contractor during further design development and construction planning and adjusted or augmented as required to ensure that the night NML is met for all residential receivers in the vicinity as at all times during tunnelling, tunnel support and tunnel fitout activities.

Sleep disturbance

At the Wakehurst Parkway east construction support site (BL13), the key OOHW stages which potentially include activities with maximum noise levels (L_{Amax}) are:

- Road and intersection modifications (WPE_02)
- Tunnelling and tunnel support (WPE_06)
- Tunnel fitout (WPE_07).

Night time intersection modification (road and intersection modifications, WPE_02) works would be short term works under a road occupancy licence, required to minimise disruption to the road network and protect the safety of workers and road users. During this work, up to 35 receiver buildings are predicted to be exposed to maximum noise levels above the sleep disturbance screening level.

During night time tunnelling and tunnel support (WPE_06) and tunnel fitout (WPE_07) works, occasional night time concrete trucks could result in high instantaneous noise impacts during arrival or departure. Up to eight receiver buildings are predicted to potentially be exposed to maximum noise levels above the sleep disturbance screening level.

Since the number of night truck movements generated by the site is not substantial compared to existing traffic numbers on Wakehurst Parkway, sleep disturbance impacts are not likely to occur from trucks accessing the site at night.

5.12.2.5 Non-residential

The predicted noise levels for non-residential receivers are presented Table 5-199. No non-residential receiver buildings or areas are predicted to experience noise level above the relevant NMLs during all construction stages.

The predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-199 – Predicted noise levels at other sensitive receiver locations, dB(A) – Wakehurst Parkway east construction support site (BL13)

Receiver type	NCA	NML	Predicted noise levels at each construction stage[1, 2]								
			WPE_01	WPE_02	WPE_03	WPE_04	WPE_05	WPE_06	WPE_07	WPE_08	WPE_09
Commercial	54.1	70	≤ 54	≤ 51	≤ 47	≤ 45	≤ 44	≤ 39	≤ 37	≤ 39	≤ 44
Childcare	53.3	50	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
Educational	53.1	55	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
Other sensitive receiver	53.2	55	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
	53.4	70	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
Recreational	53.3	60	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
	53.4	65	≤ 35	35	< 35	< 35	< 35	< 35	< 35	< 35	< 35
	54.1	65	44 – 56	43 - 55	38 - 53	36 - 50	44 - 49	40 – 48	40 – 44	39 – 43	44 - 51

Notes:
1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML
2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

5.12.2.6 Cumulative construction noise impacts

As outlined in Section 4.2.4, potential cumulative noise impacts from other major construction projects around the Wakehurst Parkway east construction support site would be considered when assessing the site and determining feasible and reasonable mitigation and management measures.

No other major projects are in close proximity to the site; however, there are a number of project related construction work areas and construction support sites located nearby. Proposed staging of concurrent construction works associated with the project that are considered for cumulative construction impact are presented in Table 5-200.

Table 5-200 – Concurrent construction works near the Wakehurst Parkway east construction support site

Project	2022	2023	2024	2025	2026	2027
Wakehurst Parkway south (WPS) construction support site						
Wakehurst Parkway east (WPE) construction support site						
Wakehurst Parkway surface road works (WKP)						

Proposed staging of concurrent work has been reviewed for the closest receivers to the site. The loudest stages for both standard construction hours and out-of-hours works have been used to calculate potential cumulative noise impacts.

If noise from one site dominates noise levels at the receiver (ie > 5-10 dB(A) above noise from other sites), that site would typically control construction noise levels at the receiver. As such, it is not likely to increase the overall $L_{Aeq,\ 15\ minute}$ construction noise level at these receivers.

If noise levels from each site are similar at a receiver, a total construction noise increase of up to 3 dB(A) is expected. Two representative NCAs adjacent to the works have been assessed in Table 5-184.

Table 5-201 – Potential cumulative noise impacts from construction projects near Wakehurst Parkway east

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 53.1	Standard hours NML= 58 dB(A)	WPE	Early works	≤ 54	1. (WPS - Establish site) Potential cumulative increases at nearest receivers to Wakehurst Parkway east (WPE), which could increase construction noise levels to the NML. 2. (WPS - Support surface road works and WKP) Negligible cumulative increase as Wakehurst Parkway east dominates during the activity, because construction noise from other works is substantially below NML. This is because noise from WPS has been mitigated.
		WPS	1. Establish site	≤ 59	
			2. Support surface road works / motorway facilities construction	< 35	
		WKP	WKP3_E Concrete pours (cut and cover / portals)	≤ 42	

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 53.1	OOHW NML D/E/N 53/44/35	WPE	Establish site	≤ 36	Potential cumulative increases that would exceed the NML if Wakehurst Parkway surface road works (WKP) were to occur concurrently with WPE intersection works. Wakehurst Parkway south works are not proposed to occur outside standard hours work.
		WPS	Establish site	-	
		WKP	WKP3_C Erection/removal of precast concrete/large items	≤ 40	
NCA 54.1	Standard hours NML= 55 dB(A)	WPE	Early works	≤ 62	1. (WPS - Establish site) Potential cumulative increases at nearest receivers to Wakehurst Parkway east (WPE), which could increase construction noise levels to the NML. Both WPE and WPS have the potential to exceed the NML. 2. (WPS - Support surface road works) Wakehurst Parkway east would likely dominate, however there is potential for impacts during concurrent works to increase construction noise levels to above the NML at the closest receivers. (WKP) Potential cumulative impacts for receivers along Kirkwood Street should be considered as part of mitigation and management of construction noise emissions.
		WPS	1. Establish site 2. Support surface road works / motorway facilities construction	41 – 85 ≤ 53	
		WKP	WKP3_E Concrete pours (cut and cover / portals)	44 - 73	
	OOHW NML D/E/N 50/44/35	WPE	Establish site	≤ 56	During site establishment, both WPE and WPS are predicted to exceed at the nearest receiver with similar construction noise levels. Wakehurst Parkway surface road works noise levels could also exceed the NML. As such, there is potential for construction noise levels to increase further if concurrent works occur. Potential cumulative impacts should be managed for these sites and the Wakehurst Parkway surface road works.
		WPS	Establish site	≤ 60	
		WKP	WKP3_C Erection/removal of precast concrete/large items	42 - 71	

At receivers not directly adjacent to the Wakehurst Parkway east construction support site, there is potential for cumulative increases of construction noise from concurrent works with the site at Wakehurst Parkway south, the Wakehurst Parkway surface road works.

At some receiver locations, when an individual site does not dominate construction noise levels at the receiver (ie it does not contribute more than 5 dB(A) more noise than other sites), cumulative construction noise levels could be up to 3 dB(A) higher than the noise levels predicted for any one activity.

Any increase due to cumulative noise is unlikely as noise generating activities would need to occur simultaneously. However, even where a cumulative construction noise increase is predicted, the total construction noise level at that receiver is expected to be below the NML.

Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5.

5.12.3 Construction related road traffic noise assessment

Vehicles would access the site directly from Wakehurst Parkway through a temporary signalised intersection north of Kirkwood Street. The intersection would allow vehicles to turn out of the site and enter Wakehurst Parkway directly. This would remove the need for construction traffic to use local roads to return to the arterial road network.

Spoil trucks would enter the site from Wakehurst Parkway from the temporary intersection. They would be loaded in the acoustic shed before returning to Wakehurst Parkway and heading north using the arterial road network to access disposal sites to the north.

Table 5-202 presents forecasted number of vehicles accessing the construction support site during the peak construction periods at this site. Up to 12 trucks would access the site each hour in the daytime period (7.00am to 10.00pm) and a maximum of one truck per hour (no more than four trucks in total) in the night time period (10.00pm to 7.00am).

Table 5-202 – Number of construction vehicles accessing the Wakehurst Parkway east construction support site (BL13)

Type of vehicle	Per day[1] over 15 hours[3,4]	Per night[2] over nine hours[3]
Heavy vehicle (deliveries, spoil haulage and concrete deliveries)	134	4
Light vehicle	110	43

Notes:
1. Day is 7.00am to 10.00pm
2. Night is 10.00pm to 7.00am
3. Numbers presented are individual vehicles, not vehicle movements
4. Vehicle numbers has been distributed onto the local road network based upon the proposed access roads. Where a vehicle accesses the site by one road and leaves by another, one vehicle movement is counted along each road once. Where a vehicle accesses and leaves the site by the same road, two vehicle movements are counted on that road.

Table 5-203 presents the predicted increase in road traffic noise from additional construction traffic, based on predicted non-project traffic volumes.

Table 5-203 – Road traffic noise impacts from the Wakehurst Parkway east construction support site (BL13)

Construction vehicle access road	Road type	Time of day	Predicted road traffic noise increase, dB(A)[1, 2]	Exceedance of the RNP criteria	Exceedance of sleep disturbance screening level
Wakehurst Parkway	Arterial	Day $L_{Aeq(15hr)}$	0.5	No	N/A
		Night $L_{Aeq(9hr)}$	<0.5	No	Yes

Note:
1. Predicted road traffic noise levels are based upon the loudest heavy vehicle
2. Predicted road traffic noise levels are based upon the nearest residential receiver to the road. Receivers further distances are expected to experience lower noise levels than those predicted.

The predicted road traffic noise increases due to the Wakehurst Parkway east construction support site (BL13) are less than 2 dB(A) during day and night time periods. Therefore, predicted noise levels on those roads comply with the RNP criteria identified in Section 3.4.2.

Maximum noise levels (L_{Amax}) from night period truck movements are predicted to exceed both the sleep disturbance screening level and the adopted awakening reaction level.

Over the entire night there would be four vehicles (eight movements). Since night time heavy vehicle movements from this site would be limited to one vehicle per hour, which is not a substantial number when compared to existing heavy vehicle movements on the Wakehurst Parkway. Nearby receivers are not likely to notice the increase in the number of maximum noise events caused by the additional truck movements generated by the site.

5.12.3.1 Total Wakehurst Parkway construction road traffic assessment

As there are a number of construction support sites and surface road construction works occurring concurrently as part of the project, there is the potential for cumulative noise impacts from the combined construction road traffic.

To assess construction road traffic noise impacts, a conservative assessment has been carried out assuming that all the construction traffic during the peak periods of each set of construction works could occur at the same time, and all traffic would travel via the Wakehurst Parkway during trips to and from the construction sites. It is unlikely that these traffic movements would result when the works are underway.

Table 5-204 presents combined forecasted number of vehicles accessing each of the the construction support sites during the peak construction periods at this site.

Table 5-204 – Number of construction vehicles accessing the construction support sites via Wakehurst Parkway

Construction support site	Per day[1] over 15 hours[3,4]		Per night[2] over nine hours[3]	
	Heavy vehicles[6]	Light vehicles	Heavy vehicles[6]	Light vehicles
Wakehurst Parkway east (BL13)	134	110	4	43
Wakehurst Parkway south (BL12)	8	116	0	52[7]
Wakehurst Parkway north (BL14)	47	68	4	22

Notes:
1. Day is 7.00am to 10.00pm
3. Night is 10.00pm to 7.00am
4. Numbers presented are individual vehicles, not vehicle movements
5. Vehicle numbers have been distributed onto the local road network based upon the proposed access roads. Where a vehicle accesses the site by one road and leaves by another, one vehicle movement is counted along each road once. Where a vehicle accesses and leaves the site by the same road, two vehicle movements are counted on that road
6. Includes deliveries, spoil haulage and concrete deliveries
7. These vehicle movements would occur in the early morning peak period between 6.00am to 7.00am.

Table 5-205 presents the predicted increase in road traffic noise from the cumulative additional construction traffic along Wakehurst Parkway, based on predicted non-project traffic volumes.

Table 5-205 – Road traffic noise impacts from the cumulative Beaches Link construction road traffic on the Wakehurst Parkway

Construction vehicle access road	Road type	Time of day	Predicted road traffic noise increase, dB(A)[1, 2]	Exceedance of the RNP criteria	Exceedance of sleep disturbance screening level
Wakehurst Parkway	Arterial	Day $L_{Aeq(15hr)}$	0.6	No	N/A
		Night $L_{Aeq(9hr)}$	< 0.5	No	Yes

Note: 1. Predicted road traffic noise levels are based upon the loudest heavy vehicles

2. Predicted road traffic noise levels are based upon the nearest residential receiver to the road. Receivers at further distances are expected to experience lower noise levels than those predicted.

The predicted road traffic noise increases due to the construction support sites that would operate along the Wakehurst Parkway is less than 2 dB(A) during day and night time periods. Therefore, cumulative road traffic predicted noise levels the Wakehurst Parkway comply with the RNP criteria identified in Section 3.4.2.

Mitigation and management measures detailed in Section 6.7 should be considered during further design development and construction planning and, where feasible and reasonable, adopted to minimise construction traffic noise impacts associated with the project.

5.12.4 Ground-borne construction noise

Ground-borne noise could result from the construction of the tunnel access decline between the Wakehurst Parkway east construction support site (BL13) and the mainline and ramp tunnel alignment. However, due to the distance of nearby occupied receiver buildings from the site, no receivers (occupied buildings) are predicted to be affected by ground-borne noise above the strictest NML of 35 dB(A) from tunnel construction, as shown in Annexure J.3.

Ground-borne noise may be generated by vibration intensive works within the construction support site. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers. Section 4.3.2 outlines the potential impacts from ground-borne noise generated by surface construction works such as these and how any ground-borne noise generated from these works should be mitigated and managed.

5.12.5 Construction vibration

The vibration generated from construction works would vary depending on the level and type of activity carried out. For the Wakehurst Parkway east construction support site (BL13), the major stages which may include vibration intensive works are:

- Early works (WPE_01)
- Piling for acoustic shed and tunnel access decline (WPE_04)
- Tunnelling (WPE_06).

Proposed vibration intensive plant items are identified in Annexure E. Minimum working distances for a range of construction plant items are presented in in Table 4-11. Presented in Annexure L are the estimated minimum working distances from the construction support site for both structural damage and adverse human response to vibration for the most vibration intensive activity proposed.

The most vibration intensive activity at this site is likely to be the use of rock hammers for utility relocation during early works (WPE_01) or piling for the acoustic shed (WPE_04) tunnel access decline.

Two heritage items were identified to be within the minimum working distances for vibration generating activities as presented in Table 5-206.

Potential vibration generated to receivers depends on the vibration source levels, separation distance, intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. This assessment considers a worst case scenario that the proposed vibration intensive plant items could be used anywhere within the boundaries of the site. However, this is unlikely to occur and the location of the vibration intensive equipment should be reviewed during detailed construction planning, as recommended in Section 6.8.

Table 5-206 – Number of structures within nominated minimum working distance for vibration impacts – Wakehurst Parkway east construction support site (BL13)

NCA	Number of structures within minimum working distances		
	Cosmetic damage		Human response
	Sound structure	Unsound structure	
Early works, build access decline and piling for shed			
54.1	-	2	-

For the tunnel access decline construction, due to the tunnel depth there are no structures that are identified within the minimum working distances presented in Section 4.4.1 for roadheader tunnelling for either cosmetic damage or human response screening levels. As such, vibration impacts above the screening levels from the tunnel access decline construction works are unlikely but should be reviewed during further design development and construction planning.

5.12.5.1 Cosmetic damage

No buildings (non-heritage) have been identified within the sound structure minimum working distance established for cosmetic damage, as presented in Table 5-206.

5.12.5.2 Heritage listed structures

Two identified heritage item are within the unsound structure cosmetic damage minimum working distances are heritage items, shown in Annexure L and identified in Table 5-207.

Refer to the Technical working paper: Non-Aboriginal heritage (Appendix J of the environmental impact statement)for the assessment of impacts to heritage items.

Table 5-207 – Heritage receivers within the cosmetic damage minimum working distance – Wakehurst Parkway east (BL13)

Place/item name	Register	Type/classification[1]	Listing number	NCA
Bantry Bay Water Pumping Station (WPS 122)	Local Environmental Plan Section 170 heritage and conservation register	Item – General -	I148 -	54.1
Bantry Bay Reservoir (WS 0008)	Local Environmental Plan Section 170 heritage and conservation register	Item – General -	I147 -	54.1

Notes: 1. Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

Before starting work with the potential to impact on heritage items, all nearby heritage items would be reviewed, structural surveys carried out where required and appropriate management strategies developed and implemented to prevent cosmetic damage to the items, further detailed Section 6.8.

5.12.5.3 Human response

The nearest residential buildings are located approximately 90 metres from the construction site footprint, and so no vibration sensitive receiver buildings have been identified within the minimum working distances for adverse human response. Piling and rock hammering would occur for limited duration only at this site; therefore, the risk of annoyance is considered low.

No receivers are expected to be exposed to vibration from tunnel access decline construction above the human response screening level. Mainline and ramp tunnel construction vibration impacts are presented in Section 5.16

5.13 Wakehurst Parkway north construction support site (BL14)

This section assesses the potential construction noise and vibration impacts, and the reasonable and feasible measures that would be considered to control impacts on noise and vibration sensitive receivers near the Wakehurst Parkway north construction support site (BL14). This site would reuse part of the demobilised Transport for NSW Northern Beaches Hospital road upgrade project site and thus site establishment would be minimal.

5.13.1 Construction support site overview

5.13.1.1 Construction support site description

Work at the site would occur in stages as presented in Table 5-208.

Table 5-208 – Wakehurst Parkway north construction support site (BL14) – major stage overview

Stage	Representative activity	Major stage activities/description
Site establishment	1. Early works	Utility works
	2. Establish site	Establishment of construction facilities and batch plant
Surface road works	3. Surface road works support activities	Operation of concrete batch plant, deliveries to site and general construction support site activities
Permanent tunnel support facilities construction	4. Construct the permanent tunnel support facilities	Construction of the permanent tunnel support facilities
Commissioning and rehabilitation	5. Site rehabilitation	Decommissioning and rehabilitation of site

5.13.1.2 Construction works program

An approximate timeframe for the operation of the site is presented in Table 5-209, subject to project approval. This site is planned to operate from the start of 2023 until the end of 2027. The longest duration activities at this construction support site would be surface activities.

Table 5-209 – Wakehurst Parkway north construction support site (BL14) – indicative program and timeline

Stage	Representative activity	Reference	Indicative construction timeframe					
			2022	2023	2024	2025	2026	2027
			1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Site establishment	1. Early works	WPN_01		■				
	2. Establish site	WPN_02		■				
Surface road works	3. Surface road works support activities	WPN_03			■	■	■	■
Permanent tunnel support facilities construction	4. Construct the permanent tunnel support facilities	WPN_04					■	■
Commissioning and rehabilitation	5. Site rehabilitation	WPN_05						■

5.13.1.3 Nearby noise and vibration sensitive receivers

The site is located on the northeast corner of the Wakehurst Parkway and Warringah Road Intersection. The site is mostly surrounded by commercial, residential and medical type receivers.

Commercial receivers are located to the east and south of the site. Residential receivers are located to the north and southwest of the site across Wakehurst Parkway. The Northern Beaches Hospital is located west of the site across Wakehurst Parkway.

The location of the site, nearby NCAs and receiver locations are shown in Figure 5-24.

Figure 5-24 – Location of Wakehurst Parkway north construction support site (BL14)



5.13.1.4 Construction duration and working hours

Table 5-210 presents each of the major stages and each of the assessed activities for the Wakehurst Parkway north construction support site (BL14), along with the duration and proposed periods of works for each activity.

During the operation of the Wakehurst Parkway north construction support site (BL14), work would typically take place during standard construction hours, presented in Table 3-2 (Section 3).

No work would take place outside standard hours, except for surface road works support activities, office activities and occasional vehicle arrivals and departures.

Table 5-210 – Wakehurst Parkway north construction support site (BL14) – construction hours

Stage	Representative activity		Reference	Assessed activities[1]	Work hours[2]			
					Day (Standard)	Day (OOHW)	Evening	Night
Site establishment	1.	Early works	WPN_01	Utility works	♦			
	2.	Establish site	WPN_02	Establish site offices, workshops and batch plant	♦			
Surface road works	3.	Surface road works support activities	WPN_03	Operate concrete batch plant, deliveries, general activities	♦			
				General activities	♦			
				Support and deliveries	♦	♦	♦	♦
Permanent tunnel support facilities construction	4.	Construct the permanent tunnel support facilities	WPN_04	Construction of the permanent tunnel support facilities	♦			
Commissioning and rehabilitation	5.	Site rehabilitation	WPN_05	Decommission site and site rehabilitation	♦			

Notes:
1. Annexure E describes the modelled plant for each activity
2. Day Standard is 7.00am to 6.00pm Monday to Friday and 8.00am to 1.00pm Saturday
   Day Out-of-Hours Work is 1.00pm to 6.00pm Saturday and 8.00am to 6.00pm Sunday/Public holiday
   Evening is 6.00pm to 10.00pm Monday to Friday and 6.00pm to 10.00pm Saturday/Sunday/Public holiday
   Night is 10.00pm to 7.00am Monday to Friday and 10.00pm to 8.00am Saturday/ Sunday/Public holiday.

5.13.1.5 Concurrent construction projects

The nearest construction work associated with this project would be the Wakehurst Parkway surface road works to the south of the Wakehurst Parkway north construction support site (BL14).

No nearby state significant projects are known to be built at the same time. The Northern Beaches Hospital road upgrade project was completed in August 2020 which would be more than two years before the commencement of the works on the project.

5.13.1.6 Construction assessment scenarios

The airborne noise assessment of the Wakehurst Parkway north construction support site (BL14) was separated into three stages. Each stage was assessed against the work periods proposed in Table 5-210. The details of modelled construction plant items and corresponding sound power levels are presented in Annexure E.

The equipment/plant listed in Annexure E represent the reasonable worst case equipment/plant operating simultaneously in any 15 minute period (refer to Section 4.2.2 for further explanation of assessment scenarios).

Multiple activities would sometimes occur concurrently within the one construction support site and were captured in the assessment as shown in Table 5-210.

5.13.1.7 Summary of assumed noise treatment and management measures

As part of the assessment process, feasible and reasonable noise treatment measures and management methods have been identified based on the preliminary site layout and the reasonable worst case plant/equipment operating, to assist in attenuating and managing noise emissions from the construction activities.

Identified feasible and reasonable noise treatment measures have been included in the noise model and are presented in Table 5-211. The results presented in this assessment are based on those noise treatments and management measures being implemented.

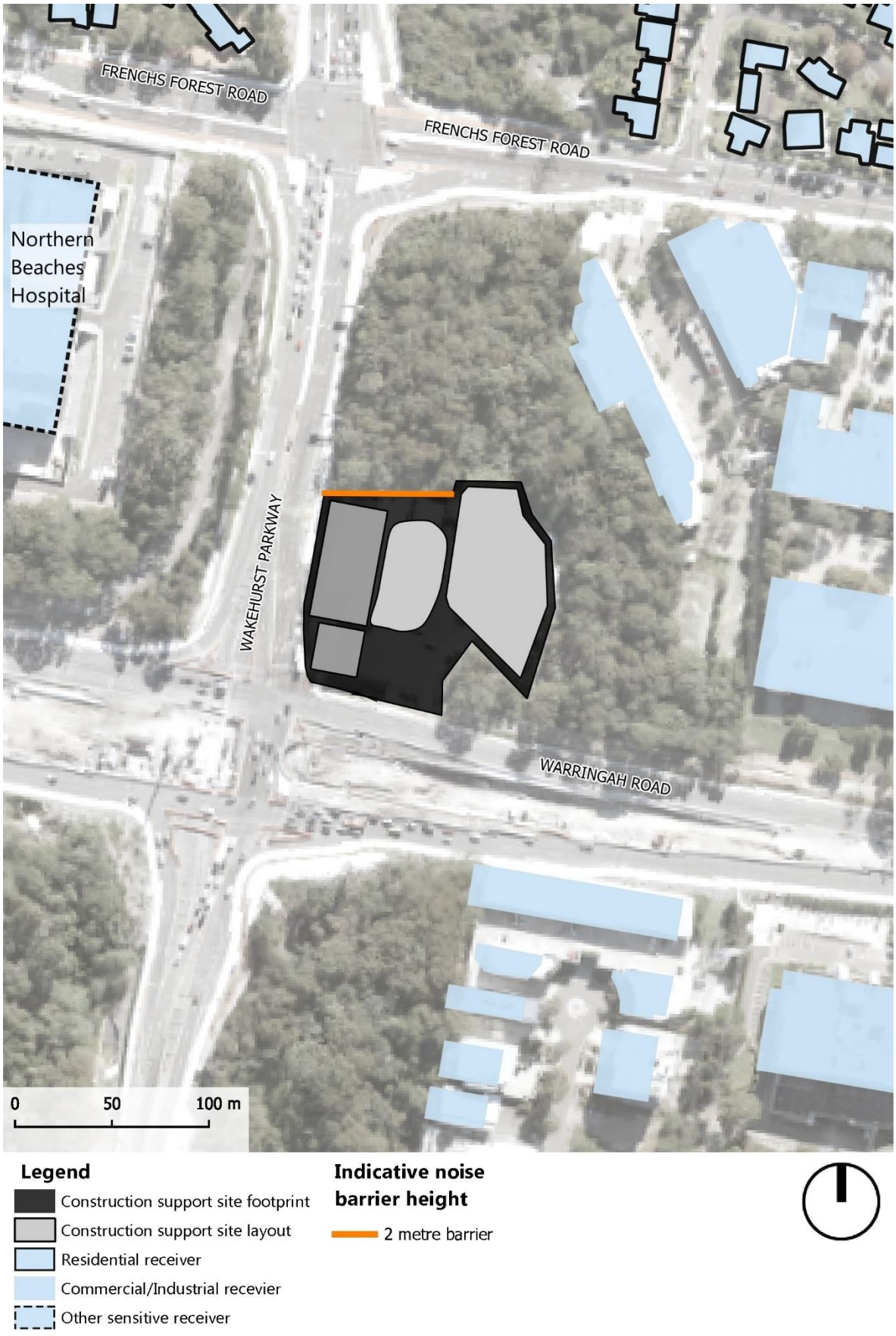
The locations of physical treatment measures are shown on Figure 5-25

Table 5-211 – Assumed noise treatment and management measures – Wakehurst Parkway north construction support site (BL14)

Activity or plant/equipment	Description of management and mitigation measures
Work outside standard hours	All work at this site would occur only in standard hours, except for deliveries, office activities and occasional activities associated with support and deliveries.
Construction support activities	An indicative two metre high noise barrier would be built along the northern boundary of the site during WPN_02.

Further design development and construction planning refinements to the construction support site layouts, equipment, construction methods or construction hours may require specific mitigation and management measures that are different from those outlined in this section. Final details for noise treatments and management measures will be confirmed during further design development and construction planning to determine what is feasible and reasonable, with consideration of cumulative construction impacts.

Figure 5-25 – Construction support site layout with indicative acoustic treatment measures at corner of Wakehurst Parkway and Warringah Road



5.13.2 Construction airborne noise

The methodology used for assessing airborne noise impacts from construction support sites is outlined in Section 4.2.2.

5.13.2.1 Nearby receiver summary and objectives

Table 5-212 presents NMLs and the screening levels for the assessment of sleep disturbance for the nearest residential receivers surrounding the Wakehurst Parkway north construction support site (BL14). Noise management levels for other (non-residential) noise sensitive receivers are presented in in Section 3.4.1. The locations of the NCAs surrounding the construction support site are shown in Figure 5-24.

Table 5-212 – Construction noise management levels and screening levels for residential receivers

NCA ID	Noise management levels (NML) $L_{Aeq(15\ minute)}$				Sleep disturbance screening levels
	Standard Hours (RBL + 10dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL + 5dB)			L_{Amax} (RBL + 15dB)
	Day	Day	Evening	Night	Night
55.1	56	51	45	35	45
55.4	56	51	45	35	45
56.1	63	58	53	39	45
57.1	56	51	45	35	45
58.1	56	51	45	35	45

5.13.2.2 Predicted noise impacts

Table 5-213 provides a key to the cell shading and text formatting used to explain results in the following tables. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-213 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes:
1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are

expected to exceed NMLs. The range is of noise impacts throughout all receivers in the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented. It is noted that the noise predictions include adjustments for annoying activities, in accordance with the ICNG.

Noise contours for the loudest early works, site establishment, and longer term tunnelling stages are shown in Annexure H.1. Maps presenting the predicted exceedance for a sample of scenarios at the construction support site with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different periods.

5.13.2.3 Residential

The predicted noise levels for residential receivers are presented in Table 5-214 for standard hours. The number of receiver buildings predicted to exceed NMLs during each stage are summarised in Table 5-216.

Predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-214 – Predicted construction noise levels during standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Wakehurst Parkway north construction support site (BL14)

NCA	Noise Management Level		Predicted noise levels at each construction stage[1, 2]				
	HNA	NML	WPN_01	WPN_02	WPN_03	WPN_04	WPN_05
55.1	75	56	≤ 53	≤ 43	≤ 42	≤ 39	≤ 40
55.4	75	56	≤ 45	≤ 38	≤ 38	< 35	≤ 35
56.1	75	63	≤ 68	≤ 56	≤ 53	≤ 52	≤ 53
57.1	75	56	≤ 63	≤ 55	≤ 54	≤ 48	≤ 52
58.1	75	56	≤ 57	≤ 52	≤ 53	≤ 49	≤ 49

Notes:
1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))
2. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-215 – Predicted construction noise levels outside standard hours (residential receivers) – $L_{Aeq(15\ minute)}$, dB(A) – Wakehurst Parkway north construction support site (BL14)

NCA	Noise Management Level				Predicted noise levels at each construction stage[3]				
	HNA	Day (O)	Eve	Night	WPN_01[1]	WPN_02[1]	WPN_03	WPN_04[1]	WPN_05[1]
55.1	75	51	45	35	-	-	< 35	-	-
55.4	75	51	45	35	-	-	< 35	-	-
56.1	75	58	53	39	-	-	≤ 37	-	-
57.1	75	51	45	35	-	-	≤ 35	-	-
58.1	75	51	45	35	-	-	≤ 35	-	-

Note:
1. No typical work is proposed outside standard construction hours
2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A))
3. Predicted noise levels for each stage are based upon the reasonable worst case 15 minute construction works scenario as described in Section 4.2.2.

Table 5-216 – Number of receiver buildings over the noise management level (all NCAs) – residential receivers – Wakehurst Parkway north construction support site (BL14)

Modelled representative activity	Assessment reference	Highly noise affected > 75 dB(A) L_{Aeq}		Day (standard hours) L_{Aeq}			Day (outside standard hours) L_{Aeq}				Evening L_{Aeq}				Night L_{Aeq}				Sleep disturbance L_{Amax}	
		Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening	Awakening
1. Early works	WPN_01[1]	0	0	31	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Establish site	WPN_02[1]	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Surface road works support activities	WPN_03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	161	0
4. Build motorway facilities	WPN_04[1]	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. Site rehabilitation	WPN_05[1]	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes: 1. No typical work is proposed outside standard construction hours

2. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period in accordance with the key presented in Table 5-213.

5.13.2.4 Residential – summary of airborne noise assessment

Standard construction hours

The highest predicted noise levels occur during early works (WPN_01). Up to 31 residential receiver buildings located in NCAs 56.1 and 57.1 are predicted to be noise affected (ie >NML) by up to 10 dB(A) above the NML.

The predicted noise levels are based on all plant operating concurrently during each assessment activity. However, in practice not all plant would typically operate all the time, meaning that for a substantial part of the time actual noise levels would be less than the predicted noise levels.

Work outside standard construction hours

Works carried out outside standard construction hours include support and delivery activities associated with the Wakehurst Parkway surface road works, as presented in Table 5-215. With feasible and reasonable noise mitigation no receivers are predicted to be noise affected outside standard hours.

Sleep disturbance

At the Wakehurst Parkway north construction support site (BL14), the key OOHW stage which potentially includes activities with maximum noise levels (L_{Amax}) is truck deliveries during surface road works support activities (WPN_03).

During this activity, up to 161 receiver buildings are predicted to potentially be exposed to maximum noise levels above the sleep disturbance screening level (up to LAmax 61 dB(A)). However, no receivers are expected to experience noise above the awakening reaction level

5.13.2.5 Non-residential

The predicted noise levels for non-residential receivers are presented in Table 5-217. The number of receiver buildings predicted to exceed the NMLs are summarised in Table 5-218.

The predicted noise levels are intended to be conservative and represent reasonable worst case impacts during the project.

Table 5-217 – Predicted noise levels at other sensitive receiver locations, dB(A) – Wakehurst Parkway north construction support site (BL14)

Receiver type	NCA	NML	Predicted noise level at each construction stage				
			WPN_01	WPN_02	WPN_03	WPN_04	WPN_05
Commercial	55.1	70	42	< 35	< 35	< 35	< 35
	56.1	70	56	46	44	42	43
	58.2	70	36 - 75	≤ 62	≤ 63	≤ 60	≤ 59
Childcare	55.1	50	42	< 35	< 35	< 35	< 35
	58.2	50	65	53	53	49	50
Educational	57.1	55	37 - 56	≤ 46	≤ 45	≤ 42	≤ 43
Other sensitive receiver	55.1	60	40 - 47	≤ 36	≤ 37	< 35	< 35
	57.1	55	≤ 70	≤ 60	≤ 57	≤ 55	≤ 57
	58.2	70	36 - 55	≤ 45	≤ 45	≤ 41	≤ 42
Recreational	55.1	65	≤ 41	≤ 35	≤ 35	< 35	< 35
	55.4	60	42 - 59	37 - 46	37 - 46	≤ 41	≤ 43
	56.1	65	44 - 66	36 - 53	≤ 52	≤ 49	≤ 50
	57.1	65	45	39	39	< 35	36
Place of worship	56.1	55	52 - 63	43 - 51	42 - 51	38 - 47	40 - 48

Notes: 1. Construction noise level cells are shaded based upon the predicted worst case NML exceedance of the controlling time period as follows: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML.

Table 5-218 – Number of other sensitive receivers over the noise management levels (all NCAs) – Wakehurst Parkway north construction support site (BL14)

Modelled representative activity	Assessment reference	Commercial[1]			Childcare			Educational			Recreational[1]			Places of worship			Other sensitive receivers[1]		
		1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
1. Early works	WPN_01	3	0	0	0	1	0	1	0	0	1	0	0	4	0	0	0	1	0
2. Establish site	WPN_02	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
3. Surface road works support activities	WPN_03	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
4. Construct the permanent tunnel support facilities	WPN_04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Site rehabilitation	WPN_05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Notes: 1. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table.

After all feasible and reasonable noise treatment and management measures are applied, up to 11 non-residential receivers are predicted to be noise affected (ie >NML) during Stages 1, 2, 3 and 5 (early works (WPN_01), site establishment (WPN_02), surface activities (WPN_03) and site rehabilitation (WPN_05).

During the longer term stage (WPN_03 surface activities), the following locations are predicted to be noise affected:

- A childcare receiver in NCA 58.2 (Kindalin Early Childhood Learning Centre) is predicted to exceed the screening NML by up to 3 dB(A), which would be considered minor
- The predicted noise levels at the Northern Beaches Hospital marginally exceeds the NML by up to 2 dB(A).

During the worst case shorter term stage (early works (WPN_01)), Northern Beaches Hospital and one childcare receiver in NCA 58.2 are predicted to be moderately noise affected as follows:

- A childcare receiver in NCA 58.2 (Kindalin Early Childhood Learning Centre) is predicted to exceed the screening NML by up to 15 dB(A)
- The predicted noise levels at the Northern Beaches Hospital exceeds the NML by up to 15 dB(A).

5.13.2.6 Cumulative construction noise impacts

As outlined in Section 4.2.4, potential cumulative noise impacts from all major construction projects around the Wakehurst Parkway north construction support site would be considered when assessing the site and determining feasible and reasonable mitigation and management measures.

No other major projects are in close proximity to the site; however, there are a number of project related construction work areas and construction support sites located nearby. Proposed staging of concurrent construction works associated with the project that are considered for cumulative construction impacts are presented in Table 5-219**.**

Table 5-219 – Concurrent construction works near the Wakehurst Parkway north construction support site

Project	2022	2023	2024	2025	2026	2027
Wakehurst Parkway north construction support site (WPN)						
Wakehurst Parkway surface road works (WKP)						

Proposed staging of concurrent work has been reviewed for the closest receivers to the site at Wakehurst Parkway north. The loudest stages for both standard construction hours and out-of-hours works have been used to calculate potential cumulative noise impacts.

If noise from one site dominates noise levels at the receiver (ie > 5-10 dB(A) above noise from other sites), that site would typically control construction noise levels at the receiver. As such, it is not likely to increase the overall $L_{Aeq,\ 15\ minute}$ construction noise level at these receivers.

If noise levels from each site are similar at a receiver, a total construction noise increase of up to 3 dB(A) is expected. Two representative NCAs adjacent to the works have been assessed in Table 5-220.

Table 5-220 – Potential cumulative noise impacts from construction projects near the Wakehurst Parkway north construction support site

NCA	Construction period (NML)	Construction work area	Works stage	$L_{Aeq\ 15\ minute}$, dB(A)	Potential change in construction noise impacts due to concurrent activities during stage
NCA 56.1	Standard hours NML= 61 dB(A)	WPN	1. Early works	≤ 68	1. Potential cumulative increase of up to 2 dB(A), combining up to 9 dB(A) over the NML. 2. Negligible cumulative increase as Wakehurst Parkway surface road works (WKP) dominates during the activity, Wakehurst Parkway north (WPN) construction noise is below NML.
			2. Establish site	≤ 56	
		WKP	WKP1A Paving/asphalting/road surface road works	55 - 66	
	OOHW NML D/E/N 56/51/37	WPN	No work	≤ 37	Wakehurst Parkway surface road works work would not occur concurrently with Wakehurst Parkway north outside standard hours work.
		WKP	No overlap		
NCA 58.1	Standard hours NML= 56 dB(A)	WPN	1. Early works	≤ 57	Negligible cumulative increase as Wakehurst Parkway north dominates during the activity, Wakehurst Parkway surface road works construction noise is below NML.
			2. Establish site	≤ 52	
		WKP	WKP1A Paving/asphalting/road surface road works	≤ 39	
	OOHW NML D/E/N 51/45/35	WPN	No work		Wakehurst Parkway surface road works work would not occur concurrently with Wakehurst Parkway north outside standard hours work.
		WKP	No overlap		

At receivers not directly adjacent to the Wakehurst Parkway north construction support site, there is potential for cumulative increases of construction noise from concurrent works with the Wakehurst Parkway surface road works.

At some receiver locations, when an individual site does not dominate construction noise levels at the receiver (ie it does not contribute more than 5 dB(A) more noise than other sites), cumulative construction noise levels could be up to 3 dB(A) higher than the noise levels predicted for any one activity.

Any increase due to cumulative noise is unlikely as noise generating activities would need to occur simultaneously. However, even where a cumulative construction noise increase is predicted, the total construction noise level at that receiver is expected to be below the NML.

Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5.

5.13.3 Construction related road traffic noise assessment

Vehicles would access the site from Wakehurst Parkway via Warringah Road.

Table 5-221 presents the forecasted number of vehicles accessing the construction support site during the peak construction period at this site. A maximum of five heavy vehicles would access the site each hour during the daytime period (7.00am to 10.00pm), which would include heavy vehicle movements associated with the concrete batch plant at Wakehurst Parkway north which could be a maximum of three heavy vehicles per hour. During the night time period (10.00pm to 7.00am) there would be a maximum of one truck per hour (no more than four trucks in total).

Table 5-221 – Number of construction vehicles accessing the Wakehurst Parkway north construction support site (BL14)

Type of vehicle	Per day[1] over 15 hours[3,4]	Per night[2] over nine hours[3]
Heavy vehicle (deliveries, spoil haulage and concrete deliveries)	47	4
Light vehicle	68	22

Notes:
1. Day is 7.00am to 10.00pm
2. Night is 10.00pm to 7.00am
3. Numbers presented are individual vehicles, not vehicle movements
4. Vehicle numbers has been distributed onto the local road network based upon the proposed access roads. Where a vehicle accesses the site by one road and leaves by another, one vehicle movement is counted along each road once. Where a vehicle accesses and leaves the site by the same road, two vehicle movements are counted on that road.

This assessment is based on predicted non-project traffic volumes. Table 5-222 presents the predicted increase in road traffic noise from additional construction traffic.

Table 5-222 – Road traffic noise impacts from the Wakehurst Parkway north construction support site (BL14)

Construction vehicle access road	Road type	Time of day	Predicted road traffic noise increase, dB(A)[1, 2]	Exceedance of the RNP criteria	Exceedance of sleep disturbance screening level
Wakehurst Parkway	Arterial	Day $L_{Aeq(15hr)}$	0.5	No	N/A
		Night $L_{Aeq(9hr)}$	<0.5	No	Yes

Notes:
1. Predicted road traffic noise levels are based upon a loudest heavy vehicle,
2. Predicted road traffic noise levels are based upon the nearest residential receiver to the road. Receivers at further distances are expected to experience lower noise levels than those predicted.

The predicted road traffic noise increase due to the Wakehurst Parkway north construction support site (BL14) is less than 2 dB(A) during day and night time periods. Therefore, predicted noise levels on those roads comply with the RNP criteria identified in Section 3.4.2.

Maximum noise levels (L_{Amax}) from night period truck movements are predicted to exceed both the sleep disturbance screening level and the adopted awakening reaction level.

However, night time heavy vehicle movements from this site would be limited to one vehicle per hour, which is not a substantial number when compared to existing heavy vehicle movements on Warringah Road and Wakehurst Parkway. Nearby receivers are not likely to notice the increase in the number of maximum noise events caused by the additional truck movements generated by the site.

Mitigation and management measures detailed in Section 6.7 should be considered during further design development and construction planning and, where feasible and reasonable, adopted to minimise construction traffic noise impacts associated with the project.

5.13.3.1 Cumulative construction road traffic assessment

As there are a number of construction support sites and surface road construction works occurring concurrently as part of the project, there is the potential for cumulative noise impacts from the combined construction road traffic along the Wakehurst Parkway.

Refer to Section 5.12.3.1 for an assessment of cumulative construction road traffic operating along the Wakehurst Parkway.

5.13.4 Ground-borne construction noise

Ground-borne noise levels have the potential to be generated during early works (WPN_01), where rock hammering may be needed for utilities adjustments. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers. Section 4.3.2 outlines the potential impacts from ground-borne noise generated by surface construction works such as these.

5.13.5 Construction vibration

The vibration generated from construction works would vary depending on the level and type of activity carried out. For the Wakehurst Parkway north construction support site (BL14), the only stage which may include vibration intensive works is early works (WPN_01), where rock hammering may be needed for utilities adjustments.

Proposed vibration intensive plant items are identified in Annexure E. Minimum working distances for a range of construction plant items are presented in in Table 4-11. Presented in Annexure L are the estimated minimum working distances from the construction support site for both structural damage and adverse human response to vibration for the most vibration intensive activity proposed.

Table 5-223 presents the identified building/structures within the minimum working distances for rock hammering at Wakehurst Parkway north construction support site (BL14). Only two commercial buildings are within the adverse human response minimum working distance, with no building/structures within the cosmetic damage range minimum working distances.

Potential vibration generated to receivers depends on the vibration source levels, separation distance, intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. This assessment considers a worst case scenario that the proposed vibration intensive plant items could be used anywhere within the boundaries of the site. However, this is unlikely to occur and the location of the vibration intensive equipment should be reviewed during detailed construction planning, as recommended in Section 6.8.

Table 5-223 – Number of structures within nominated minimum working distance for vibration impacts – site at Wakehurst Parkway north construction support site (BL14)

NCA	Number of structures within minimum working distances		
	Cosmetic damage		Human response
	Sound structure	Unsound structure	
Early works			
58.2	-	-	2

5.14 Wakehurst Parkway surface road works

5.14.1 Construction works overview

5.14.1.1 Summary of construction works

The project would connect to the Wakehurst Parkway at Killarney Heights. On and off ramps and tunnel portals in addition to widening and upgrading of the Wakehurst Parkway would be carried out to provide connection to the surface road network, detailed as follows:

- Surface earthworks and tunnel portals to connect the tunnels to the Wakehurst Parkway at Killarney Heights
- Widening and upgrading of Wakehurst Parkway between Kirkwood Street at Seaforth and Warringah Road at Frenchs Forest from two to four lanes
- Earthworks would be completed using conventional methods of road construction. The general earthworks method would include:
  - Vegetation clearance and topsoil stripping. Mulched vegetation and topsoil would be stockpiled for later re-use in site rehabilitation and landscaping works
  - Areas of new cut and fill to design levels and widening of existing cuts and embankments. This may include reuse of tunnel spoil for fill embankments and the construction of retaining walls and reinforced soil walls
  - Installation of road drainage infrastructure
- Controlled blasting where identified as beneficial for deep cut excavation areas (see Section 5.17 for assessment)
- Roadside furniture including lighting, traffic signals, safety barriers, fencing and retaining walls
- Fauna crossings at Wakehurst Parkway to provide fauna connectivity between Garigal National Park and Manly Dam Reserve and fauna fencing along Wakehurst Parkway
- Noise attenuation including noise barriers and at-property treatments
- Surface drainage, utility connections and modifications
- New and upgraded pedestrian and cyclist infrastructure around surface connections and along the upgraded Wakehurst Parkway, including two new active transport bridges.

During the works, there would be two support sites that would support the tunnel portal construction, permanent facilities and surface road works. These sites would be the main support sites for project management, laydown, offices and toilets.

The Wakehurst Parkway south construction support site (BL12) at Judith Street, Seaforth would support the tunnel portal construction, motorway facilities construction and surface road works, which are assessed in Section 5.11.

The Wakehurst Parkway north construction support site (BL14) at the northeast corner of Warringah Road and Wakehurst Parkway would support the operational maintenance building construction and surface road works and then transition to a tunnel support facility. This site is assessed in Section 5.13.

The noise assessment has assessed five major works areas which have been identified for potential use during the construction works. The location of the overall works areas and the surrounding noise sensitive receivers is presented in Figure 5-26, with the locations of the major works areas and assessment areas presented in Figure 5-27 to Figure 5-28.

The key features of the Wakehurst Parkway surface road works are provided in Table 5-224.

Table 5-224 – Wakehurst Parkway surface road works – key works summary

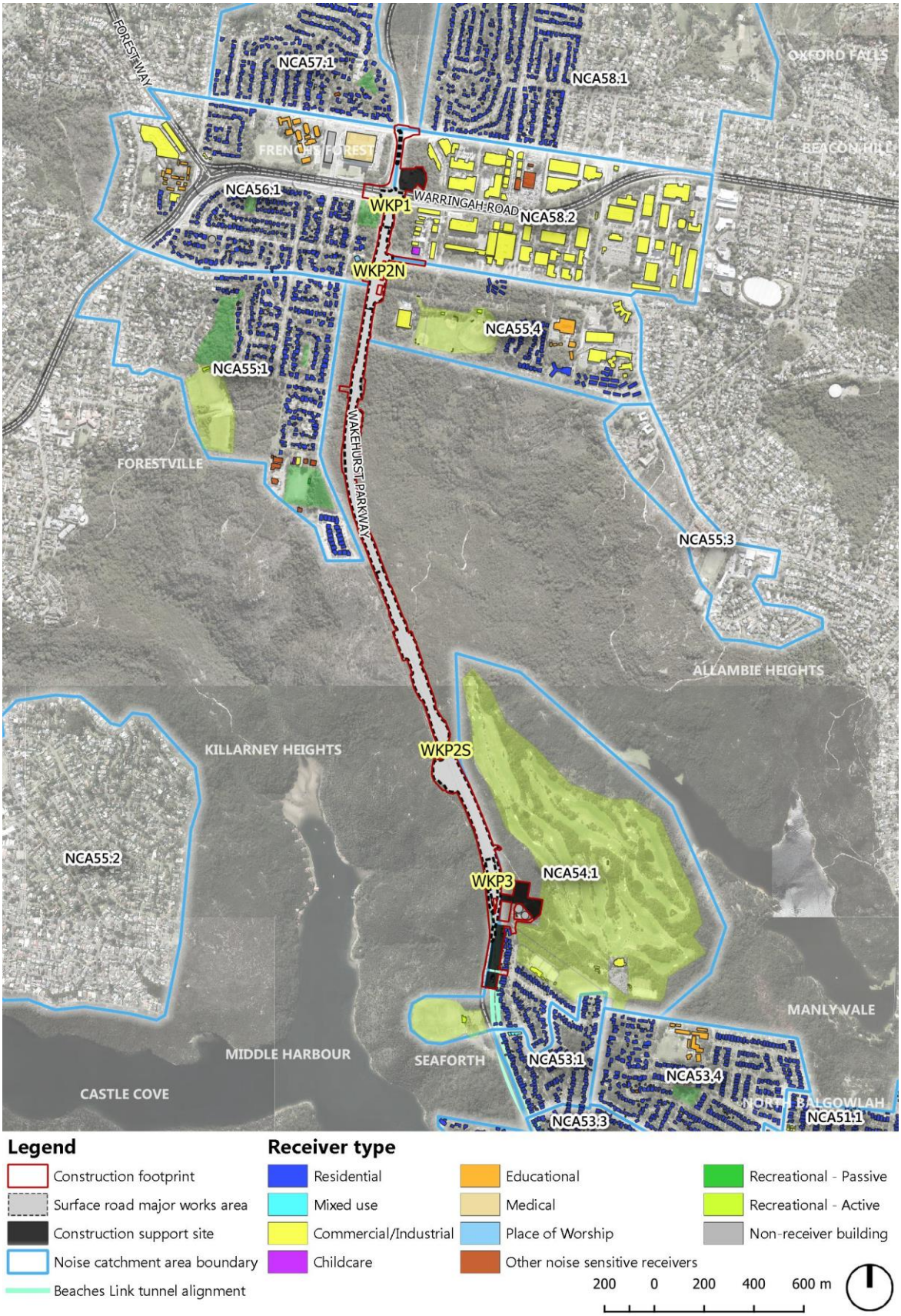
Key works element	Description	Relevant works areas
Beaches Link connections		
Ramps and portals to Beaches Link	-	3
Ventilation outlet and motorway facilities	Construction of the permanent motorway facility and ventilation outlet above the tunnel portal	3
Surface road widening and upgrading works	Widening and upgrading of Wakehurst Parkway between Kirkwood Street at Seaforth and Warringah Road at Frenchs Forest from two to four lanes	1-3
Bridge works		
Wakehurst Parkway active transport bridge	Replacement of the existing pedestrian bridge across the Wakehurst Parkway, with a new shared user bridge about 350 metres south of Warringah Road at Frenchs Forest	2
Utilities including sewerage and infrastructure works		
Surface drainage and stormwater modification works	Channels, culverts throughout works areas	1-3
Shared pedestrian/bike paths	-	1-3
Lighting, signage and road infrastructure	Throughout works areas	1-3
Utilities modification works	Throughout works areas	1-3
Landscaping	Throughout works areas	1-3

5.14.1.2 Nearby noise and vibration sensitive receivers

Figure 5-26 presents the site location, nearby noise sensitive receivers and the NCA boundaries.

The NCAs that are in proximity to the Wakehurst Parkway surface road works range from NCA 39.2 through to NCA 58.2. Refer to Annexure B.1 for the complete information on the nearby noise sensitive receivers and the NCA boundaries.

Figure 5-26 –Wakehurst Parkway surface road works major works areas, nearby noise sensitive receivers, and noise catchment area (NCA) boundaries



5.14.1.3 Assessed construction works

The assessment of construction noise and vibration impacts associated with the Wakehurst Parkway surface road works has three main areas of construction works, which have been broken into, are five major works areas for assessment purposes, which are presented in Table 5-225 and shown in Figure 5-27 and Figure 5-28.

Table 5-225 – Wakehurst Parkway surface road works – construction assessment work areas

Work area assessment scenario reference (Figure 5-26)	Location	Works description
WKP1	Warringah Road / Wakehurst Parkway intersection	• Earthworks • Construction of drainage structures • Paving • Construction of bridge structures • Installation of road furniture, lighting and signage • Architectural finishes and landscaping.
WKP2N	Wakehurst Parkway full length north of Burnt Street, Seaforth	
WKP2C		
WKP2S		
WKP3	Wakehurst Parkway, north of Judith Street, Seaforth	• Tunnel portals and Wakehurst Parkway tunnel connection – cut and cover works area • Construction of motorway facilities and ventilation outlet.

Additionally, there are some ancillary local area road works or utility adjustment works that would be required for relatively short term periods (less than one month) within the construction footprint. These would occur during standard hours where practicable. However, works outside standard construction hours may be required due to road congestion and road safety issues. These works have been assessed separately, which is presented in Section 5.15.1.

Figure 5-27 – Wakehurst Parkway surface road works – assessment work areas (north)

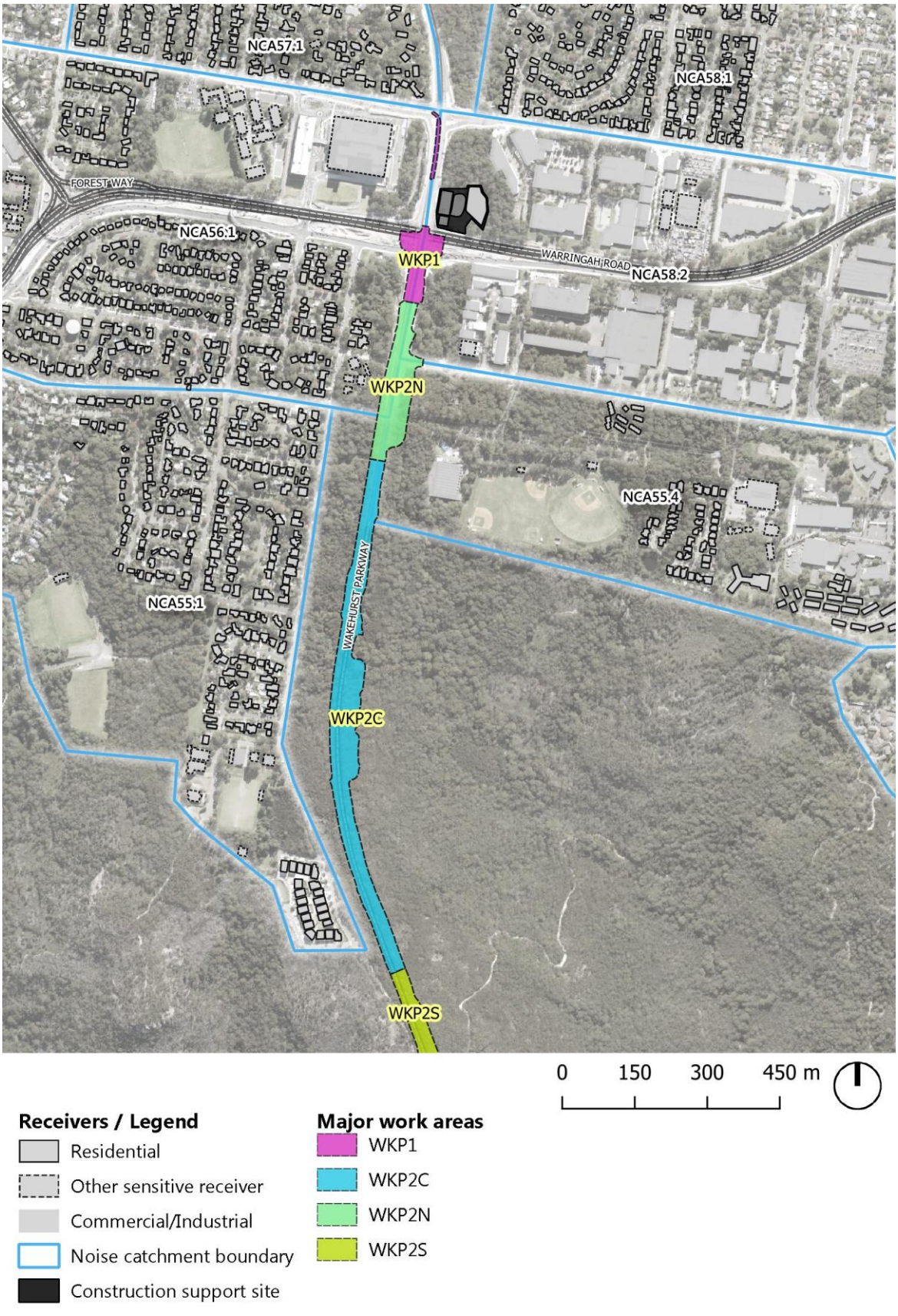
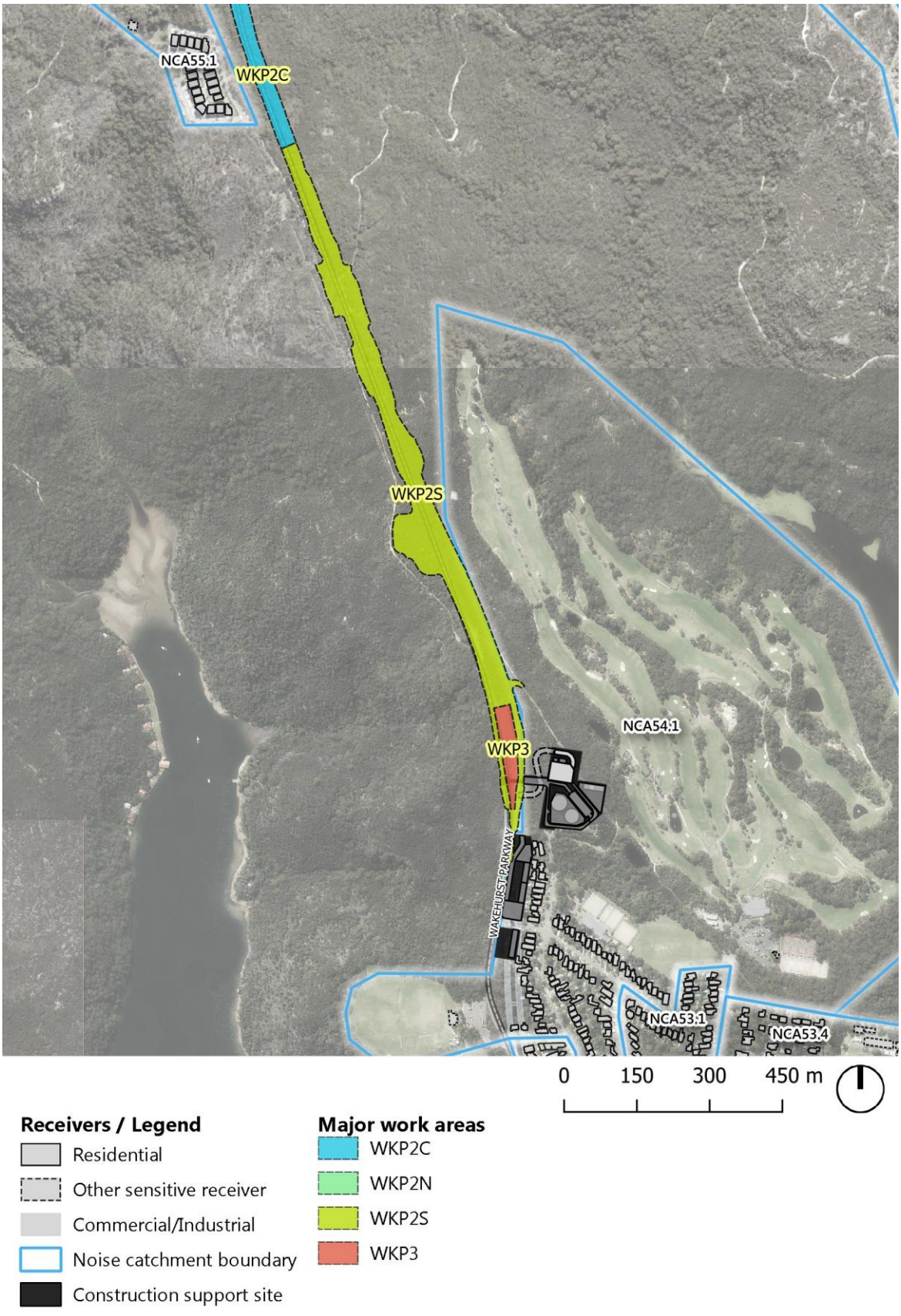


Figure 5-28 – Wakehurst Parkway surface road works – assessment work areas (south)



5.14.1.4 Construction works program

The proposed approximate timeframe for the Wakehurst Parkway surface road works is presented in Table 5-226 and Table 5-227, subject to project approval. These works would occur from the middle of 2023 until early 2027. The activity with the longest duration at would be the surface road upgrade works.

Table 5-226 – Wakehurst Parkway surface road works – indicative program and timeline

Project component	Indicative construction timeframe																			
	2023				2024				2025				2026				2027			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Wakehurst Parkway surface road works																				

Table 5-227 – Wakehurst Parkway surface road works – indicative duration of construction work

Type of construction works	Works area reference (Figure 5-26)	Indicative duration of works
Surface road upgrade	WKP1 WKP2N WKP2C WKP2S	3 years and 3 months
Cut and cover portals	WKP3	24 months
Motorway facilities construction		24 months

5.14.1.5 Construction working hours and required out of hours work

Where feasible and reasonable, works would be carried out during standard construction hours. However, some key activities would occur during night time road closures, as the works would require occupancy of Wakehurst Parkway lanes, such as for road tie ins, traffic management and diversion activities, and delivery and installation of large construction items.

Due to the importance of these roads to the Greater Sydney road network, works would require ROLs that typically require that access to the work area would not normally be allowed during periods of high traffic volumes, and so construction work would typically need to happen in the night time. ROL conditions can vary and depend on existing road traffic volumes.

The key OOHW required, and the justifications as to why, are presented in Table 5-228.

Table 5-228 – Required out of hours work – Wakehurst Parkway surface road works

Work area reference (Figure 5-26)	Required OOHW	Percentage of program days OOHW is required	Justification
WKP1 – Road upgrade - Warringah Road/ Wakehurst Parkway road modifications	Pavement/road modifications works in major traffic corridor	10	ROL required, impact on road network performance, safety for workers and road users within road corridor
WKP2N – Road upgrade	1. Bridge modification/ construction works within/ adjacent/ over to traffic corridor 2. Completion of temporary diversions, traffic controls and traffic switches	10	1. ROL required to minimise impacts on road network performance, worker safety and road user safety during construction/demolition of bridge elements. 2. Large load lifts over existing roads 3. Impact on road network performance/safety from oversized loads
WKP2C – Road upgrade	Completion of temporary diversions, traffic controls and traffic switches	10	ROL required, impact on road network performance, safety for workers and road users within road corridor
WKP2S – Road upgrade	Completion of temporary diversions, traffic controls and traffic switches	10	ROL required, impact on road network performance, safety for workers and road users within road corridor
WKP3 – Cut and cover portals and motorway facilities	1. Deliver/shifting of oversized items for the Cut and cover portals 2. Completion of tie-ins at the extents of the road construction	10	1. ROL required to minimise impacts on road network performance, worker safety and road user safety during construction/demolition of bridge elements. 2. Large load lifts over existing roads 3. Impact on road network performance/safety from oversized loads

Notes: 1. Based on an estimated number of days of the overall stage duration that may require OOHW, rounded up to the nearest 10 per cent. Estimated period of OOHW would be refined during detailed construction planning stage.

As well as the above key OOHW, modifications to utilities, including sewage infrastructure, would be required as part of the works. Where the works would require occupation of trafficable parts of the roadway and immediately adjacent areas they would typically be required to be carried out outside standard construction hours for safety reasons or to minimise traffic disruptions, as required under an ROL. These would be managed, where feasible and reasonable, through traffic management and traffic switches incorporated into the detailed construction planning.

5.14.1.6 Concurrent construction projects

The nearest construction support sites associated with this project would be the Wakehurst Parkway east construction support site (BL13) supporting tunnelling for the project, adjacent to the southern end of the Wakehurst Parkway surface road works areas, the Wakehurst Parkway south construction support site (BL12) also adjacent to the southern end of the Wakehurst Parkway surface road works areas, and the Wakehurst Parkway north construction support site (BL14) located at the northern end of the Wakehurst Parkway surface road works areas.

The nearest other construction works areas associated with the project would be the Balgowlah surface road works and Balgowlah Golf Course construction support site (BL10), located about 2 kilometres southeast of this construction support site. At this distance, it is unlikely there would be a substantial cumulative construction impacts on any receiver.

No nearby state significant projects are known to be built at the same time. The Northern Beaches Hospital road upgrade project was completed during 2020 and so any construction noise impacts following the commencement of the works on the project would be separated by more than two years.

5.14.2 Construction airborne noise

The methodology used to assess airborne noise impacts from surface road works has been used in this assessment. The methodology is outlined in Section 4.2.3.

5.14.2.1 Construction activities and noise sources

A range of construction activities are to be carried out within each major works area. Presented in Table 5-229 is the range of potential types of construction activities, associated assessment SWLs that may occur as part of the surface road works, and an indication if these are to occur in each major works area. Works that could occur during standard construction hours are indicated as 'D', works modelled during OOHW periods are indicated as 'O', and where the activity may occur during both period it is indicated as 'DO'.

For assessment purposes, not all activities could be modelled, so only the most noise intensive activities have been modelled. They are highlighted in Table 5-229, with **blue** shading where the activity has been modelled during standard construction hours, and **orange** shading where the activity has been modelled outside standard construction hours. However, other noted activities may also occur as part of the construction works. As presented the noise impacts would vary as the construction activities vary.

A construction contractor, once appointed, would review and refine the project design and construction methodology during further design development and construction planning. The contractor should review noise impacts with a better understanding of the construction plant and equipment required for specific works, the locations they would likely operate, and the potential for concurrent activities in order to make more accurate predictions of the nature and duration of impacts.

Table 5-229 – Proposed construction activities and construction hours across the works areas and assessed works activities – Wakehurst Parkway surface road works

Assessment scenario reference	Road works	Concrete barriers and traffic controls	Demolition (rock hammering)	Pavement/road modification works	Paving/asphalting/road surface road works (with concrete saw)	Paving/asphalting/road surface road works (without concrete saw)	Resurfacing works	Road furniture installation/modification	Earthworks	Clearing and grubbing works	Bulk earthwork	Pile breaking	Piling - bored	Rock drilling	Rock trimming	Shotcrete	Structures	Concrete formwork/reinforcement	Concrete pours	Erection of structural steelwork	Erection/removal of large items	Noise barrier installations	Services/utilities	Utilities modification works	Support activities	Deliveries	Deliveries (oversized)	Mobilisation/demobilisation/site setup	Spoil handling	Support site general activities
Worst case SWL[1]		105	121	120	120	114	118	114		116	119	122	117	117	121	112		113	116	117	111	118		120		104	111	110	106	105
Typical case SWL[1]		99	109	110	109	109	112	107		112	116	113	108	95	116	109		104	112	111	110	111		110		98	110	108	104	100
WKP1 – Road upgrade - Warringah Road/ Wakehurst Parkway road modifications		DO		D	D	DO	D	D							D			D	D		D			DO		D		D		D
WKP2 – Road upgrade		DO	D	D	D	DO	D	D		D	D				D			D	D		DO	D		DO		D	DO	D		
WKP3 – Cut and cover portals and motorway facilities		DO	D	D	D	DO	D	D		D	D	D	D			D		D	D	D	DO	D		DO		D	DO	D	D	

Notes:
1. The activity SWL includes the adjustments for quantity of equipment assumed operating, equipment usage factor, and penalties for annoying characteristics in accordance with the ICNG. Refer to Annexure F
2. ACTIVITY KEY - Standard construction hours = 'D', OOHW = 'O', Standard construction hours and OOHW = 'DO'
3. MODELLED SCENARIO KEY – Shaded **blue** = Standard construction hours, Shaded **orange** = OOHW.

5.14.2.2 Construction assessment scenarios

Presented in Table 5-230 are the assessed activities for each works area, which represents the reasonable most intensive noise activity required as part of the works. However, it should be noted that the type of plant and equipment used throughout the stage would vary depending upon the construction activities being carried out. The range of potential activities that may also take place across the works areas is presented in Table 5-229.

More details of the modelled plant items and relevant sound power levels are presented in Annexure F. The equipment/plant listed in Annexure F represent the reasonable 'typical' and 'worst case' equipment/plant operating simultaneously in any 15 minute period (refer to Section 4.2.3 for further explanation of assessment scenarios).

Where plant items are not operating simultaneously, or for reduced times in the 15 minute period, noise impacts could be lower than predicted.

Table 5-230 – Assessed construction activities – Wakehurst Parkway surface road works

Work area	Assessment scenario reference	Standard hours works	SWL level range, $L_{Aeq\ (15\ minute)}$ dB(A)		Out-of-hours works	SWL level range $L_{Aeq\ (15\ minute)}$ dB(A)	
			Typical	Worst case		Typical	Worst case
WKP1 - Warringah Road/ Wakehurst Parkway	WKP1_A	Paving/asphalting/road surface road works (including concrete sawing)	109	120	Paving/asphalting/road surface road works	109	114
WKP2 – Wakehurst Parkway road upgrade (North)	WKP2N_A	Clearing and grubbing works	112	116	-	-	-
	WKP2N_B	Paving/asphalting/road surface road works (including concrete sawing)	109	120	Erection/removal of precast concrete/large items	110	111
	WKP2N_C	Concrete barriers and traffic controls	99	105	Concrete barriers and traffic controls	99	105
	WKP2N_D	Road furniture installation/ modification	107	114	-	-	-
WKP2 – Wakehurst Parkway road upgrade (Centre)	WKP2C_A	Clearing and grubbing works	112	116	-	-	-
	WKP2C_B	Paving/asphalting/road surface road works (including concrete sawing)	109	120	-	-	-
	WKP2C_C	Concrete barriers and traffic controls	99	105	Concrete barriers and traffic controls	99	105
	WKP2C_D	Road furniture installation/ modification	107	114	-	-	-

Work area	Assessment scenario reference	Standard hours works	SWL level range, $L_{Aeq\ (15\ minute)}$ dB(A)		Out-of-hours works	SWL level range $L_{Aeq\ (15\ minute)}$ dB(A)	
			Typical	Worst case		Typical	Worst case
WKP2 – Wakehurst Parkway road upgrade (South)	WKP2S_A	Clearing and grubbing works	112	116	-	-	-
	WKP2S_B	Paving/asphalting/road surface road works (including concrete sawing)	109	120	-	-	-
	WKP2S_C	Concrete barriers and traffic controls	99	105	Concrete barriers and traffic controls	99	105
	WKP2S_D	Road furniture installation/ modification	107	114	-	-	-
WKP3 – Wakehurst Connection cut and cover tunnel portals and motorway facilities	WKP3_A	Piling – Bored	108	117	-	-	-
	WKP3_B	Bulk earthwork	116	119	Paving/asphalting/road surface road works	109	114
	WKP3_C	Erection/removal of precast concrete/large items	110	111	Erection/removal of precast concrete/large items	110	111
	WKP3_D	Deliveries	103	104	-	-	-
	WKP3_E	Concrete pours	112	116	-	-	-

Notes 1. The activity SWL includes the adjustments for quantity of equipment assumed operating, equipment usage factor, and penalties for annoying characteristics in accordance with the ICNG. Refer to Annexure F for a description of the assumed equipment/plant that are operating.

5.14.2.3 Construction noise prediction summary

5.14.2.3.1 Major works areas

Table 5-232 to Table 5-239 present the predicted noise levels from construction activities for the Wakehurst Parkway surface road works and compare them with the NMLs for residential receivers during both standard construction hours and outside standard hours.

Table 5-240 and Table 5-241 present the approximate number of residential receiver buildings that exceed the NMLs in each NCA, and the number of receiver buildings that are potentially highly noise affected over the entire duration of the works stage.

All receiver building counts presented in this assessment are based upon the reasonably highest noise levels that would occur throughout a works stage and when the works are working closest to each receiver building, defined as the highest noise level envelope explained in Section 4.2.3.2.1. In practice during any individual period of construction works the actual number of receiver buildings that could experience the highest predicted noise levels would be less that these maximum receiver building counts.

Residential receivers

The predicted noise levels generally do not exceed the NMLs for standard construction hours, except for NCAs 54.1, 55.1, 56.1, 57.1 and 58.1.

- During works around the Warringah Road and Wakehurst Parkway intersection (WKP1) the highest predicted noise levels occur for receivers in NCA 57.1 on Frenchs Forest Road, Frenchs Forest
- During the Wakehurst Parkway surface road works (WKP2) the highest predicted noise levels for the northern area occur for receivers in NCA 56.1, receivers in NCA 55.1 for the central area and for receivers along Bantry Bay Road, Frenchs Forest. In the southern section, the highest predicted noise levels are for receivers in NCA 54.1 along Kirkwood Street, Seaforth
- One receiver building may be highly noise affected (ie >75 dB(A)) when works take place nearby during the Warringah Road and Wakehurst Parkway intersection (WKP1) works
- Up to five receiver buildings may be highly noise affected (ie >75 dB(A)) when works take place in the southern section of the Wakehurst Parkway surface road works (WKP2). No receivers are predicted to be highly noise affected (ie >75 dB(A)) from the works in the cut and cover portal area (WKP3).
- During paving/asphalting/road surface works (including concrete sawing) at the Warringah Road and Wakehurst Parkway intersection (WKP1) works area, construction noise levels during typical surface road works are predicted to be above the daytime NMLs at up to four receiver buildings. When worst case activities occur, there is potential for up to 49 receiver buildings to be above the daytime NMLs.
- The highest noise impacts during typical surface road works (WKP2) would likely be during clearing and grubbing activities. Noise levels are predicted to be above the daytime NML at up to two receiver buildings for works in the northern area (WKP2N), 20 for the central area (WKP2C) and 15 for the southern area (WKP2S). All predicted noise levels are less than 10 dB(A) above the daytime NML, except for up to six residential receiver buildings during works in the southern section (WKP2S).
- The highest noise impacts during worst case surface road works (WKP2) would likely be during paving and asphalting. Noise levels are predicted to be above the daytime NMLs at up to 15 receiver buildings for works in the northern area (WKP2N), 77 for the central area (WKP2C) and 34 for the southern area (WKP2S). Noise levels during worst case construction works are predicted to be greater than 20 dB(A) above the daytime NML at up to five of those receiver buildings where noise levels could be considered highly intrusive. However, noise levels are not predicted to be more than 20 dB(A) above the daytime NML at any receiver buildings during typical construction work.
- Bulk earthworks for the cut and cover portal (WKP3) are predicted to result in the highest noise levels and are predicted to be above the daytime NMLs at up to 21 receiver buildings during worst case works, four of which are above the NML by more than 10 dB(A). This level is considered moderately intrusive.

During works outside standard construction hours, the key activity that was assessed was delivery and installation of oversized structures such as pre-fabricated bridge sections, cut and cover portal and motorway facilities construction, and road paving and asphalting road works as part of new lane tie in. Most construction works would occur during standard construction hours, so works outside standard construction hours would generally be infrequent and would coincide with traffic switches. Results of the assessment of noise impacts during works outside standard construction hours are as follows:

- During night works around the Warringah Road and Wakehurst Parkway intersection (WKP1), up to 431 receiver buildings are predicted to exceed the NMLs during typical works. Up to 886 receiver buildings are predicted to be noise affected during worst case works. The highest levels are predicted at receivers in NCA 57.1 (Frenchs Forest) and NCA 54.1 (Seaforth).
- During night period oversized lifting works in the northern section of the Wakehurst Parkway surface road works (WKP2N) up to 199 receiver buildings are predicted to exceed the NMLs during typical works. Up to 249 receiver buildings are predicted to be noise affected during worst case works. The highest levels are predicted at receivers in NCA 56.1 (Frenchs Forest).
- During night works in the central and southern sections of the Wakehurst Parkway surface road works (WKP2C and 2S), up to 77 and 33 receiver buildings, respectively, are predicted to exceed the NMLs during typical works. Up to 139 and 59 receiver buildings, respectively, are predicted to be noise affected during worst case works. The highest levels are predicted at receivers in NCA 56.1 (Frenchs Forest) and NCA 54.1 (Seaforth).
- During night period works related to the cut and cover portals and ventilation outlet and motorway facilities (WKP3) up to 91 receiver buildings are predicted to exceed the NMLs during typical works. Up to 168 receiver buildings are predicted to be noise affected during worst case works. The highest levels are predicted at receivers in NCA 54.1 (Seaforth)
- No receivers are predicted to exceed the NML by more than 25 dB(A) for works in the central Wakehurst Parkway surface road works (WKP2C). In the worst case, noise from other work areas is predicted to exceed the NML by more than 25 dB(A) which would be considered highly intrusive. This could occur at six receiver buildings during WKP1 work, one during WKP2N work, five during WKP2S work and up to four during WKP3 work.

Non-residential receivers

A number of other sensitive receivers adjacent to the Wakehurst Parkway are predicted to be noise affected (ie >NML) during the Wakehurst Parkway road upgrade and the cut and cover portal construction works. Exceedances would generally be minor (1-10 dB(A)) during typical works with only greater exceedances predicted during worst case works. The key impacts are identified as follows:

No non-residential receivers are predicted to experience noise levels greater than NMLs during works in the southern extent of the Wakehurst Parkway surface road works (WKP2S) and the cut and cover portals and motorway facilities works (WKP3).

During the Warringah Road and Wakehurst Parkway intersection upgrade (WKP1) the following noise impacts are predicted:

- Noise levels at a childcare centre in NCA 58.2 (Kindalin Early Childhood Learning Centre), which is predicted to exceed the screening NML by up to 5 dB(A) during typical works, and up to 16 dB(A) during worst case noise intensive works
- When works are closest to the Northern Beaches Hospital, construction noise levels are predicted to exceed the NML by up to 5 dB(A) during typical works, or 16 dB(A) during worst case noise intensive works
- The NML is predicted to be exceeded by up to 9 dB(A) at a place of worship (Frenchs Forest Anglican Church) in NCA 56.1
- The NML is predicted to be exceeded by up to 15 dB(A) at two recreational areas/facilities in NCAs 55.4 and 56.1
- The NML may be marginally exceeded at two commercial buildings by up to 2 dB(A).

During the Wakehurst Parkway surface road works northern and central extents (WKP2N and WKP2C) the following noise impacts are predicted:

- Noise levels at two childcare centres in NCA 55.1 (Little Bloomers Early Learning Centre) and NCA 58.2 (Kindalin Early Childhood Learning Centre) are predicted to exceed the NML by up to 9 dB(A) during the worst case noise intensive works
- The NML is predicted to be marginally exceeded by up to 2 dB(A) at two other sensitive receivers (community centres) in NCA 55.1
- The NML is predicted to be exceeded by up to 9 dB(A) at a place of worship (Frenchs Forest Anglican Church) in NCA 56.1
- The NML is predicted to be marginally exceeded by up to 2 dB(A) at three recreational areas/facilities in NCAs 54.1, 55.1, and 55.4.

During the Wakehurst Parkway cut and cover portals and ventilation outlet and motorway facilities (WKP3) construction work a childcare centre in NCA 55.1 (Little Bloomers Early Learning Centre), and recreational areas in NCA 54.1 are predicted to be noise affected (ie above the NML).

5.14.2.3.2 Surface road works construction support sites

The following two surface road work construction support sites would support the works:

- Wakehurst Parkway south construction support (BL12) site at Judith Street, Seaforth would support the tunnel portal construction, motorway facilities construction and surface road works, which are assessed in Section 5.11
- Wakehurst Parkway north construction support site (BL14) would support the tunnel support facility construction and surface road works in addition to supporting concreting requirements. This site is assessed in Section 5.13.

5.14.2.3.3 Sleep disturbance

The most likely source of maximum levels during night construction works would be from truck air brakes, or metal on metal bangs of other equipment associated with night deliveries. Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from works outside standard construction hours.

Predicted noise levels show exceedances of the sleep disturbance screening levels where works outside standard construction hours are required during the night period. The highest predicted maximum noise levels are during the Warringah Road and Wakehurst Parkway intersection works (WKP1) were during typical construction activities such as air brake releases. Up to 86 receiver buildings would exceed the L_{Amax} sleep disturbance screening levels. Only 11 receiver buildings are predicted to exceed the awakening reaction level. However, during periods of worst case works this may to increase to 115 receiver buildings above the sleep disturbance screening level, of which 16 receiver buildings may exceed the awakening reaction level. The impacts are mostly in NCAs 54.1, 56.1, 57.1 and 58.1.

Where sources of high noise events (ie metal on metal bangs or air brake releases) are managed or eliminated, this potential for sleep disturbance can be mitigated. Construction mitigation and management measures are provided in Section 6 to assist in reducing OOHW construction noise impacts to receivers.

5.14.2.3.4 Construction noise assessment outcomes

The Wakehurst Parkway surface road works requires limited OOHW; however, due to the low background noise levels, where the activities are proposed, a number of residential receivers are predicted to exceed even with the incorporation of feasible and reasonable mitigation.

Due to the nature of the surface road works, further acoustic mitigation, programming and alternative construction activity locations should be reviewed during detailed construction planning, to further reduce the residual impacts identified in this assessment. These measures are detailed in Section 6, with further surface road works measures included in Section 6.4.

5.14.2.4 Construction noise prediction tables

Table 5-231 provides a key to the cell shading and text formatting used to explain results in the following tables, along with the corresponding level of perception of the construction noise. Colours and formatting are based on the highest predicted value, with ranges to show variations across the NCA.

Table 5-231 – Key to the results tables

Assessment	Time of day	Key			
$L_{Aeq(15\ minute)}$	Standard hours[1]	0-10 dB(A) over NML (light blue) Clearly audible	11-20 dB(A) over NML (mid blue) Moderately intrusive	>20 dB(A) above NML (dark blue) Highly intrusive	
	Outside standard hours	1-5 dB(A) above NML (green) Noticeable	6-15 dB(A) above NML (yellow) Clearly audible	16-25 dB(A) above NML (orange) Moderately intrusive	>25 dB(A) above NML (purple) Highly intrusive
	Any time	**Highly noise affected (>75 dB(A), bold)**[2]			
Sleep disturbance	Night only	L_{Amax} above sleep disturbance screening criterion (yellow)		L_{Amax} above awakening level (>65 dB(A), (purple)	

Notes:
1. Standard hours shading is applied for non-residential receivers
2. Highly noise affected (HNA) applies to residential receivers only.

The modelling results present the range of the highest predicted noise levels for each NCA for residential receivers, commercial and other noise sensitive receivers, unless no receivers of that type in that NCA are expected to exceed NMLs. The range is of noise impacts throughout all receivers in the NCA. If the lower noise level of the range is below the NML, only the upper noise level is presented.

The predicted noise levels for nearby receiver locations are presented in the following tables:

- Table 5-232 to Table 5-234 for residential receivers during standard construction hours
- Table 5-235 to Table 5-236 for residential receivers outside standard construction hours
- Table 5-237 to Table 5-239 for non-residential receivers.

It is important to note that all results presented in this section represent the noise levels that occur over an entire stage/works area and not an individual activity/night. As such, the number of noise affected (ie >NML) receivers during individual works/activities or on an individual night area would be less than those presented.

The construction NMLs for all residential receivers nearby are presented in Annexure B.2, and for all other non-residential receivers see Section 3.4.1.2.

The number of receiver buildings predicted to exceed NMLs during each stage and time period are summarised in Table 5-240 to Table 5-242. Predicted noise levels are intended to be conservative and represent reasonable typical and worst case impacts during the project.

The highest 'typical' noise levels for all major works areas, and the representative scenarios across the work areas, are presented as noise contour envelopes in Annexure H.2. These present the extent of typical predicted noise impacts during standard hours, and for key OOHW periods, to give an indication of the likely extent of noise levels from various major works areas that make up the Wakehurst Parkway surface road works. Maps presenting the predicted exceedance for a sample of scenarios from the major works areas with the likelihood to generate the highest noise levels from construction works are presented in Annexure H.3.

Different colour schemes have been used for the noise contours to differentiate works during standard hours construction works (coloured with shades of blue) and works outside standard construction hours (green through to purple) to clearly separate the predicted noise levels during the different periods.

Table 5-232 – WKP1(A), WKP2N(A to D) and WKP2C(A) predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – standard hours (residential receivers) – Wakehurst Parkway surface road works

Major works area/assessment reference				WKP1_A		WKP2N_A		WKP2N_B		WKP2N_C		WKP2N_D		WKP2C_A	
Typical/worst case activity noise intensity				Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver				Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level		Predicted noise levels, $L_{Aeq\ (15\ minute)}$											
		HNA	NML												
Allambie Heights	55.4	75	56	31 / 39	42 / 50	39 / 47	43 / 51	36 / 44	47 / 55	< 35	32 / 40	34 / 42	41 / 49	37 / 43	41 / 47
Forestville	55.1	75	56	≤ 40	36 / 51	40 / 48	44 / 52	37 / 45	48 / 56	< 35	33 / 41	35 / 43	42 / 50	43 / 63	47 / 67
Frenchs Forest	56.1	75	63	49 / 60	60 / 71	49 / 66	53 / 70	46 / 63	57 / 74	36 / 53	42 / 59	44 / 61	51 / 68	31 / 45	35 / 49
	57.1	75	56	51 / 67	62 / **78**	35 / 43	39 / 47	32 / 40	43 / 51	< 35	28 / 36	30 / 38	37 / 45	≤ 36	≤ 40
	58.1	75	56	49 / 57	60 / 68	32 / 39	36 / 43	≤ 36	40 / 47	< 35	< 35	< 35	34 / 41	< 35	≤ 36

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-231
5. Table features are explained further in Section 4.2.3.2.

Table 5-233 – WKP2C(B to D) and WKP2S(A to C) predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – standard hours (residential receivers) – Wakehurst Parkway surface road works

Major works area/assessment reference				WKP2C_B		WKP2C_C		WKP2C_D		WKP2S_A		WKP2S_B		WKP2S_C	
Typical/worst case activity noise intensity				Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver				Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level		Predicted noise levels, $L_{Aeq\ (15\ minute)}$											
		HNA	NML												
Seaforth	54.1	75	55	< 35	30 / 37	< 35	< 35	< 35	< 35	43 / 73	47 / **77**	40 / 70	51 / **81**	30 / 60	36 / 66
Allambie Heights	55.4	75	56	34 / 40	45 / 51	< 35	30 / 36	32 / 38	39 / 45	< 35	≤ 38	< 35	25 / 42	< 35	< 35
Forestville	55.1	75	56	40 / 60	51 / 71	30 / 50	36 / 56	38 / 58	45 / 65	40 / 57	44 / 61	37 / 54	48 / 65	≤ 44	33 / 50
Frenchs Forest	56.1	75	63	≤ 42	39 / 53	< 35	≤ 38	≤ 40	33 / 47	< 35	≤ 39	< 35	30 / 43	< 35	< 35

Notes: As per Table 5-232 above.

Table 5-234 – WKP2S(D) and WKP3(A to E) predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – standard hours (residential receivers) – Wakehurst Parkway surface road works

Major works area/assessment reference				WKP2S_D		WKP3_A		WKP3_B		WKP3_C		WKP3_D		WKP3_E	
Typical/worst case activity noise intensity				Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver				Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level		Predicted noise levels, $L_{Aeq\ (15\ minute)}$											
		HNA	NML												
Seaforth	53.1	75	58	≤ 37	34 / 44	≤ 38	34 / 47	34 / 47	37 / 50	≤ 40	≤ 41	< 35	< 35	≤ 42	33 / 46
	53.2	75	58	< 35	32 / 38	< 35	38 / 40	38 / 40	41 / 43	< 35	< 35	< 35	< 35	33 / 35	37 / 39
	53.3	75	58	< 35	31 / 37	< 35	37 / 39	37 / 39	40 / 42	< 35	< 35	< 35	< 35	< 35	36 / 38
	54.1	75	55	38 / 68	45 / 75	30 / 59	39 / 68	39 / 68	42 / 71	32 / 61	33 / 62	≤ 54	≤ 55	34 / 63	38 / 67
North Balgowlah	53.4	75	58	< 35	30 / 38	< 35	38 / 41	38 / 41	41 / 44	< 35	32 / 35	< 35	< 35	33 / 36	37 / 40
Allambie Heights	55.4	75	56	< 35	< 35	< 35	42 / 43	42 / 43	45 / 46	35 / 36	36 / 37	< 35	< 35	37 / 38	41 / 42
Forestville	55.1	75	56	35 / 52	42 / 59	< 35	33 / 35	33 / 35	36 / 38	< 35	< 35	< 35	< 35	< 35	< 35

Notes
1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-231
5. Table features are explained further in Section 4.2.3.2.

Table 5-235 – WKP1(A), WKP2N(B and C) predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – outside standard hours (residential receivers) – Wakehurst Parkway surface road works

Major works area/assessment reference						WKP1_A		WKP2N_B		WKP2N_C	
Typical/worst case activity noise intensity						Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver						Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level				Predicted noise levels, $L_{Aeq\ (15\ minute)}$					
		HNA	Day (O)	Eve	Ngt						
Allambie Heights	55.4	75	51	45	35	31 / 39	36 / 44	37 / 45	38 / 46	< 35	32 / 40
Forestville	55.1	75	51	45	35	≤ 40	30 / 45	38 / 46	39 / 47	< 35	33 / 41
Frenchs Forest	56.1	75	58	53	39	49 / 60	54 / 65	47 / 64	48 / 65	36 / 53	42 / 59
	57.1	75	51	45	35	51 / 67	56 / 72	33 / 41	34 / 42	< 35	≤ 36
	58.1	75	51	45	35	49 / 57	54 / 62	30 / 37	31 / 38	< 35	< 35

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-231
5. Table features are explained further in Section 4.2.3.2.

Table 5-236 – WKP2C(C), WKP2S(C) and WKP3(B and C) predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – outside standard hours (residential receivers) – Wakehurst Parkway surface road works

Major works area/assessment reference						WKP2C_C		WKP2S_C		WKP3_B		WKP3_C	
Typical/worst case activity noise intensity						Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver						Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
Suburb	NCA	Noise Management Level				Predicted noise levels, $L_{Aeq\ (15\ minute)}$							
		HNA	Day (O)	Eve	Ngt								
Seaforth	53.1	75	53	44	35	< 35	< 35	< 35	< 35	≤ 39	31 / 44	≤ 40	≤ 41
	53.2	75	53	44	35	< 35	< 35	< 35	< 35	< 35	36 / 38	< 35	33 / 35
	53.3	75	53	44	35	< 35	< 35	< 35	< 35	< 35	35 / 37	< 35	< 35
	54.1	75	50	44	35	< 35	< 35	≤ 50	≤ 56	41 / 70	46 / 75	42 / 71	43 / 72
North Balgowlah	53.4	75	53	44	35	< 35	< 35	< 35	< 35	< 35	35 / 38	< 35	32 / 35
Allambie Heights	55.4	75	51	45	35	< 35	30 / 36	< 35	< 35	34 / 35	39 / 40	35 / 36	36 / 37
Forestville	55.1	75	51	45	35	30 / 50	36 / 56	< 35	< 35	52 / 54	57 / 59	53 / 55	54 / 56
Frenchs Forest	56.1	75	58	53	39	< 35	≤ 38	< 35	< 35	< 35	< 35	< 35	< 35

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Green is ≤ 5 dB(A) above NML, Yellow is 6-15 dB(A) above NML, Orange is 16-25 dB(A) above NML., Purple is >25 dB(A) above NML, and **bold** text is highly noise affected (HNA) (>75 dB(A)). A full key is presented in Table 5-231
5. Table features are explained further in Section 4.2.3.2.

Table 5-237 – WKP1(A), WKP2N(A to D) and WKP2C(A) predicted $L_{Aeq\ (15\ minute)}$ construction noise levels, dB(A) – non-residential receivers – Wakehurst Parkway surface road works

Major works area/assessment reference			WKP1_A		WKP2N_A		WKP2N_B		WKP2N_C		WKP2N_D		WKP2C_A	
Typical/worst case activity noise intensity			Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver			Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
OSR type	NCA	NML[6]	Predicted noise levels, $L_{Aeq\ (15\ minute)}$											
Commercial	58.2	70	49 / 61	60 / 72	46 / 57	50 / 61	43 / 54	54 / 65	33 / 44	39 / 50	41 / 52	48 / 59	32 / 41	36 / 45
Childcare	55.1	50	< 35	≤ 41	< 36	32 / 40	< 35	36 / 44	< 35	< 35	< 35	30 / 38	32 / 51	36 / 55
	58.2	50	43 / 55	54 / 66	48 / 58	52 / 62	45 / 55	56 / 66	35 / 45	41 / 51	43 / 53	50 / 60	38 / 47	42 / 51
Other sensitive receiver	57.1	55	44 / 60	55 / 71	43 / 51	47 / 55	40 / 48	51 / 59	30 / 38	36 / 44	38 / 46	45 / 53	≤ 39	≤ 43
Place of worship	56.1	55	43 / 54	54 / 65	43 / 59	47 / 63	40 / 56	51 / 67	30 / 46	36 / 52	38 / 54	45 / 61	37 / 50	41 / 54
Recreational	55.4	65	35 / 43	46 / 54	50 / 58	54 / 62	47 / 55	58 / 66	37 / 45	43 / 51	45 / 53	52 / 60	52 / 58	56 / 62
	56.1	60	53 / 64	64 / 75	44 / 60	48 / 64	41 / 57	52 / 68	31 / 47	37 / 53	39 / 55	46 / 62	≤ 40	30 / 44

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML. A full key is presented in Table 5-231
5. Table features are explained further in Section 4.2.3.2
6. Other sensitive receivers have a range of NMLs based upon the receiver classification as outlined in Section 3.4.1.2.The exceedances are based upon the respective receiver NML.

Table 5-238 – WKP2C(B to D) and WKP2S(A to C) predicted $L_{Aeq\ 15\ min}$ construction noise levels, dB(A) – non-residential receivers – Wakehurst Parkway surface road works

Major works area/assessment reference			WKP2C_B		WKP2C_C		WKP2C_D		WKP2S_A		WKP2S_B		WKP2S_C	
Typical/worst case activity noise intensity			Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver			Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
OSR type	NCA	NML	Predicted noise levels, $L_{Aeq\ (15\ minutes)}$											
Childcare	55.1	50	≤ 48	40 / 59	≤ 38	≤ 44	≤ 46	34 / 53	≤ 40	≤ 44	≤ 37	31 / 48	< 35	< 35
	58.2	50	35 / 44	46 / 55	< 35	31 / 40	33 / 42	40 / 49	< 35	≤ 38	< 35	30 / 42	< 35	< 35
Other sensitive receiver	55.1	60	31 / 51	42 / 62	≤ 41	≤ 47	≤ 49	36 / 56	≤ 44	31 / 48	≤ 41	35 / 52	< 35	≤ 37
Recreational	54.1	60	< 35	≤ 36	< 35	< 35	< 35	< 35	32 / 62	36 / 66	≤ 59	40 / 70	≤ 49	≤ 55
	55.1	60	31 / 51	42 / 62	≤ 41	≤ 47	≤ 49	36 / 56	≤ 43	30 / 47	≤ 40	34 / 51	< 35	≤ 36
	55.4	65	49 / 55	60 / 66	39 / 45	45 / 51	47 / 53	54 / 60	≤ 37	≤ 41	< 35	≤ 45	< 35	< 35
Place of worship	56.1	55	34 / 47	45 / 58	≤ 37	30 / 43	32 / 45	39 / 52	≤ 36	≤ 40	< 35	31 / 44	< 35	< 35

Notes

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML. A full key is presented in Table 5-231
5. Table features are explained further in Section 4.2.3.2
6. Other sensitive receivers have a range of NMLs based upon the receiver classification as outlined in Section 3.4.1.2.The exceedances are based upon the respective receiver NML.

Table 5-239 – WKP2S(D) and WKP3(A to E) predicted $L_{Aeq\ 15\ min}$ construction noise levels, dB(A) – non-residential receivers – Wakehurst Parkway surface road works

Major works area/assessment reference			WKP2S_D		WKP3_A		WKP3_B		WKP3_C		WKP3_D		WKP3_E	
Typical/worst case activity noise intensity			Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]	Typical[1]	Worst case[2]
Location of noise generating works within works area relative to receiver			Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]	Far/Near[3]
OSR type	NCA	NML	Predicted noise levels, $L_{Aeq\ (15\ minutes)}$											
Childcare	55.1	50	32 / 48	43 / 59	37 / 38	43 / 44	45 / 46	52 / 53	38 / 40	42 / 44	35 / 37	46 / 48	< 35	< 35
	58.2	50	33 / 44	44 / 55	< 35	39 / 40	41 / 42	48 / 49	< 35	37 / 38	< 35	41 / 42	< 35	< 35
Other sensitive receiver	55.1	60	34 / 51	45 / 62	39 / 41	45 / 47	47 / 49	54 / 56	42 / 44	46 / 48	39 / 41	50 / 52	< 35	35 / 37
Recreational	54.1	60	< 35	≤ 36	< 35	< 35	< 35	< 35	≤ 62	≤ 66	≤ 59	≤ 70	≤ 49	≤ 55
	55.1	60	34 / 51	45 / 62	39 / 41	45 / 47	47 / 49	54 / 56	42 / 43	46 / 47	39 / 40	50 / 51	< 35	35 / 36
	55.4	65	38 / 55	49 / 66	44 / 45	50 / 51	52 / 53	59 / 60	36 / 37	40 / 41	< 35	44 / 45	< 35	< 35
Place of worship	56.1	55	34 / 47	45 / 58	36 / 37	42 / 43	44 / 45	51 / 52	35 / 36	39 / 40	< 35	43 / 44	< 35	< 35

Notes:

1. Typical predicted noise levels represent a 'typical' noise intensive construction scenario without the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
2. Worst case predicted noise levels represent a 'reasonable worst case' noise intensive construction scenario with the loudest plant and equipment items (eg rock hammers or road saws), as described in Section 4.2.3.2.2
3. The 'Near' level is the highest predicted noise level that could be expected when works are in close proximity to the nearest noise sensitive receiver shown in the assessment. The 'Far' noise level is when these works take place at the furthest location in the assessed work area from this same receiver, as described in Section 4.2.3.2.3. A range is not presented if noise levels are within 1 dB, or the lower end is less than 30 dB(A)
4. Construction noise level cells are shaded based on the 'Near' level: Light blue is ≤ 10 dB(A) above NML, Mid blue is 11-20 dB(A) above NML, Dark blue is >20 dB(A) above NML. A full key is presented in Table 5-231
5. Table features are explained further in Section 4.2.3.2

Other sensitive receivers have a range of NMLs based upon the receiver classification as outlined in Section 3.4.1.2.The exceedances are based upon the respective receiver NML.

Table 5-240 – Number of residential receiver buildings over the noise management level (major works areas) – All NCAs – Wakehurst Parkway surface road works

Works area	Assessment reference	Typical/worst case activity noise intensity	Highly noise affected > 75 dB(A)		Day (standard hours)			Day (outside standard hours)				Evening				Night				Sleep disturbance	
			Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening level (L_{Amax})	Awakening (L_{Amax})
WKP1 - Warringah Road/Wakehurst Parkway	WKP1_A	Typical	0	0	3	1	0	9	3	1	0	32	15	1	0	288	118	24	1	76	7
		Worst case	**1**	0	44	4	1	29	12	1	0	80	43	4	1	455	374	51	6	115	16
WKP2 – Wakehurst Parkway road upgrade (North)	WKP2N_A[1]	Typical	0	-	2	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	-	4	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WKP2N_B	Typical	0	0	0	0	0	3	1	0	0	14	4	0	0	138	48	13	0	36	4
		Worst case	0	0	14	1	0	2	2	0	0	18	4	0	0	171	63	14	1	57	7
	WKP2N_C	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	14	7	0	0	36	4
		Worst case	0	0	0	0	0	1	0	0	0	3	1	0	0	35	22	4	0	57	7
	WKP2N_D[1]	Typical	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	-	4	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WKP2 – Wakehurst Parkway road upgrade (Centre)	WKP2C_A[1]	Typical	0	-	20	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	-	51	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WKP2C_B[1]	Typical	0	-	4	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	-	67	10	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WKP2C_C	Typical	0	0	0	0	0	0	0	0	0	10	0	0	0	30	47	0	0	86	2
		Worst case	0	0	0	0	0	10	0	0	0	37	15	0	0	51	73	15	0	103	15
	WKP2C_D[1]	Typical	0	-	1	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	-	37	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Works area	Assessment reference	Typical/worst case activity noise intensity	Highly noise affected > 75 dB(A)		Day (standard hours)			Day (outside standard hours)				Evening				Night				Sleep disturbance	
			Standard hours	Outside standard hours	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	1 - 5 dB(A)	6 - 15 dB(A)	16 - 25 dB(A)	> 25 dB(A)	Screening level (L_{Amax})	Awakening (L_{Amax})
WKP2 – Wakehurst Parkway road upgrade (South)	WKP2S_A[1]	Typical	0	-	9	6	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	**1**	-	13	9	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WKP2S_B[1]	Typical	0	-	8	5	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	**5**	-	21	8	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WKP2S_C	Typical	0	0	5	0	0	2	5	0	0	4	8	1	0	12	14	7	0	26	11
		Worst case	0	0	8	1	0	4	8	1	0	10	8	5	0	22	24	8	5	31	13
	WKP2S_D[1]	Typical	0	-	8	3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	-	12	7	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WKP3 – Wakehurst Connection tunnel portals – cut and cover works area	WKP3_A[1]	Typical	0	-	3	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	-	11	3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WKP3_B	Typical	0	0	11	3	0	2	4	0	0	11	8	2	0	55	21	6	0	18	3
		Worst case	0	0	17	4	0	13	6	0	0	14	17	4	0	86	63	15	4	21	4
	WKP3_C	Typical	0	0	4	0	0	6	4	0	0	9	10	2	0	56	25	8	2	18	3
		Worst case	0	0	5	0	0	7	5	0	0	9	11	3	0	57	30	10	2	21	4
	WKP3_D[1]	Typical	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WKP3_E[1]	Typical	0	-	6	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Worst case	0	-	10	2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:
1. No typical work is proposed outside standard construction hours
2. 'Typical' and 'Worst case' case noise assessment scenarios are explained in Section 4.2.3.2.2, and demonstrated in Figure 4-8
3. Refer to the "Required out of hours work" table in the section "Construction hours and durations" of this assessment section for an indication of the duration and how often these noise impacts are expected to occur
4. An indicative program and timeline in provided at the beginning of this section to provide an indication of the duration of these construction works and the associated construction noise impacts.

Table 5-241 – Number of non-residential receivers over the noise management level (major works areas) (All NCAs) (WKP1, WKP2N, WKP2C and WKP2S) – Wakehurst Parkway surface road works

Works area	Assessment reference	Typical/worst case activity noise intensity	Commercial[2]			Childcare			Educational			Recreational[2]			Places of worship			Other sensitive receivers[2]		
			1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
Paving/asphalting/road surface road works (including concrete sawing)	WKP1_A	Typical	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0
		Worst case	2	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0
Clearing and grubbing works	WKP2N_A[1]	Typical	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Worst case	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0
Paving/asphalting/road surface road works (including concrete sawing)	WKP2N_B	Typical	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Worst case	0	0	0	0	1	0	0	0	0	2	0	0	0	1	0	1	0	0
Concrete barriers and traffic controls	WKP2N_C	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Road furniture installation/modification	WKP2N_D[1]	Typical	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0
Clearing and grubbing works	WKP2C_A[1]	Typical	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paving/asphalting/road surface road works (including concrete sawing)	WKP2C_B[1]	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	2	0	0	0	0	0	2	0	0	1	0	0	2	0	0
Concrete barriers and traffic controls	WKP2C_C	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Road furniture installation/modification	WKP2C_D[1]	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clearing and grubbing works	WKP2S_A[1]	Typical	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Worst case	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Notes:
1. No typical work is proposed outside standard construction hours
2. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table
3. 'Typical' and 'Worst case' case noise assessment scenarios are explained in Section 4.2.3.2.2, and demonstrated in Figure 4-8
4. Refer to the "Required out of hours work" table in the section "Construction hours and durations" of this assessment section for an indication of the duration and how often these noise impacts are expected to occur
5. An indicative program and timeline in provided at the beginning of this section to provide an indication of the duration of these construction works and the associated construction noise impacts.

Table 5-242 –Number of non-residential receivers over the noise management level (major works areas) (All NCAs) (WKP2S and WKP3) – Wakehurst Parkway surface road works

Works area	Assessment reference	Typical/worst case activity noise intensity	Commercial[2]			Childcare			Educational			Recreational[2]			Places of worship			Other sensitive receivers[2]		
			1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)	1 - 10 dB(A)	11 - 20 dB(A)	> 20 dB(A)
Paving/asphalting/road surface road works (including concrete sawing)	WKP2S_B[1]	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Concrete barriers and traffic controls	WKP2S_C	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Road furniture installation/modification	WKP2S_D[1]	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	2	0	0	0	0	0	2	0	0	1	0	0	2	0	0
Piling – Bored	WKP3_A[1]	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulk earthwork	WKP3_B	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Erection/removal of precast concrete/large items	WKP3_C	Typical	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Worst case	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Deliveries	WKP3_D[1]	WKP3_D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Concrete pours	WKP3_E[1]	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes:
1. No typical work is proposed outside standard construction hours
2. Commercial, industrial, recreational active and passive and other sensitive receivers have been assessed against the respective NMLs, and exceedances have been presented in the count table
3. 'Typical' and 'Worst case' case noise assessment scenarios are explained in Section 4.2.3.2.2, and demonstrated in Figure 4-8
4. Refer to the "Required out of hours work" table in the section "Construction hours and durations" of this assessment section for an indication of the duration and how often these noise impacts are expected to occur
5. An indicative program and timeline in provided at the beginning of this section to provide an indication of the duration of these construction works and the associated construction noise impacts.

5.14.2.5 Cumulative construction noise impacts

No other major projects are proposed in the area of the Wakehurst Parkway surface road works during the proposed construction period. The Northern Beaches Hospital road upgrade project was completed in August 2020, more than two years before the commencement of the works on this project.

Cumulative impacts from tunnelling operations based at the Wakehurst Parkway east tunnel support site, in addition the cut and cover portal (WKP3) construction works have the potential to result in cumulative impacts on the nearby receivers in NCAs 53.1, 53.2, 53.3, 53.4 and 54.1.

For the Wakehurst Parkway surface road works, the proposed staging of concurrent construction works associated with the project that are considered for cumulative construction impacts are presented in Table 5-243.

Table 5-243 – Concurrent construction works near the Wakehurst Parkway surface road works

The project	2022	2023	2024	2025	2026	2027
Wakehurst Parkway surface road works (WKP)						
Wakehurst Parkway south (WPS) construction support site						
Wakehurst Parkway north (WPN) construction support site						
Wakehurst Parkway east (WPE) construction support site						

In addition, all feasible and reasonable noise mitigation measures and any additional noise mitigation measures required by the CNVG would be coordinated between the Wakehurst Parkway east construction support site and the Wakehurst Parkway surface road works.

Potential impacts from cumulative construction noise should be mitigated and managed as outlined in Section 6.5.

5.14.3 Construction related road traffic noise

5.14.3.1 Changes in road traffic noise impacts due to construction works

As the traffic speeds are to be maintained at the current posted speeds of 60 kilometres per hour in the vicinity of Judith Street, or where required decrease to 40 kilometres per hour, this would result in a change in noise impacts from road traffic noise where the new lanes are constructed and traffic switches are implemented.

Based upon the distances from the existing roads and the proposed road, where traffic switches are implemented, the change in speed or shift in traffic onto the new closer lanes would not result in an increase greater than 2 dB(A). As such, the road traffic noise impacts would not exceed 2 dB(A) as a result of the construction traffic switching requirements.

Table 5-244 – Changes in road traffic noise impacts due to construction works, dB(A) - Wakehurst Parkway surface road works

Assessment period	Maintain speed, and all traffic on to existing road	Maintain speed, and all traffic on to new road	Reduced speed, and all traffic on to existing road	Reduced speed, and all traffic on to new road
Assessed traffic speed[4]	60 km/hr	60 km/hr	40 km/hr	40 km/hr
Day[1]	0.1	1.2	-1.7	-0.6
Night[2]	0.1	1.2	-1.9	-0.8

Notes:
1. Assume distance to existing road is 62m and new road is 44m
2. Day is 7.00am to 10.00pm
Night is 10.00pm to 7.00am
Southern end of works assessed as closest receivers to the road upgrade
Posted Speed = 60 km/hr.

5.14.3.2 Heavy vehicle operations associated with the surface road works.

Two heavy vehicles per hour are expected to be required during the standard hours works typically associated with the road works upgrade and the operation of the support sites such as the Wakehurst Parkway south or Wakehurst Parkway north construction support site (BL14). There would be additional heavy vehicle movements associated with the concrete batch plant at Wakehurst Parkway north construction support site (BL14) which could be a maximum of three heavy vehicles per hour. No vehicle movements other than oversized deliveries are expected to be required outside standard construction hours.

During peak traffic periods the existing heavy vehicle numbers on the Wakehurst Parkway are expected to be around 40 vehicles per hour, with daily existing heavy vehicle numbers typically 250 to 300.

As such, heavy vehicle operations associated with the Wakehurst Parkway surface road works is likely to have a minimal impact on the road network and are unlikely to increase road traffic noise levels by 2 dB(A) are nearby sensitive receivers.

Mitigation and management measures detailed in Section 6.7 should be considered during further design development and construction planning and, where feasible and reasonable, adopted to minimise construction traffic noise impacts associated with the project.

5.14.3.3 Cumulative construction road traffic assessment

As there is a number of construction support sites and surface road construction works occurring concurrently as part of the project, there is the potential for cumulative noise impacts from the combined construction road traffic along the Wakehurst Parkway.

Refer to Section 5.12.3.1 for an assessment of cumulative construction road traffic operating along the Wakehurst Parkway.

5.14.4 Ground-borne construction noise

Ground-borne noise levels have the potential to be generated by vibration intensive works at the surface road works and associated construction support sites. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers. Section 4.3.2 outlines the potential impacts from ground-borne noise generated by surface construction works such as these.

5.14.5 Construction vibration

The vibration generated from construction works would vary depending on the level and type of activity carried out at each site during each major works stage.

Vibration intensive activities such large rock hammers could be used as part of the Wakehurst Parkway surface road works. Minimum working distances of 22 metres for sound structures, 30 metres for unsound structures and 73 metres for adverse human response have been used to assess potential vibration impacts. A range of other vibration intensive plant may be used as part of the works. The typical minimum working distances for other vibration intensive plant items that may be used in the works are presented in Table 4-11.

The number of properties that are within the minimum working distances across the major works areas have been assessed and are presented in Table 5-245. Potential vibration impacts to receivers would depend on vibration source levels, the separation distance, the intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. When construction works occur within the minimum working distance of nearby sensitive structures they should be assessed during further design development and construction planning, as recommended in Section 6.8.

Table 5-245 – Number of structures within nominated minimum working distance for vibration impacts – Wakehurst Parkway surface road works

Vibration intensive works location	NCA	Within minimum working distance		
		Cosmetic damage		Human response
		Sound structure	Unsound structure	
WKP1 (Warringah Road/Wakehurst Parkway)	57.1	-	-	2
	58.1	-	-	1
WKP2 (Road length upgrade)	54.1	-	3	9
	55.1	-	1	6
	56.1	-	-	9
WKP3 (Cut and cover portals, motorway facilities and ventilation outlet)	54.1	-	1	-

5.14.5.1 Cosmetic damage

No non-heritage receiver buildings have been identified within the minimum working distance for light framed sound structures for the whole of the Wakehurst Parkway surface road works. If vibration intensive works are proposed within working distances presented in Table 4-11 the risk of structural damage is to be mitigated by measures including condition surveys, on site vibration testing and monitoring, as outlined in Section 6.

5.14.5.2 Human response

Up to 27 sensitive receiver buildings are identified within the minimum working distance for adverse human response from the Wakehurst Parkway surface road works as presented in Annexure L. The highest number is identified during the surface road works (WKP2). For these receivers there is the potential to perceive vibration impacts during activities that require vibration intensive activities such as large rock hammers.

This is a conservative screening assessment and where less vibration intensive plant are used, vibration is attenuated or there are discontinuities in the ground structure between the plant and receiver, the chance of vibration perception reduces.

5.14.5.3 Heritage listed structures

The figures in Annexure L show the relative locations of heritage items nearby to all the assessed major works areas, along with the minimum working distances for vibration impacts.

The heritage items listed in Table 5-246 have been identified as within the minimum working distance for unsound structures. A large rock hammer could be used as part of the Wakehurst Parkway cut and cover portal works, which typically has a minimum working distance of 30 metres for unsound structures. Each identified heritage item should o be assessed in detail during detailed construction planning to determine specific vibration mitigation and management measures, with consideration of the vibration intensive activities proposed at each site. Four different heritage items are identified as within the worst case minimum working distance for an unsound structure.

Refer to the Technical working paper: Aboriginal cultural heritage assessment report (Appendix L of the environmental impact statement) and Technical working paper: Non-Aboriginal heritage (Appendix J of the environmental impact statement)for the assessment of impacts to heritage items.

Table 5-246 – Heritage receivers within minimum working distance for unsound structures

Place/item name	Register	Type/classification[1]	Listing number	NCA
WKP1				
-	-	-	-	-
WKP2				
Frenchs Bullocks Track	Local Environmental Plan	Item - Landscape	I63	54.1
Frenchs Forest; Bantry Bay Road	NPW Act (AHIMS registered site) [2]	Rock Engraving	45-6-0655	55.1
Frenchs Forest; Bantry Bay; Wakehurst Parkway	NPW Act (AHIMS registered site)[2]	Rock Engraving	45-6-0662	54.1
Rock engraving (Garigal National Park)	NPW Act (AHIMS registered site) [2]	-	45-6-2940	54.1
WKP3				
Frenchs Bullocks Track	Local Environmental Plan	Item - Landscape	I63	54.1

Notes: 1. Conservation areas have not been considered as they do not form a structure that would be impacted by vibration
2. National Parks and Wildlife Act (AHIMS registered site).

5.14.5.4 Vibration mitigation and management

Further analysis and assessment of potential vibration impact should be carried out during the detailed construction planning phase, when likely plant and equipment, timing and location of works are confirmed.

Due to the varying nature of vibration intensive activities, cumulative vibration impacts are unlikely to result in increased vibration levels at sensitive receivers. However, all vibration generating activities should be considered during detailed construction planning and individual activities would not be considered only in isolation.

Vibration mitigation and management measures should be used to minimise any possible impacts on sensitive receivers. The measures recommended for this project are outlined in Section 6and should be included in a CNVMP.

5.14.5.5 Controlled blasting

Controlled blasting has been identified as an opportunity during construction planning for the Wakehurst Parkway surface road works. The benefits and reasons for incorporating controlled blasting into excavation works are explained in Section 5.17.1, detailing how the use of specifically designed controlled blasts can assist in reducing both noise and vibration impacts to receivers and the overall construction timeframe.

Some sections of the Wakehurst Parkway surface road works require deep excavations (greater than five metres), with construction of about 150 metres of Wakehurst Parkway cut and cover portals located in WKP3 and about 80 metres of road construction within WKP2S (Figure 5-28). It is noted that the

closest residential receivers to the cut and cover portals are more than 280 metres to the south. Moreover, the closest listed heritage item (AHIMS 45-6-0899) is about 80 metres to the southeast of the cut and cover portals (this excludes the Frenchs Bullocks Track (Local heritage item I63)). Due to relatively large vacant lands surrounding the works location, managing noise and vibration due to the controlled blasting is considered viable. Table 5-255 (Section 5.17) presents general estimations for the minimum distances to achieve the vibration and over-pressure criteria from blasting presented in Section 3.4.6.

Where controlled blasting could be beneficial for both these identified areas or other areas along the Wakehurst Parkway surface road works, this alternative excavation method would be investigated during detailed construction planning to determine if the noise and vibration limits are achievable at the nearest sensitive receivers during various stages of the project.

5.15 Other construction activities

5.15.1 Local area and utility adjustment works

Local area and utility adjustment works may be needed at various stages during the project, in particular as part of establishing construction support sites. These would include works such as service and utility identification works, electricity, sewerage, communications and other utility adjustments in addition to minor road works in the local area around the construction sites.

Some areas of work are known and these have been assessed as part of the relevant construction support site or surface road works area. Some utilities requirements and local area road works extents are still being investigated, so additional works may be needed close to, or further away from, construction support sites. Work locations would be finalised during detailed construction planning.

For this assessment, typical utility and local area work activities and their equipment have been assessed to describe typical noise levels that would be associated with these works at the nearest sensitive receivers. Typical local area and utility adjustment works are presented in Table 5-247.

Table 5-247 – Assessed local area road works and utility adjustment works construction equipment

Construction activity	Asphalt truck and sprayer	Bobcat	Concrete pump	Dump truck	Excavator with bucket	Excavator with rock hammer[1]	Generator/Daymaker	Line marking truck	Pavement laying machine	Road saw[1]	Roller	Truck	Ute/light vehicle	Vacuum Truck
Utilities modification / Utilities installation				◆	◆	◆[2]	◆			◆[2]		◆	◆	◆
Pavement/road modification (remove/construct kerbing or pavement)			◆		◆	◆[2]	◆			◆[2]			◆	◆
Paving/asphalting (including concrete sawing)	◆						◆		◆[2]	◆[2]	◆	◆		
Linemarking	◆	◆[2]					◆	◆			◆[2]	◆		

Notes: 1. Assumed the excavator with medium rock hammer and road saw would not operate concurrently
2. Worst case (noise intensive) equipment.

For nearby receivers, it is typical that not all plant and equipment are operating concurrently, and often at the closest receivers, individual plant or activities usually dominate. Table 5-248 presents predicted noise levels from the equipment that is usually required for local area and utility works construction activities.

Table 5-248 – Assessment of local area works noise at the nearby receivers

Construction equipment/plant	Individual item sound power level, dB(A)	Usage factor[2]	Penalty[4]	Construction noise level, $L_{Aeq(15\ min)}$, dB(A)[5]			
				10 metres	20 metres	40 metres	60 metres
Asphalt truck and sprayer	103	15	-	75	69	63	59
Bobcat	107	15	-	79	73	67	63
Concrete pump	103	15	-	75	69	63	59
Dump truck	108	15	-	80	74	68	64
Excavator with bucket	105	7.5	-	74	68	62	58
Excavator with medium rock hammer[6]	118	7.5	5	92	86	80	76
Generator/Daymaker	94	15	-	66	60	54	50
Line marking truck	108	15	-	80	74	68	64
Pavement laying machine[6]	114	15	-	86	79	73	70
Road saw[6]	121	5	5	93	87	81	78
Roller	109	7.5	-	78	72	66	62
Delivery truck	103	15	-	75	69	63	59
Ute/light vehicle	89	15	-	61	55	49	45
Vacuum truck	108	15	-	80	74	68	64
Heavy vehicle airbrake (L_{Amax})[1,3]	117	-	-	89	83	77	73
Metal on metal bang (L_{Amax})[1,3]	120	-	-	92	86	80	76

Notes:
1. Maximum instantaneous noise level (eg maximum noise level an object generates when it is dropped or airbrake release) for assessment of potential sleep disturbance impacts
2. Usage factor is number of minutes in use during a typical 15 minute period
3. LAmax levels only noted for equipment potentially used during the night period
4. Penalty applied for annoying activities in accordance with the ICNG
5. Predicted noise levels consider some localised shielding (approximately 5 dB(A), such as temporary noise barriers, see Section 6.4.1, or shielding from nearby buildings/structures in between the construction works and the receiver location)
6. Worst case (noise intensive) equipment.

Table 5-252 presents the typical and worst case noise levels that would be expected at various setback distances from the construction activities when all the equipment is operating. Around the construction support sites associated with the project, residences are typically set back by about ten metres from the nearest road; therefore, Table 5-252 presents these noise levels that would be expected at the closest residential receiver buildings.

The predictions account for distance attenuation and some localised shielding (such as temporary noise barriers, see Section 6.4.1, or shielding from nearby buildings/structures in between the construction works and the receiver location) and are expected to be conservative (over-predict) as they do not account for other location specific shielding and effects such as ground absorption and terrain effects.

Table 5-249 – Assessment of typical and worst case local area works noise at the nearest receivers

Distance from construction works (metres)	Utilities modification			Pavement modification			Paving or asphalting			Line marking		
	$L_{Aeq(15\ min)}$		L_{Amax}	$L_{Aeq(15\ min)}$		L_{Amax}	$L_{Aeq(15\ min)}$		L_{Amax}	$L_{Aeq(15\ min)}$		L_{Amax}
	Typical	Worst case		Typical	Worst case		Typical	Worst case		Typical	Worst case	
10	77	88	93	77	87	87	76	87	93	77	80	84
20	71	82	87	71	81	81	70	81	87	71	74	78
40	65	76	81	65	75	75	64	75	81	65	68	72
60	62	72	77	62	72	72	61	72	77	61	64	68

Notes:
1. Typical activity - (eg when the road saw/rock hammer is not used)
2. Worst case (noise intensive) - (eg when the road saw/rock hammer is used)
3. Sound power levels and operating assumptions are as per Table 5-247 and Table 5-248
4. Some localised shielding has been included (approximately 5 dB(A)) (such as temporary noise barriers, see Section 6.4.1).

The distances where residential receivers would be considered highly noise affected (ie >75 dB(A)) are presented in Table 5-250 for the various types of local area and utility adjustment work activities. Table 5-250 indicates that residential receivers could be above the highly noise affected level when they are located within 13 metres from typical works, or about 45 metres from worst case (noise intensive) works.

Table 5-250 – Assessment of typical and worst case local area works noise at the nearest receivers

Distance to the highly noise affected (ie > 75 dB(A) $L_{Aeq\ 15\ minutes}$) level (metres)							
Utilities modification		Pavement modification		Paving or asphalting		Line marking	
Typical	Worst case	Typical	Worst case	Typical	Worst case	Typical	Worst case
13	43	13	42	12	42	12	17

Notes:
1. Typical activity - (eg when the concrete saw/rock hammer is not used)
2. Worst case (noise intensive) - (eg when the concrete saw/rock hammer is used)
3. Some localised shielding has been included (approximately 5 dB(A)) (such as temporary noise barriers, see Section 6.4.1)

In most NCAs, with a standard construction hours NML of 55 dB(A) or more, the predicted noise at the closest receivers from typical equipment used for local area construction works would be about 20 dB(A) above the NML, and when noise intensive equipment such as road saws or excavators with rock hammers are required this would increase the construction noise levels to 33 dB(A) above the NML. When works occur at greater distances from a receiver, the predicted noise levels would be less.

Outside standard hours, construction noise from local area works at the closest receivers when typical equipment is operating would be about 35 dB(A) above the NML, based upon the night time NML being 40 dB(A). When noise intensive equipment such as road saws or excavators with rock hammers are required this would increase the construction noise levels to 48 dB(A) above the NML. If not managed, airbrakes and metal equipment could generate maximum noise events above sleep disturbance screening levels.

Local area and utility adjustment works would take place during standard construction hours where feasible and reasonable, and where they do not pose a risk to the public or worker safety. Often ROLs prevent these works from occurring before the evening or night period, due to the importance of the

road to the functionality of the road network. In these cases, construction works would often need to occur during the night period, or OOHW Period 2 as indicated in Table 3-2.

These works are typically of short duration, temporary, and progressive works that move along. This means that, as works progress, nearby sensitive receivers would only receive high noise levels for a small time out of the entire works program.

Local area and utility works can also include vibration intensive activities. In the case that vibration intensive activities are required potential vibration impacts are to be managed as outlined in Section 6.8.

5.15.2 Deliveries outside standard hours

Delivery of most plant and equipment to the work sites would be carried out during standard construction hours. However, during various stages of construction works some oversized deliveries would be needed.

Oversized deliveries can cause disruptions to existing traffic on public roads and can be a safety hazard for road users. Therefore, oversized vehicles typically travel during off peak hours when traffic volumes are lower to reduce risks to road user and public safety and minimise disruption to the road network.

Deliveries may require the use of more than one traffic lane. Where this occurs, all movements must be made strictly in accordance with Transport for NSW guidelines for oversized movements and the relevant ROL, if required. While these deliveries may have the potential to cause sleep disturbance along the delivery routes and in the vicinity of the destinations, the elevated noise generated would typically be temporary and short-lived, and would occur very infrequently, minimising the potential for substantial amenity impacts.

5.15.3 Truck marshalling areas

Heavy vehicles would likely require marshalling areas to be used when delays are experienced at the construction support sites. The locations of these marshalling areas are not known at this stage and would be selected during detailed construction planning. As the locations are not known, a quantitative assessment has not been carried out.

During detailed construction planning potential noise impacts from additional heavy vehicle movements on local roads and noise emissions from heavy vehicles within the truck marshalling area should be assessed in accordance with the project approval and appropriate feasible and reasonable mitigation measures identified and implemented.

Where required, the locations should be selected away from residential receivers. Where feasible and reasonable, the site layout should maximise the use of on site or adjacent non-receiver structures to maximise acoustic shielding to nearby noise sensitive receivers from heavy vehicle idling and accelerating locations.

All drivers should be required to comply with a Heavy Vehicle Code of Conduct, which includes noise management methods such as limiting idling and compression braking, and traffic management practises to minimise noise emissions from vehicles entering and leaving the site.

During further design development and construction planning, in order to ensure that traffic noise impacts are minimised, the construction traffic associated with the project should include the mitigation and management measures detailed in sections 6.2 and 6.7 where feasible and reasonable.

5.16 Mainline and ramp tunnelling construction noise and vibration impacts

The tunnels would comprise a mainline tunnel (about six kilometres in length) in each direction, together with entry and exit ramp tunnels to connections at the surface. The mainline tunnels comprise three lanes of traffic in each direction between Cammeray and Seaforth. Each entry and exit ramp tunnel would comprise of two lanes:

- Eastbound and westbound connections between Seaforth and the surface at Burnt Bridge Creek Deviation, Balgowlah (about 1.4 kilometres in length)
- Northbound and southbound connections between Seaforth and the surface at Wakehurst Parkway, Killarney Heights (about 2.5 kilometres in length)
- Eastbound and westbound connections between Northbridge and the surface at the Gore Hill Freeway and Reserve Road, Artarmon (about two kilometres in length).

The tunnels would mostly be driven tunnels, except for the crossing of Middle Harbour between Northbridge and Seaforth which would be twin three lane immersed tube tunnels and cut and cover tunnels at each portal.

5.16.1 Construction ground-borne noise assessment

Ground-borne noise emissions from driven tunnel construction works were determined by modelling the noise sources, tunnel location and depth, and receiver locations, based on the information presented in Section 4.3. The indicative tunnel crown depth is presented in Annexure I.

Ground-borne noise management levels are presented in Section 3.4.4.

The estimated number of potentially ground-borne noise affected properties are summarised in Table 5-251 to Table 5-252 and Annexure J.

5.16.1.1 Roadheader tunnelling

Table 5-251 summarises the number of receiver buildings in each NCA potentially exposed to ground-borne noise levels above the ground-borne noise management levels during roadheader tunnelling.

Table 5-251 – Summary of the estimated number of potentially ground-borne noise affected receiver buildings during roadheader tunnelling.

Suburb	NCA	Number of ground-borne noise affected receiver buildings (ie above ground-borne NMLs)				
		Residential			Other sensitive receivers	Commercial/ industrial receivers
		> 35 to ≤ 40 dB(A)	> 40 to ≤ 45 dB(A)	> 45 dB(A)		
North Sydney	23.2	-	-	-	-	-
Neutral Bay	23.1	-	-	-	-	-
Crows Nest	24.1	-	-	-	-	-
	30.1	-	-	-	-	-
Cammeray	25.1	5	-	-	-	-
	28.1	-	-	-	-	-
	29.1	3	-	-	-	-
	30.3	-	-	-	-	-
	31.2	-	-	-	-	-
Cremorne	26.1	-	-	-	-	-
Naremburn	30.2	-	-	-	-	-
	31.1	-	-	-	-	-
	31.3	-	-	-	-	-
	32.1	15	-	-	-	-
	37.1	-	-	-	-	-
Artarmon	33.1	-	-	-	-	-
	33.2	-	-	-	-	-
	34.1	-	-	-	-	-
Willoughby	36.1	1	-	-	-	-
Northbridge	38.1	-	-	-	-	-
	38.2	-	-	-	-	-
	38.3	-	-	-	-	-
	39.1	-	-	-	-	-
	40.1	-	-	-	-	-
Seaforth	39.2	-	-	-	-	-
	42.1	-	-	-	-	-
	44.1	-	-	-	-	-
	46.2	-	-	-	-	-
	47.1	-	-	-	-	-
	47.2	-	-	-	-	-
	49.1	3	-	-	-	-
	53.1	26	-	-	-	-
	53.2	-	-	-	-	-
	53.3	42	-	-	-	-
	54.1	12	-	-	-	-
Clontarf	46.1	-	-	-	-	-
Balgowlah	48.1	-	-	-	-	-
	50.1	-	-	-	-	-
North Balgowlah	51.1	-	-	-	-	-
Overall		**107**	**0**	**0**	**0**	**0**

The predicted ground-borne noise levels presented in Annexure J and Table 5-251 above identifies that there may be ground-borne noise affected residential receiver buildings as a result of roadheader tunnelling. This review found that:

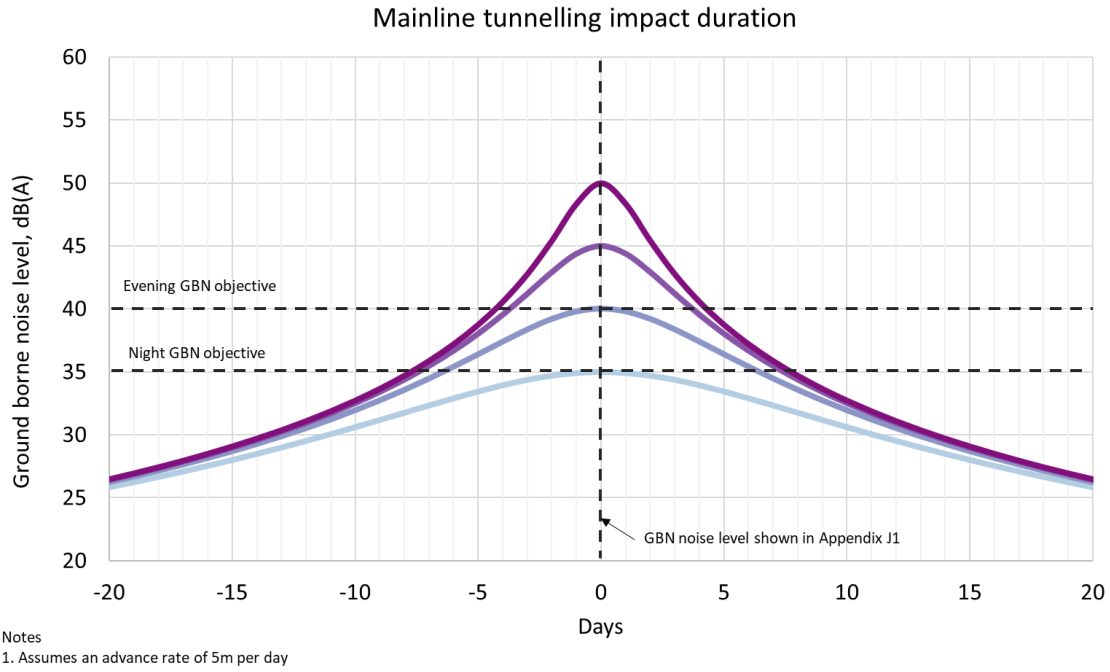
- 107 residential buildings could be ground-borne noise affected during the night period (above 35 dB(A))
- No residential buildings are predicted to be exposed to ground-borne noise levels above 40 dB(A)
- Other noise sensitive receivers and commercial/industrial premises are not expected to be ground-borne noise affected during roadheader tunnelling.

Ground-borne noise affected properties would require, as a minimum, letterbox notification to advise that tunnelling would be occurring and that noise levels are likely to be clearly audible during tunnelling works.

However, as outlined in Section 4.3, as tunnelling progresses the tunnelling equipment would approach or move away from individual receiver locations. The predicted noise levels are the peak noise levels that a receiver would be exposed to when the roadheader is at its closest point to the property, shown as the noise level at the zero day mark in Figure 5-29. The noise levels are then expected to drop away as the tunnelling moves further away from the receiver, with individual receivers potentially exposed to noise levels above the ground-borne NMLs for only relatively short periods of time, as shown in Figure 5-29. Due to the presence of multiple tunnel alignments, on and off ramps, cross passages and ventilation tunnels, affected receivers might experience ground-borne noise on multiple occasions throughout the overall program of tunnelling works.

Even when the ground-borne noise levels achieve the objectives, they may still be audible or perceivable within residences.

Figure 5-29 – Indicative duration of impacts of ground-borne noise levels from roadheaders



Annexure J.1 presents the predicted highest noise level at 0 days, as the roadheader passes at the closest distance to each receiver building.

Measures for managing exceedance of the ground-borne NMLs are identified in Section 6. Additional ground-borne noise mitigation measures are presented in Section 6.10.2.

5.16.1.2 Rock hammer tunnelling

Table 5-252 summarises the number of receiver buildings in each NCA potentially exposed to ground-borne noise levels above the ground-borne NMLs during rock hammer excavation works.

The predicted ground-borne noise levels show that there are more receivers likely to be impacted during rock hammering than roadheader tunnelling. However, rock hammering is proposed for clearing the bench of tunnel and follows behind the roadheader. Rock hammering might also be used to excavate other tunnel features, such as niches for motorway equipment. Where rock hammering is not associated with excavations that require subsequent ground support, there is more scope for rock hammering activities to be scheduled to reduce impacts (eg not occur during the night period) on nearby receivers than for roadheader tunnelling.

In a similar manner to roadheader tunnelling, the predicted noise levels are the peak noise levels that a receiver would be exposed to. The noise levels are then expected to drop away as the rock hammering location moves further away from the receiver, with individual receivers potentially exposed to noise levels above the ground-borne NMLs for only relatively short periods of time during period of time when rock hammering occurs.

Table 5-252 – Summary of the estimated number of potentially ground-borne noise affected receiver buildings during rock hammer tunnelling

Suburb	NCA	Number of ground-borne noise affected receiver buildings (ie above ground-borne NML)				
		Residential			Other sensitive receivers	Commercial/ industrial receivers
		> 35 to ≤ 40 dB(A)	> 40 to ≤ 45 dB(A)	> 45 dB(A)		
North Sydney	23.2	-	1	-	-	-
Neutral Bay	23.1	-	-	-	-	-
Crows Nest	24.1	2	-	-	-	-
	30.1	28	28	18	1	-
Cammeray	25.1	11	13	29	-	-
	28.1	3	5	1	-	-
	29.1	13	18	32	-	-
	30.3	15	11	1	1	-
	31.2	-	-	-	-	-
Cremorne	26.1	-	-	-	-	-
Naremburn	30.2	2	-	-	-	-
	31.1	-	-	-	-	-
	31.3	111	13	2	1	-
	32.1	11	8	28	-	-
	37.1	32	19	-	-	-
Artarmon	33.1	2	1	-	-	-
	33.2	-	-	-	-	-
	34.1	-	-	-	-	-
Willoughby	36.1	40	29	47	2	1
Northbridge	38.1	40	4	-	-	-
	38.2	-	-	-	-	-
	38.3	25	-	-	-	-
	39.1	60	6	-	-	-
	40.1	15	11	-	-	-
Seaforth	39.2	17	4	1	-	-
	42.1	24	59	7	-	-
	44.1	14	54	40	-	-
	46.2	19	9	32	-	13
	47.1	21	3	21	2	-
	47.2	61	37	6	-	-
	49.1	16	15	27	-	-
	53.1	2	9	44	-	-
	53.2	8	5	5	-	-
	53.3	36	44	151	1	-
	54.1	6	6	33	-	-
Clontarf	46.1	4	7	6	-	2
Balgowlah	48.1	-	-	-	-	-
	50.1	-	-	-	-	-
North Balgowlah	51.1	-	-	-	-	-
Overall		**638**	**419**	**531**	**8**	**16**

The predicted ground-borne noise levels in Table 5-252 and Annexure J identify that there are potential ground-borne noise affected residential receiver buildings as a result of rock hammer excavation. Review of predicted ground-borne noise levels from rock hammer tunnelling found that:

- There are a large number of residential receivers that may exceed either the night period ground-borne NML (above 35 dB(A)) or the evening period ground-borne NML (above 40 dB(A)).
- 531 residential receiver buildings could be exposed to ground-borne noise levels above 45 dB(A)
- Eight other sensitive receiver buildings could be ground-borne noise affected (ie above ground-borne NML)
- 16 commercial premise is expected to be ground-borne noise affected (ie above ground-borne NML) during rock hammer tunnelling activities.

The predicted noise levels and land use survey indicate that some areas may be able to be excavated outside standard construction hours with minimal potential to exceed the relevant ground-borne NMLs, where the tunnel is located away from residential receiver buildings.

Measures for managing ground-borne noise impacts are provided in Section 6.

5.16.2 Construction tunnelling vibration predictions

Vibration generated by tunnelling was estimated based on the tunnel depth and excavation methodology. The indicative tunnel crown depth is presented in Annexure I. Vibration levels were calculated by modelling the vibration source, tunnel location and receiver locations, based on the information presented earlier in Section 4.3.

The number of heritage items that are within the minimum working distances for cosmetic damage from tunnelling vibration are shown in Table 5-253.

The number of receiver buildings where modelling results suggest a risk of human disturbance due to tunnelling vibration are also shown in Table 5-253. The risk of human disturbance for receiver buildings is identified based upon the minimum working distances presented in Table 4-11, Section 4.4.1, which are based upon residential receivers.

During detailed construction planning, where receiver buildings in proximity to the tunnel are highly sensitive to vibration (eg hospital operating theatres and precision laboratories where sensitive operations are occurring) a detailed review should be carried out against the requirement outlined in Section 3.4.5. Similarly, where buildings are identified but the use and activities within the occupied buildings are less sensitive to disturbance from vibration impacts (eg offices, schools, educational institutions and places of worship) then acceptable vibration levels may be greater than the suitable levels identified in Section 3.4.5.

The figures in Annexure K show the mainline and ramp tunnel, along with the areas which are within minimum working distances from tunnelling activities for various potential vibration impacts.

Table 5-253 – Assessment of vibration impacts for all receiver types

Suburb	NCA	Number of items/receiver buildings impacted	
		Roadheader tunnelling	Rock hammer tunnelling (bench only)
Risk of structural or cosmetic damage (sound structures)			
	All NCAs	-	-
Risk of structural or cosmetic damage (unsound structures) – Heritage items			
Cammeray	26.2	-	1
Artarmon	33.1	1	1
Risk of human disturbance (all occupied receiver buildings included)			
Cammeray	25.1	-	22
	29.1	-	16
Crows Nest	30.1	-	8
Naremburn	32.1	-	27
Artarmon	33.2	-	1
Willoughby	36.1	-	41
Seaforth	42.1	-	6
	44.1	-	31
	46.2	-	35
	47.1	-	22
	47.2	-	4
	49.1	-	25
	53.1	-	36
	53.2	-	3
	53.3	-	124
	54.1	-	32
Clontarf	46.1	-	7

Vibration impacts from roadheader tunnelling are predicted to be below the vibration limits for human disturbance at all receivers. Therefore, vibration from roadheader tunnelling presents a negligible risk of impact.

Vibration from rock hammer excavation of the tunnels may be noticeable inside vibration sensitive premises in the NCAs identified in Table 5-253 above. Occupants of up to 440 occupied receiver buildings fall within the minimum working distance for adverse human response for rock hammer tunnelling. Where building occupants could potentially be impacted by vibration from mainline and ramp tunnelling at levels exceeding those identified in Section 3.4.5, additional mitigation measures would be provided in accordance with the CNVG, as presented in Section 6.

5.16.2.1 Heritage receivers

The figures in Annexure K show the locations of heritage items near the mainline and ramp tunnel, along with the locations which are within minimum working distances from tunnelling activities for various potential vibration impacts.

The heritage items listed in Table 5-254 have been identified as within the minimum working distance for unsound structures. Two heritage items have been identified as within the worst case minimum working distance for an unsound structure during rock hammer bench clearing tunnelling activities.

A large rock hammer could be used during bench clearing tunnelling activities, which typically requires a minimum working distance of 20 metres during tunnelling for unsound structures.

Heritage items that fall within minimum working distances from tunnelling activities would be assessed in detail during detailed construction planning to determine specific vibration criteria and mitigation and management measures for each item, with consideration of the vibration intensive activities proposed at each site.

As the tunnel breaks out at Artarmon at a location which is identified as containing potential archaeological deposits (Aboriginal), if there are items that may be sensitive to vibration, they would be managed in accordance with the heritage requirements for the cut and cover construction works that are to occur at this location.

Refer to the Technical working paper: Aboriginal cultural heritage assessment report (Appendix L of the environmental impact statement) and Technical working paper: Non-Aboriginal heritage (Appendix J of the environmental impact statement)for the assessment of impacts to heritage items.

Table 5-254 – Heritage items within minimum working distance for unsound structures

Place/item name	Register	Type/classification[1]	Listing number	NCA
Roadheader tunnelling				
Artarmon Park potential archaeological deposits	NPW Act (AHIMS registered site)[2]	Potential archaeological deposits (Aboriginal)	-	33.1
Rock hammer tunnelling (benching)				
Cammeray Park (including golf course)	Local Environmental Plan	Item - Landscape	I0024	26.2
Artarmon Park potential archaeological deposits	NPW Act (AHIMS registered site)[2]	Potential archaeological deposits (Aboriginal)	-	33.1

Notes: 1. Conservation areas have not been considered as they do not form a structure that would be impacted by vibration
2. National Parks and Wildlife Act (AHIMS registered site).

5.17 Blasting

This section documents construction airborne and ground-borne noise and vibration impacts from blasting.

5.17.1 Overview

Blasting may occasionally be required during mainline and ramp tunnelling or excavation works, and for excavation works along the Wakehurst Parkway surface road works (further detailed in Section 5.14.5.5).

Traditional methods of excavation involve the heavy use of rock hammers, which commonly result in substantial noise and vibration impacts to receivers that are located nearby, and can be required to take place for long periods of time compared to the duration of blasting methods. Where appropriate for the particular tunnelling conditions, the incorporation of blasting into excavation works can substantially reduce the overall construction timeframe required for excavation.

Excavation using rock hammers can be highly variable in terms of excavation progress due to varying rock strengths. This can result in delays to planned completion times and community commitments not being met. While some rock hammering may be required for secondary breakage and/or trimming walls, controlled blasting for deep cut areas would result in a substantially reduced noise exposure periods compared to traditional excavation. Blasting noise and vibration management levels are provided in Section 3.4.6.

There are two main impacts from blasting – overpressure and ground vibration:

- Overpressure travels as an airwave and is able to cause a vibration response in structures such as buildings. It is dominated by low frequencies that are typically inaudible
- Ground vibration is transmitted through the ground that surrounds the blast as a series of waves and can rapidly travel substantial distances, gradually reducing in strength over distance.

It is possible for a blast to be felt, but not heard, due to ground vibration and overpressure.

Ground vibration and overpressure have the potential to cause discomfort or annoyance to sensitive receivers near the blast area. At high levels ground vibration and overpressure have the potential to cause structural damage.

5.17.2 Potential impacts from blasting

Vibration and air blast overpressure impacts from blasting depend on the specific details of blasting (blast design) and are managed primarily through site and blast specific assessments. Overpressure and vibration are predicted during blast design.

It is important that the actual buffer zone around each blast site is identified and appropriate measures are taken to limit blast over pressure and vibration to acceptable levels at the nearest affected receiver

locations. Blast charge masses and configurations would therefore be selected to ensure the objectives identified in Section 3.4.6 are not exceeded.

Due to some receiver buildings and vibration sensitive items being close to potential blast locations, a series of initial test blasts at reduced charge can be carried out before any full scale blasting occurs. Air blast overpressure and vibration is measured from test blasts to establish site specific propagation characteristics and increase the accuracy of blasting predictions. This information would be used to define allowable blast sizes and design requirements to meet the air blast overpressure and ground vibration limits.

Table 5-255 provides general guidance for estimating the likely 'minimum distance limits' from blasting in terms of the vibration and over-pressure criteria described above, for a range of blast Maximum Instantaneous Charge (MIC) quantities.

The distance limits relating to vibration are set out in Table 5-255 and have been determined using the formula in AS 2187.2-2006, which applies to free face blasting in 'average field conditions' and states:

$$V = 1140\left(\frac{R}{Q^{1/2}}\right)^{-1.6}$$

where

V = ground vibration as peak particle velocity in mm/s

R = distance between charge and point of measurement in metres

Q = effective charge mass per delay or maximum instantaneous charge in kilograms

$$P = 100\left(\frac{R}{Q^{1/3}}\right)^{-1.45}$$

where

P = overpressure in pascals

R = distance between charge and point of measurement in metres

Q = effective charge mass per delay or maximum instantaneous charge in kilograms

K = site constant between 10 and 100 for confined blasts

An indication of acceptable blast sizes to satisfy the overpressure and vibration limits set in Section 3.4.6 has been determined based on the above algorithms. It is noted that the algorithms are considered conservative. The nominated maximum instantaneous charge (effective charge mass per delay) (MIC) that would achieve the overpressure and vibration limits might vary substantially depending on the geological conditions, local shielding and meteorological factors at the site.

Previously measured blast emissions data indicate a dominant frequency of the vibration signal of a blast event is approximately between 10 Hz to 30 Hz at an offset of approximately 50 metres.

For the purpose of conservative assessment, the dominant frequency of a blast is assumed to be 10 Hz and peak particle velocities (vector sum) (PPV), instead of peak component particle velocities, are considered in this assessment.

Table 5-255 – Summary of typical MIC and estimated compliant separation distance

Blast impact	Receiver	Blast management level	Estimated charge separation distance (metres)/MIC					
			1 kg	2 kg	5 kg	10 kg	20 kg	50 kg
Overpressure[1]	Sensitive – Short-term	115 dBL[3]	108	136	184	231	290	393
Ground vibration	Sound structure	15 mm/s[2]	15	21	33	47	67	106
	Human response – Short-term	10 mm/s[2]	19	27	43	61	86	136
	Heritage	2.5 mm/s[2]	46	65	103	145	205	325

Notes:
1. Site constant of K=10 was used in the predictions for overpressure. For confined blasts, AS 2187.2-2006 notes that the site constant can range between 10 and 100. At K=100 with 1 kilogram MIC the predicted overpressure is greater than 115 dBL at 500 metres, which is further than the distance to the closest receiver to the proposed Wakehurst surface road works potential blasting areas. Estimated distances to achieve the blast management levels would be confirmed during detailed construction planning considering site specific conditions, depth of burial and the proposed blast design. Additional mitigation measures would be incorporated to the blast design to control airblast overpressure where required
2. Peak particle velocities (vector sum) (PPV)
3. dBL – decibels linear.

If blasting is proposed and deemed appropriate for the tunnelling conditions in a particular location, further analysis and assessment of potential blast impacts would be carried out during further design development and construction planning phase to ensure that the objectives identified in Section 3.4.6 are not exceeded. Measures to mitigate and manage impacts from blasting are provided in Section 6.

6 Construction noise and vibration mitigation and management approaches

Construction noise and vibration impacts across the project should be reviewed and updated during detailed construction planning to reflect the contractor's preferred constructability approach. Refinements to construction works areas, locations, layouts, equipment, construction methods or construction hours might require specific mitigation and management measures that differ from those outlined in each relevant section.

The construction contractor should prepare location and activity specific CNVIS based on the detailed construction methodology. As a minimum CNVIS should be prepared to cover the following:

- Construction support sites
- Works outside standard construction hours (OOHW)
- Works with the potential to result in highly noise affected residential receivers (ie exposed to noise levels that exceed 75 dB(A))
- Works with the potential to exceed the relevant human response and cosmetic damage criteria for vibration
- Subsurface tunnelling activities.

The contractor should consider potential noise and vibration impacts of all these activities during development of the detailed construction methodology. Mitigation and management measures, with the aim meeting all relevant noise and vibration performance objectives (Section 3) and with consideration of the CNVG, should be documented in the CNVIS and implemented during the relevant activities. The following sections describe recommend approached to mitigate and manage the construction noise and vibration impacts identified in Section 5.

Site specific noise mitigation and management measures have been incorporated as part of each assessment, as outlined in step 4 of the assessment process outlined in Figure 4-1. The assumed mitigation and management measures for each site are outlined in the corresponding section shown in Table 6-1.

Table 6-1 – Assumed site specific noise treatment and management measures

Location	Report section
Warringah Freeway surface road works	Section 5.2.2
Cammeray Golf Course (BL1/CGC)	Section 5.3.1.7
Gore Hill Freeway Connection surface road works (GHC)	Section 5.4.2
Flat Rock Drive (BL2/FRD)	Section 5.5.1.7
Punch Street (BL3/PUN)	Section 5.6.1.7
Middle Harbour crossing (MHC)	Section 5.7.1.7
Spit West Reserve (BL9/SMH)	Section 5.8.1.7

Location	Report section
Balgowlah Golf Course (BL10/BAL)	Section 5.9.1.7
Balgowlah surface road works (BGC)	Section 5.10.2
Wakehurst Parkway south (BL12/WPS)	Section 5.11.1.7
Wakehurst Parkway east (BL13/WPE)	Section 5.12.1.7
Wakehurst Parkway north (BL14/WPN)	Section 5.13.1.7
Wakehurst Parkway surface road works (WKP)	Section 5.14.2

In addition to these, this section outlines recommendations for the mitigation and management that should be implemented across the project during further design development and construction planning.

Each of the detailed assessments in Section 5 indicates the number of receivers where noise levels are expected to be above the NMLs after the implementation of reasonable and feasible noise treatments and management measures.

Further acoustic management and mitigation measures, outlined in the standard CNVG measures as per Section 6.2, should be reviewed during detailed construction planning when specific construction work details are known and adopted where feasible and reasonable as part of the preparation of a site specific CNVIS during the detailed construction planning when specific construction work details are known.

Where residual noise levels still exceed the NMLs, additional mitigation measures, as presented in Section 6.10.1, should be investigated and implemented to manage construction noise impacts in accordance with the CNVG.

6.1 Feasible and reasonable construction noise and vibration mitigation and management

The ICNG outlines how 'feasible' and 'reasonable' mitigation and management measures is a key component of the guideline.

'Feasible' is explained as:

> *work practice or abatement measure {that} is capable of being put into practice or of being engineered and is practical to build given project constraints such as safety and maintenance requirements.*

While 'reasonable' is a more complex issue, which is explained as:

> *Selecting reasonable measures from those that are feasible involves making a judgment to determine whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects, including the cost of the measure. To make such a judgement, consideration may be given to:…*

- Noise level impacts (eg how many people would be impacted by noise levels above the NML? How long would these noise impacts last?)
- Noise mitigation benefits (eg would the mitigation measures result in an overall noticeable reduction at receivers? Would the mitigation help many people or just one?)
- Cost effectiveness of noise mitigation (eg are there more effective mitigation measures for a similar cost? Is the cost of the mitigation equitable based on the extent of mitigation provided and or number of receivers benefited?)
- Community views (eg liaising with the community to gain preferences on where noise mitigation is installed and what it may look like. Liaising with commercial receivers to locate mitigation that would not interfere with their access. Consulting with the community to determine if they would prefer managed night works and/or more traffic/transport distribution resulting in a longer construction program; or weekend work and/or louder night activities resulting in a shorter construction program).

All construction noise mitigation and management must to take into account concurrent construction works either from other projects or from other nearby project works when assessing the reasonableness of mitigation or management measures.

6.2 Standard mitigation and management measures

Noise management measures in accordance with the CNVG would be implemented for the project. Appendix B of the CNVG presents the standard noise and vibration mitigation measures, identifying potentially feasible and reasonable construction noise and vibration mitigation and management measures, which are reproduced in Annexure G.1.

A CNVMP should be prepared during detailed construction planning that documents, in more detail, how all mitigation measures are to be implemented for this project. Where applicable, additional mitigation and management measures such as those outlined for the surface road works (Section 6.4) should be considered across the construction works associated with the project, and adopted where feasible and reasonable. All feasible and reasonable mitigation measures have been included in the assessment of the project's construction noise and vibration impacts. Mitigation measures should be confirmed during detailed construction planning, and appropriate measures should be added when preparing site specific CNVISs.

6.3 Highly noise affected receivers

Some residential receivers nearest to the construction support sites and/or construction work sites may be 'highly noise affected' (ie exposed to noise levels that exceed 75 dB(A)) as a result of:

- Relocation and protection of existing utility and infrastructure services requiring the use of rock hammers and road/concrete saws
- Vegetation clearing works within construction support sites, including the use of chainsaws, or tub grinders

- Early works and site establishment activities requiring rock hammers and pneumatic hammers during the house/ building demolition works
- Cofferdam construction using impact piling and rock hammers
- Bulk excavation works, including the use of rock hammers during rock excavation
- Road works, including saw cutting of concrete pavement and rock hammers.

Where feasible and reasonable, high noise impact activities should be carried out during standard construction hours to limit the number of highly noise affected receivers, with the following potential respite periods:

- High noise impact activities should only be carried out between:
  - 7.00am and 6.00pm Monday to Friday
  - 8.00am and 1.00pm Saturday
- High noise impact activities should be carried out in continuous blocks of up to three hours. Respite from high noise impact activities would be provided between each block for at least one hour. No high noise impact activities should be carried out during this one hour respite period.

During OOHW periods, appropriate respite and additional mitigation measures should be adopted for highly affected receivers in accordance with the CNVG, as outlined in Section 6.10.1.

6.4 Surface road works mitigation and management options and opportunities

In addition to the standard CNVG mitigation and management measures outlined in Annexure G.1, a range of mitigation measures have been considered for the surface road works due to the requirement for extensive out of hours works. These should be reviewed and incorporated where reasonable and feasible as part of the CNVMP.

6.4.1 On site/at-works mitigation and management

Construction works generating moderately intrusive to highly intrusive noise levels should utilise temporary noise screens where feasible and reasonable to provide noise mitigation. Where reasonable and feasible, the screens should be located as close as practicable to the work area to provide shielding of the plant/construction works to receivers. These can be in the form of temporary screens installed for the period of the works, or mobile acoustic screens which move along with the noise generating plant.

All acoustic screens need to be installed so that they do not contain holes or gaps. In assessing the reasonableness of acoustic screens, the following should be considered:

- Effectiveness of the screen, especially mobile screens, to ensure that line of sight to the critical receivers is being broken

- Usability of the screen does not result in substantially longer noise generating works
- Whether a small reduction in noise is outweighed by the substantial increase in overall works duration making the use of acoustic screens unreasonable.

Temporary noise screens can provide 5 to 10 dB noise reduction but only where they can break line of sight between the noise source and the impacted receiver.

6.4.2 Community consultation and engagement

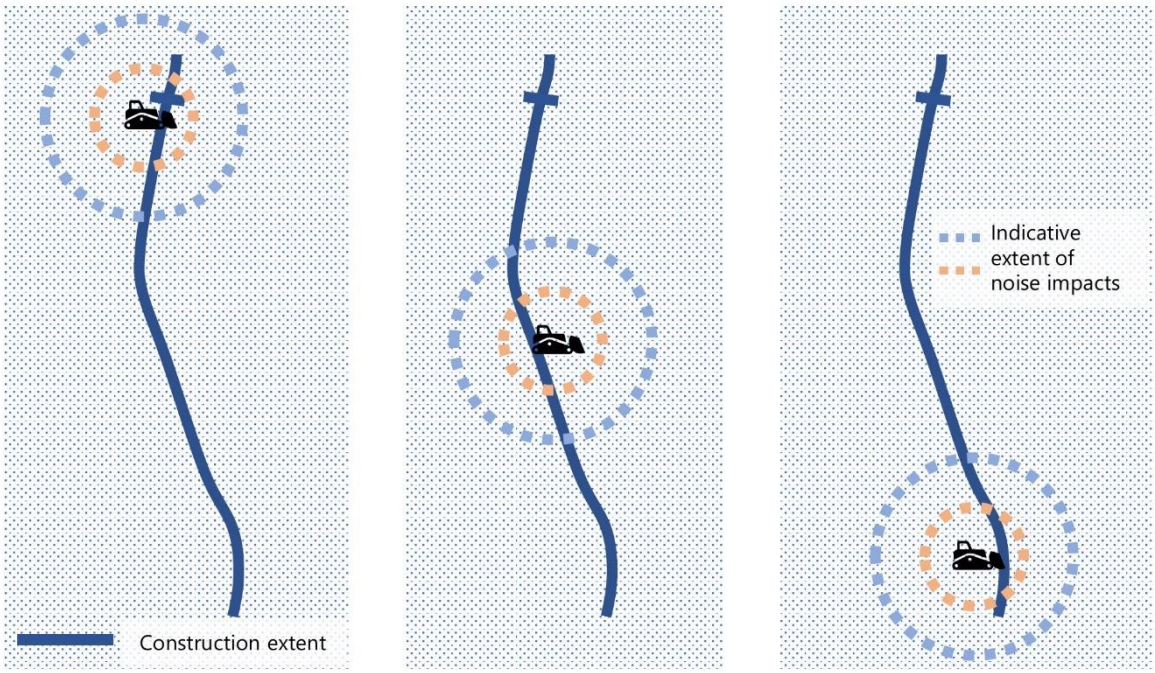
Extensive community consultation should be carried out to inform the most effective noise mitigation and management strategy that should suit nearby sensitive receivers during the detailed construction planning process. For example, where high noise impact works might result in a substantially shorter construction period than slightly less noise intensive activities, the community might prefer to adopt a louder methodology to reduce the overall disruption caused by the construction noise impacts.

6.4.3 Construction programming

Some of the surface road works associated with the project cover large linear areas. Receivers in one suburb might not be noise impacted while works are carried out at the other end of the same surface road works area. Scheduling of works within a work areas based on locations can be used to allow multiple consecutive days of OOHW while still providing respite to noise affected (ie > NML) receivers.

The location and distance between construction work sites where the same receiver would be noise affected would vary depending on the construction activity being carried out and the associated equipment used, the extent of the activity work area. Depending on how noise intensive the construction activity is, by moving and shifting the construction works along the extent of surface road works or within a major works area, it is possible to provide receivers with respite from construction noise while continuing to undertake project construction works. This programming and shifting of the works to provide less impact to receivers, while working at different locations within the same surface road works extent is indicatively presented in Figure 6-1. This would allow the construction works to continue throughout the week, while providing receivers with respite from construction noise impacts.

Figure 6-1 – Indicative example of construction programming opportunities for providing respite during consecutive days of out of hours work



6.4.4 Out of hours work protocols to provide respite

The CNVG recommends the following construction respite periods for OOHW, unless alternative hours can be negotiated with the community:

- Two consecutive evenings or nights per week
- Three evenings or nights per week
- Six evenings or nights per month.

For night works, the above periods should be separated by not less than one week. A similar approach to the above has historically been adopted by the NSW EPA for infrastructure projects. While provide appropriate respite, this approach can increase the overall duration the construction stage of the project, increasing the overall duration of amenity impacts. It is possible that alternative respite arrangements can be developed and implemented to appropriately manage the amenity of sensitive receivers in the vicinity. It is recommended that a more detailed OOHW Protocol be developed and adopted to better manage OOHW construction.

Other major infrastructure projects throughout Sydney have developed OOHW Protocols which classify works based on level and duration of impact, beyond the standard approach in the CNVG. The protocols considered the following to allow OOHW to proceed.

- Programming of works
- Alternative construction techniques/programming
- Alternative plant and equipment

- Community consultation (eg letter box drops, email correspondence, community briefing session)
- Noise monitoring
- Receiver specific notifications
- Receiver specific contact
- Respite periods
- Project specific respite offer (eg good will offer)
- Reasonable temporary relocation offer.

The project should develop an OOHW Protocol based on the above considerations, to assist in speeding up the completion of the overall project, minimising the overall duration of noise impacts, while providing appropriate respite to impacted receivers during the construction works and ensuring the project construction is completed within a reasonable timeframe.

6.4.5 Limiting the timing of noise intensive works

Where out of hours work is required and justified, it may be feasible and reasonable to program higher noise impact works during the parts of the OOHW period when ambient noise levels are higher. Lower noise impact activities could then be programmed to the OOHW period where ambient noise levels are lower. The result would be a reduction of overall noise impact while still allowing the required OOHW to be completed.

Where feasible and reasonable, higher noise impact works should be programmed to occur in the evening period and lower noise impact works to occur in the night period (see Section 3.2 for definition of assessment time periods). However, where OOHW are required and a road occupancy licence (ROL) is not available until after the evening period (or later), noise intensive works may need be carried out during the night period. In these circumstances it can be beneficial if high noise works (eg road sawing and rock hammering) are programmed to the earlier part of the night period, before 11.00pm, as recommended in the CNVG or before 12.00am, to minimise the impacts on nearby residential receivers.

Additional assessment periods called 'shoulder' periods could be considered and used, in accordance with the methodology outlined in the NPfI, such as:

- Shoulder period (night-day) – between 5.00am and 7.00am
- Shoulder period (evening-night) – between 10.00pm and 12.00am.

Where existing background and ambient noise levels in these periods are higher than for the rest of the night period, which often occurs where the receivers are on or near a busy road network, these shoulder periods might be used to minimise the potential for noise impacts outside standard construction hours. A review of noise logger data should occur to confirm if existing background noise levels are steadily rising in the early morning night to day transition between 5.00am and 7.00am or are not yet decreasing in the evening to night transition period between 10.00pm and 12.00am before steadily decreasing after

12.00am. Once confirmed, NMLs could be established for the shoulder periods to assess impact over the shoulder period. Higher noise impact works could be programmed to the shoulder period.

A review of the noise logger data for the project confirmed that shoulder periods could be utilised to minimise potential impacts from high noise activities outside standard construction hours in 32 of the 87 NCAs across the project.

6.4.6 Weekend road closures

There might be benefits from adopting a 'weekend road closure' approach for the surface road works in the project, like that adopted on rail construction and maintenance projects where 'weekend possessions' take place. The ROL could commence on Friday evening and conclude on Monday morning. Weekend possessions allow for a longer overall construction period with less time lost to site set up and pack up as would be required for weeknight OOHW. The net result would be an overall reduction in the number of weeknight OOHW periods required to complete the project.

Another advantage of weekend road closures is that there is more opportunity to program higher noise impact construction works to the less sensitive (weekend) day and evening periods. Lower noise impact works could be programmed to the night periods, thereby reducing the level of noise impact over the OOHW period. If it is not possible to program works, offers of alternative accommodation might be required for highly impacted receivers in accordance with the additional mitigation measures outlined in the CNVG (See Section 6.10).

This approach is subject to assessment of potential impacts to the road network by the relevant road authority, but is likely to be less disruptive to the road network and less inconvenient to affected residents over a weekend period than midweek.

6.4.7 Out-of-hours deliveries

Where feasible and reasonable, delivery of plant and equipment should be carried out during standard construction hours. However, to support the surface road works, some delivery of material, plant and equipment would be required out of hours due to the extensive works that are required outside standard construction hours.

Oversized delivery vehicles can cause disruptions to traffic flow and can be a potential hazard for road users. There is a need for these vehicles to move during off peak periods when traffic volumes are typically at a minimum, thereby ensuring safety for the road user and the public and minimising disruption to the road network.

Out-of-hours deliveries (except in emergency situations), including appropriate mitigation measures that consider the receivers around the destination locations and the existing acoustic environment, should be documented in an OOHW Protocol developed as part of the CNVMP.

6.4.8 Early installation of operational noise mitigation

Early installation of noise mitigation required for the operational stage of the project (see sections 7.2.2 and 7.2.3) can help to reduce the impacts of noise during construction. For road projects such as the Beaches Link, the final road design is still being developed during early construction stages. This means the operational noise mitigation would not have been finalised when construction activities commence.

Installing all operational noise mitigation measures identified in sections 7.2.2 and 7.2.3 while the final road design is being developed, could lead to ineffective or inadequate operational noise mitigation in addition to less adequate construction noise mitigation.

The project proposes a staged approach to early installation of operational mitigation. When the final road design is confirmed, operational noise mitigation measures that would also provide a benefit during the construction stage of the project would be identified. These measures should be prioritised for installation so that the noise reduction benefit is experienced during construction.

Early installation of operational noise mitigation measures should form part of the overall construction mitigation and management measures. In some cases alternative mitigation measures can result in the same acoustic outcomes for construction noise affected receivers as what be achieve through the early installation of operational noise mitigation. As such the feasible and reasonable nature of early installation of operational noise mitigation should be considered along with the construction mitigation and management measures that are refined during detailed construction planning.

6.4.9 Noise management outside standard construction hours for strategic roads

For works on the carriageways of strategic roads such as Warringah Freeway and Gore Hill Freeway, the option for implementing physical noise mitigation measures are limited due to constraints around the configuration of the worksite and the need to get the road back into service at the end of the ROL work period.

As such, an approach specifically tailored to the Warringah Freeway and Gore Hill Freeway works is being developed by Transport for NSW in order to manage these construction works and would be used by the project to manage the complex nature of operating a construction worksite within this major Sydney road corridor. The noise management approach would provide focus on the specific mitigation and management measures required outside of standard construction hours along the Warringah Freeway and Gore Hill Freeway. These measures may be different to those measures outlined in the CNVG.

6.5 Management of cumulative impacts from major projects

As outlined in Section 4.2.4, concurrent major construction projects or projects that overlap or follow on one after the other can lead to sensitive receivers being impacted by construction noise and/or vibration over an extended duration, with insufficient respite. This may lead to construction fatigue.

The following specific measures should be used to mitigate and manage cumulative noise impacts along with potential construction fatigue:

- Considering the potential for cumulative impacts due to other major projects in the locality during development of the detailed construction methodology. The construction methodology should be developed to minimise overall noise impacts and the need for respite for potentially affected receivers wherever feasible and reasonable
- Coordinating with other major project construction works, within the project and external to the project, that will affect the same area to ensure that affected receivers get appropriate respite from high noise impact activities and works outside standard construction hours, where feasible and reasonable
- Implementing additional feasible and reasonable at source mitigation for concurrent construction activities, where programming is not practical to avoid cumulative noise impacts
- Community consultation to seek feedback on and identify key noise and vibration issues relevant to the local community so that current or future works can be managed to limit cumulative impacts
- Consideration of cumulative construction noise impacts would feed into the development of noise mitigation and management measures for the worksites, including coordination between construction projects, where feasible and reasonable.

The project CNVMP should include how the above measures would be incorporated at each site.

6.6 Assessing the effectiveness of mitigation measures using spot checks

Spot check measurements are suggested by the CNVG as a way of providing greater confidence in noise predictions and mitigation measures. Spot checks should take place during construction to:

- Understand the range in background noise levels and associated criteria within each NCA, as background noise levels may vary between receiver locations
- Understand the range in background noise levels or the range in construction noise impact between facades on the same building which have different noise exposures
- Verify that actual construction noise levels are within predicted noise levels at each receiver location
- Provide greater confidence in the effectiveness of mitigation measures to adequately address noise impacts, both at the most affected receiver and across the catchment area.

Spot checks should be included in the CNVMP.

6.7 Management of construction related traffic noise impacts

Potential noise impacts from construction related traffic on public roads should be assessed during detailed construction planning based on the proposed construction methodology. Management

measures should be developed as part of the CNVMP to minimise the potential traffic noise impacts on nearby sensitive receivers, considering the following where feasible and reasonable:

- Limit heavy vehicle movements associated with the project to standard construction hours
- Where out of hours heavy vehicle movements are required, they should be programmed to occur during less sensitive time periods where feasible and reasonable
- Select construction traffic routes to curtail the use of local roads
- Select construction worksite access points away from sensitive receivers
- Develop a Heavy Vehicle Code of Conduct (HVCC) for all drivers to adhere to. The HVCC should require appropriate training of project contractors. It should include noise management methods such as limiting idling and compression braking, and traffic management practises to minimise noise emissions from vehicles entering and leaving the site
- Require delivery vehicles to be fitted with straps rather than chains for unloading, wherever feasible and reasonable and with consideration of safety requirements
- Limit the use of engine compression brakes at night and in residential areas
- Vehicles should be fitted with a silencer that complies with the National Transport Commission's 'In-service test procedure' and standard
- Where feasible, arrange on site parking to minimise worker/contractors' vehicles from parking in the surrounding streets.

Where existing road traffic noise barriers require relocation or removal to facilitate construction of new road infrastructure, the new road traffic noise barriers should be installed prior to removing the existing road traffic barrier, where feasible and reasonable. Where it is not possible to install the new road traffic barriers before removing the existing barriers, the duration between removing the existing and installing the new barriers should be minimised. Temporary road traffic noise barriers should be installed as an interim measure to limit the increase in road traffic noise levels to no more than 2 dB(A) at noise affected residential receiver buildings, where feasible and reasonable.

6.8 Works occurring within the recommended minimum vibration working distance for sensitive receivers

6.8.1 Cosmetic damage

As the construction methodology develops during the detailed construction planning stage of the project, all vibration generating construction activities should be reviewed to determine the risk of cosmetic damage to nearby structures or vibration sensitive items. Minimum working distances should be established with consideration of:

1. Minimum distance between vibration generating plant/equipment and the foundations of building/structure being assessed
2. The screening criterion for potentially affected buildings based on:

  - Type of item/building/structure considering the criterion in Section 3.4.5
  - Heritage status of item, and importance/difficulty to repair. This step would require input from heritage specialists
  - Structural soundness of the item. This step would require input from a structural engineer
3. Type of vibration intensive activity.

If vibration intensive work is proposed to occur within the recommended minimum working distance (refer to Table 4-11 in Section 4.4.1, Annexure K and Annexure L), the following should be carried out:

- Evaluate whether alternative (less vibration intensive) construction methods, plant or equipment can be utilised for the works and reassess potential impacts (if required)
- For heritage structures, consult an appropriately qualified structural engineer who is familiar with heritage structures to determine the susceptibility of the structure to cosmetic damage from vibration and reassess potential impacts (if required) (see Section 6.8.2 for the general approach).
- For reinforced commercial-type buildings, a higher cosmetic damage screening criterion may be applicable. Reassess potential impacts (if required) in consultation with a structural engineer and/or review of building condition survey report
- Undertake vibration measurements (attended or unattended as required based on the nature of the proposed vibration intensive works) at the commencement of and during vibration generating activities confirm actual vibration levels and compare to appropriate damage criteria.
- If, based on the monitoring results, the criteria are likely to be exceeded, cease the vibration intensive activities at that location and reassess to identify an alternative construction methodology where the criteria would not be exceeded or adopt an agreed management approach with the owner of the potentially impacted building/structure/item.

6.8.2 Heritage items

The general approach to manage potential vibration impacts on heritage items would be to:

1. Identify heritage items where the 2.5 mm/s peak component particle velocity objective may be exceeded during specific construction activities, and if it susceptible to damage due to vibration. If is not susceptible to damage due to vibration. no further action is required
2. Structural engineering report would be carried out on identified heritage items, to confirm structural integrity of the building and confirm if item is ‘structurally sound’
3. If the item was confirmed as ‘structurally sound’, the screening criteria from BS 7385-2 would be adopted
4. If the item was confirmed as ‘structurally unsound’, the more conservative cosmetic damage objectives of 2.5 mm/s peak component particle velocity would be adopted.

6.8.3 Human comfort (response)

Where the predicted vibration levels exceed the human comfort (response) levels presented in Section 3.4.5.1, then the additional mitigation measures presented in Section 6.10.3 would be implemented (as per Section 7.1 and Appendix C of the CNVG) in order to mitigate the potential impacts at sensitive receivers.

6.9 At source ground-borne noise control and management measures

The extent of mitigation and management required to limit potential impacts to receivers would be determined by considering not only the level of noise impact, but also the duration that receivers are likely to be exposed to ground-borne noise levels above the noise management level.

The following at source control and noise management measures are recommended to reduce potential ground-borne noise impacts.

Table 6-2 – At-source ground-borne noise control and management measures

Control type	Control measure	Typical use
At-source control measures	Limit equipment in use	Only the equipment needed to undertake a specific construction task would be operated. Equipment not required for the task would be switched off to reduce noise.
	Equipment selection	Use quieter and less noise/vibration emitting construction methods where feasible and reasonable.
	Timing of equipment in use	Where feasible and reasonable, rock hammering should be limited to the least sensitive time periods for the affected receiver. That is, for: • Residential receivers and hotels: rock hammering would only be carried out during standard construction hours: - 7.00am to 6.00pm, Monday to Friday - 8.00am to 1.00pm, Saturday • 'Other' sensitive receivers (eg educational institutions, places of worship) and commercial/industrial premises: The contractor should consult with these receivers and meet reasonable and feasible requirements. For example, rock hammering can be carried out during the evening/night period when/if the premises are not in use.
	Respite periods	High ground-borne noise impact activities associated with surface works should be carried out in continuous blocks of up to three hours. Respite from such high noise impact activities should be provided between each block for at least one hour. No high noise impact activities should be carried out during this one hour respite period. Respite periods should be considered where residential properties are exposed to ground-borne noise in excess of 65 dB(A), in particular where this is likely to occur for two days or more.

Control type	Control measure	Typical use
Noise management measures	Site inductions and toolbox talks	All employees, contractors and subcontractors should receive a Project induction. The environmental component covered in toolbox talks should include: • the locations of the nearest sensitive receivers • any project specific and standard noise and vibration mitigation and management measures relevant to the works • permissible hours of work • OOHW procedures and any documentation required.
	Community consultation	Inform community of construction activity and potential impacts.
	Noise monitoring	Air blast overpressure, noise and vibration monitoring should be monitored during construction. Any necessary adaptive management requirements would be identified and implemented where reasonable and feasible. Where appropriate, verification monitoring should be undertaken during tunnelling work to determine if ground-borne noise levels inside residential receiver buildings are below the predicted noise levels and comply with the ground-borne noise NMLs. Ground-borne noise from access decline tunnel construction should be managed by reviewing construction hours, or if justified, in accordance with Section 6.10.2 Noise monitoring is also to be carried out as spot checks as detailed in Section 6.6 to confirm construction noise impacts and the effectiveness of mitigation measures.

6.10 Triggers for additional mitigation measures

Following the implementation of all reasonable and feasible mitigation measures, it is not always possible for the noise impacts to achieve the recommended NMLs or vibration criteria for all impacted receivers. Where this is the case, Appendix C of the CNVG provides details of additional mitigation measures that would be implemented to manage the noise and vibration impacts from the project.

The additional mitigation measures reference tables from Appendix C of the CNVG are presented below, identifying the mitigation measures that are recommended for various noise or vibration exceedances. The range and extent of additional mitigation measures should be refined during detailed construction planning when preparing site specific CNVISs taking into consideration potential cumulative noise and vibration impacts and nearby concurrent construction works.

6.10.1 Airborne noise

Where applicable, Table 6-3 below should be used to determine the appropriate additional noise mitigation measures based on airborne noise impacts.

Table 6-3 – Triggers for additional mitigation measures – airborne noise (Appendix C, CNVG)

Predicted airborne $L_{Aeq(15\ min)}$ noise level at receiver			Additional mitigation measures type[1]	Mitigation levels[2]
Perception	**dB(A) above RBL**	**dB(A) above NML**		
All hours				
75 dB(A) or greater			N, V, PC, RO	HA
Standard Hours: Mon - Fri (7.00am - 6.00pm), Sat (8.00am - 1.00pm), Sun/Public holiday (Nil)				
Noticeable	5 to 10	0	-	NML
Clearly audible	10 to 20	< 10	-	NML
Moderately intrusive	20 to 30	10 to 20	N, V	NML+ 10
Highly intrusive	> 30	> 20	N, V	NML+ 20
OOHW Period 1: Mon - Fri (6.00pm - 10.00pm), Sat (7.00am - 8.00am and 1.00pm - 10.00pm), Sun/public holiday (8.00am - 6.00pm)				
Noticeable	5 to 10	< 5	-	NML
Clearly audible	10 to 20	5 to 15	N, R1, DR	NML+5
Moderately intrusive	20 to 30	15 to 25	V, N, R1, DR	NML+15
Highly intrusive	> 30	> 25	V, IB, N, R1, DR, PC, SN	NML+25
OOHW Period 2: Mon - Fri (10.00pm - 7.00am), Sat (10.00pm - 8.00am), Sun/public holiday (6.00pm -7.00am)				
Noticeable	5 to 10	< 5	N	NML
Clearly audible	10 to 20	5 to 15	V, N, R2, DR	NML+5
Moderately intrusive	20 to 30	15 to 25	V, IB, N, PC,SN, R2, DR	NML+15
Highly intrusive	> 30	> 25	AA, V, IB, N, PC, SN, R2, DR	NML+25

Notes: 1. The additional mitigation measures have used the following abbreviations: AA = Alternative accommodation, RO = Respite offer, R1 = Respite period 1, R2 = Respite period 2, DR = Duration respite, V = Verification, PC = Phone calls, IB = Individual briefings, SN = Specific notifications, N = Notification, HA = Highly Affected (> 75 dB(A) - applies to residences only)

2. Table from Appendix C1 of the CNVG.

6.10.2 Ground-borne noise

Where applicable, Table 6-4 below should be used to determine the appropriate additional noise mitigation measures based on ground-borne noise impacts.

Table 6-4 – Triggers for additional mitigation measures – ground-borne noise (Appendix C, CNVG)

Predicted airborne $L_{Aeq(15\ min)}$ noise level at receiver		Additional mitigation measures	
Perception	**dB(A) above ground-borne NML**	**Type[1]**	**Apply to[2]**
Standard Hours: Mon - Fri (7.00am- 6.00pm), Sat (8.00am- 1.00pm), Sun/Public holiday (Nil)			
N/A	Vibration impacts only applicable during standard hours (Refer to Table 6-5)		
OOHW Period 1: Mon - Fri (6.00pm- 10.00pm), Sat (7.00am- 8.00am and 1.00pm- 10.00pm), Sun/public holiday (8.00am - 6.00pm)			
Clearly audible	< 10	N	All
Moderately intrusive	10 to 20	V, N, R1, DR, SN	All
Highly intrusive	> 20	V, IB, N, PC, SN, R1, DR	All
OOHW Period 2: Mon - Fri (10.00pm- 7.00am), Sat (10.00pm – 8.00am), Sun/public holiday (6.00pm-7.00am)			
Clearly audible	< 10	V, N, SN	All
Moderately intrusive	10 to 20	AA, V, IB, N, PC, RP, SN, R2, DR	All
Highly intrusive	> 20	AA, V, IB, N, PC, RP, SN, R2, DR	All

Notes:
1. The additional mitigation measures have used the following abbreviations: AA = Alternative accommodation, R1 = Respite period 1, R2 = Respite period 2, RP = Respite period, DR = Duration respite, V = Validation of predicted noise level, PC = Phone calls, IB = Individual briefings, SN = Specific notifications, N = Notification
2. All affected receivers
3. Table from Appendix C2 of the CNVG.

6.10.3 Vibration

Where applicable, Table 6-5 below would be used to determine the appropriate additional vibration mitigation measures, based on vibration impacts.

Table 6-5 – Triggers for additional mitigation measures – vibration (Appendix C, CNVG)

Predicted vibration level at receiver	Additional mitigation measures	
Perception	**Type[1]**	**Apply to[2]**
Standard Hours: Mon - Fri (7.00am - 6.00pm), Sat (8.00am - 1.00pm), Sun/Public holiday (Nil)		
Predicted vibration exceeds maximum levels for human comfort	V, N, RP	All
OOHW Period 1: Mon - Fri (6.00pm - 10.00pm), Sat (7.00am - 8.00am and 1.00pm - 10.00pm), Sun/public holiday (8.00am - 6.00pm)		
Predicted vibration exceeds maximum levels for human comfort	V, IB, N, RO, PC, RP, SN	All
OOHW Period 2: Mon - Fri (10.00pm - 7.00am), Sat (10.00pm - 8.00am), Sun/public holiday (6.00pm - 7.00am)		
Predicted vibration exceeds maximum levels for human comfort	AA, V, IB, N, PC, RP, SN	All

Notes:
1. The additional mitigation measures have used the following abbreviations: AA = Alternative accommodation, V = Validation of predicted level, PC = Phone calls, IB = Individual briefings, SN = Specific notifications, N = Notification drops, RP = Respite period
2. All affected receivers
3. Table from Appendix C3 of the CNVG.

The following is a summary of the additional noise mitigation measures that should be considered following the implementation of all reasonable and feasible mitigation measures:

- Prior to the commencement of work, sensitive receivers should be notified to advise that noise from the works may at times be audible
- All potentially impacted receivers should be kept informed of the nature of works to be carried out, the expected noise levels and duration, and be given contact details for enquiries and noise complaints
- A complaints handling procedure should be developed and implemented by the construction contractor. The complaints handling procedure should comply with Transport for NSW and NSW EPA requirements for recording, investigation and responding to complaints
- Where applicable, in accordance with the requirements of the CNVG, additional mitigation measures should be provided to a receiver (such as notification, respite period, etc) based on the level of exceedance above the established NMLs and if a receiver is highly noise affected.

6.11 Blast mitigation and management

Any blasting and associated activities should be carried out in a manner that does not generate unacceptable overpressure and vibration impacts or pose a substantial risk of impact to structures and sensitive receivers. Prior to any blasting, all potentially affected noise and vibration sensitive receivers and structures in the vicinity should be identified. Appropriate tests should be carried out at each proposed blasting location to develop site-specific laws that take into account relevant factors such as underlying geology and separation distance to sensitive receivers and features to determine appropriate charge sizes and blast design to ensure compliance with relevant vibration and overpressure criteria.

All blasting should be carried out in accordance with the specific-laws. Monitoring should occur to determine compliance with the relevant criteria, and the site-specific laws should be adjusted as required based on the monitoring results to ensure ongoing compliance. The potentially affected community should be kept informed about proposed blasting activities.

7 Operational noise assessment

Operational road traffic noise impacts were assessed for surface roads associated with the project. Noise modelling predictions were carried out for all noise sensitive receiver locations. For multi storey buildings, all floor levels which accommodate noise sensitive receivers have been included as part of the road traffic noise assessment. A separate receiver has been assigned to each floor level of a multi storey building; for example, assessment of a two storey residential dwelling covers each of the two levels of the building as individual (single) receivers.

Furthermore, operational noise impacts from the proposed operational facilities associated with the project have been assessed for noise sensitive receivers surrounding the proposed fixed facilities.

7.1 Operational road traffic noise predictions without mitigation

7.1.1 Project only scenario

Road traffic noise associated with the project impacting on noise sensitive receivers has been predicted for the 'Do Minimum' (No Build) and the 'Do Something' (Build) scenarios where no mitigation measures have been implemented, other than the existing measures (eg existing noise barriers) and those that are incorporated into the road design. The modelled scenarios are detailed in Table 4-13.

Detailed noise modelling results for the above scenarios and the assessment against the NCG requirements are provided in Annexure O. The results of the assessment identify the sensitive receivers that would qualify for consideration of additional noise mitigation as a result of the project ('Do Something').

The results of the noise predictions indicate that receivers adjacent to the project are generally impacted by existing road traffic noise levels that exceed the NCG noise criteria levels presented in Section 3.5.2

Table 7-1 presents the number of receiver buildings that have been predicted to exceed the NCG noise criteria levels for the 'Do Minimum' (No Build) and 'Do Something' (Build) scenarios for the opening year and design year without any mitigation measures implemented.

It is noted that if a receiver is predicted to exceed the NCG noise criteria, it may not necessarily be eligible for additional noise mitigation. Eligibility for additional noise mitigation measures is subject to the processes and criteria discussed in Section 4.7 and involves considering (in order of preference):

- Source controls (eg low noise road pavements)
- Path controls (eg noise mounds/walls)
- At-property controls (eg architectural treatments).

Table 7-1 – Number of receiver buildings exceeding the NCG noise criteria without mitigation

Noise catchment area[1]	2027 'Do Minimum' (No Build)[2]		2027 'Do Something' (Build)[2]		2037 'Do Minimum' (No Build)[2]		2037 'Do Something' (Build)[2]	
	Day	Night	Day	Night	Day	Night	Day	Night
Warringah Freeway								
15.1	0	0	0	0	0	0	0	0
15.2	0	0	0	0	0	0	0	0
15.3	22	9	23	9	24	9	24	9
15.4	5	3	7	1	5	3	7	2
16.1	34	35	35	35	35	36	35	35
16.2	0	0	0	0	0	0	0	0
16.3	20	7	20	7	20	9	20	8
17.1	89	75	89	74	95	82	99	82
17.2	22	23	23	23	23	27	28	27
17.3	156	172	117	119	166	179	124	124
17.4	117	130	61	46	137	149	73	54
18.1	1	2	2	2	2	2	2	2
18.2	7	10	4	6	8	11	6	7
18.3	200	215	25	22	214	226	48	30
19.1	22	21	22	21	22	21	22	21
20.1	10	10	10	10	10	10	10	10
21.1	12	12	12	11	12	12	12	11
21.2	27	18	27	18	27	18	27	18
22.1	107	87	106	87	107	88	107	87
22.2	45	34	44	35	46	35	46	36
22.3	182	178	182	178	182	178	182	178
23.1	140	138	124	118	143	142	127	122
23.2	24	22	22	20	24	22	22	20
24.1	126	124	124	122	128	126	124	122
25.1	46	46	43	41	48	47	43	42
26.1	31	30	24	23	33	32	26	24
26.2	0	0	0	0	0	0	0	0
27.1	0	0	0	0	0	0	0	0
28.1	25	35	7	5	38	40	9	5
29.1	50	50	49	48	51	51	50	49
30.1	197	179	188	171	200	184	202	172
30.2	69	67	61	52	72	73	62	57
30.3	70	75	64	60	76	76	67	62
30.4	8	8	8	8	8	8	8	8
31.1	29	29	28	27	30	30	28	28
31.2	38	23	32	22	38	26	33	22

Noise catchment area[1]	2027 'Do Minimum' (No Build)[2]		2027 'Do Something' (Build)[2]		2037 'Do Minimum' (No Build)[2]		2037 'Do Something' (Build)[2]	
	Day	Night	Day	Night	Day	Night	Day	Night
31.3	131	130	121	118	137	134	126	123
32.1	146	147	144	139	154	157	149	148
36.1	42	41	42	41	42	41	42	41
37.1	16	14	14	11	16	15	15	13
38.1	0	0	0	0	0	0	0	0
38.3	0	0	0	0	0	0	0	0
TOTAL	**2266**	**2199**	**1904**	**1730**	**2373**	**2299**	**2005**	**1799**
Gore Hill Freeway Connection								
33.1	141	118	137	110	143	121	142	115
33.2	8	1	8	1	8	1	8	1
59.1	50	50	51	48	51	50	51	49
33.4	27	27	27	27	28	27	27	27
34.1	1	1	1	1	1	1	1	1
35.1	18	19	19	18	19	19	20	19
36.1	20	20	20	20	21	21	21	21
TOTAL	**265**	**236**	**263**	**225**	**271**	**240**	**270**	**233**
Connections to and from Burnt Bridge Creek Deviation								
45.1	0	0	0	0	0	0	0	0
46.1	37	36	25	24	38	37	27	26
46.2	13	13	13	12	13	13	13	12
47.1	47	46	46	43	47	46	47	44
48.1	52	41	46	36	52	43	51	37
49.1	67	55	66	55	69	57	68	56
50.1	116	86	134	128	122	89	144	137
51.1	110	103	120	119	118	107	127	123
52.1	20	19	24	24	21	20	26	25
TOTAL	**462**	**399**	**474**	**441**	**480**	**412**	**503**	**460**
Connections to and from the Wakehurst Parkway								
53.1	35	26	36	33	36	29	36	35
53.2	5	5	5	5	5	5	5	5
53.3	8	8	8	8	9	8	8	8
53.4	1	1	1	1	1	1	1	1
54.1	38	14	42	38	42	17	44	41
55.1	9	7	31	25	14	8	32	27
55.4	0	0	0	0	0	0	0	0
56.1	43	41	43	42	44	41	44	44

Noise catchment area[1]	2027 'Do Minimum' (No Build)[2]		2027 'Do Something' (Build)[2]		2037 'Do Minimum' (No Build)[2]		2037 'Do Something' (Build)[2]	
	Day	Night	Day	Night	Day	Night	Day	Night
57.1	19	7	19	9	19	9	20	9
58.1	0	0	0	0	0	0	0	0
58.2	2	1	2	1	2	1	2	1
TOTAL	**160**	**110**	**187**	**162**	**172**	**119**	**192**	**171**

Notes:
1. Refer to Annexure B for location of noise catchment areas
2. Refer to Table 4-13 for a description of the 'Do Minimum' and 'Do Something' operational road traffic noise scenarios
3. The eligibility requirements for a receiver to qualify for additional noise mitigation is based on the processes and criteria discussed in Section 4.7
4. An individual receiver building is considered as a single receiver for the purposes of this assessment; ie one multi-dwelling residential building = one receiver building.

The number of receivers predicted to experience a decrease in traffic noise; experience a minor increase in traffic noise of no more than 2 dB(A); or experience an increase in traffic noise by more than 2 dB(A) due to the project, are presented in Table 7-2 for the Warringah Freeway, Gore Hill Freeway Connection, the connections to and from Burnt Bridge Creek Deviation and the connections to and from the Wakehurst Parkway. The results are based on no additional mitigation measures being implemented.

Table 7-2 – Predicted changes in noise levels (2037 'Do Something' – 'Do Minimum')

Study area	Number of receiver buildings					
	<0 dB(A)		0 dB(A) – 2 dB(A)		>2 dB(A)	
	Day	Night	Day	Night	Day	Night
Warringah Freeway	5326	5582	1423	1169	15	13
Gore Hill Freeway Connection	149	719	993	425	5	3
Connections to Burnt Bridge Creek Deviation	822	896	1493	1303	37	153
Connections to and from the Wakehurst Parkway	17	33	901	783	317	419

Notes:
1. Based on no mitigation measures implemented, except existing noise barriers
2. Includes other sensitive receivers (OSRs) that are non-residential, where applicable
3. An individual receiver building is considered as a single receiver for the purposes of this assessment; ie one multi-dwelling residential building = one receiver building.

From the results presented in Table 7-1 and Table 7-2 above, the following outcomes are identified:

- The project is predicted to typically decrease the number of receiver buildings exceeding the NCG noise criteria when compared to the 'Do Minimum' scenario during the day and night periods at the Warringah Freeway and Gore Hill Freeway Connection
- The decrease in the number of receiver buildings would be due to the reduction in forecast traffic volumes as a result of the project, as traffic along existing surface roads would move to the proposed tunnels
- At the connections to and from Burnt Bridge Creek Deviation and the connections to and from the Wakehurst Parkway and surface road works at Seaforth, Killarney Heights and Frenchs Forest, the project is predicted to increase the overall number of receiver buildings exceeding

the NCG noise criteria when compared to the 'Do Minimum' scenario during the day and night periods. This is due to the widening of the Burnt Bridge Creek Deviation and Wakehurst Parkway and the predicted increase in traffic volumes along Wakehurst Parkway due to the project

- For NCA 50.1 (Balgowlah), NCA 51.1 (North Balgowlah) and NCA 54.1 (Allambie Heights) the number of receiver buildings exceeding the NCG noise criteria during the night period are predicted to increase significantly due to the project when compared to the 'Do Minimum' (No Build) scenario. A review of the traffic data indicates that traffic volumes during the night period along Wanganella Street, Balgowlah are forecast to increase significantly due to the project, increasing traffic noise levels for some receiver buildings within NCA 50.1. Similarly, traffic volumes during the night period along Judith Street, Seaforth and Woodbine Street, North Balgowlah are forecast to increase significantly, resulting in an increase in traffic noise levels for some receivers within NCA 54.1 and NCA 51.1 respectively. The predicted increase in traffic volumes are modelled without inclusion of mitigation through proposed traffic calming measures. Transport for NSW has committed to investigation of additional calming measures in consultation with Northern Beaches Council during further design development of the project with the objective of minimising the increase in traffic volumes as a consequence of the project on local roads in Seaforth, North Balgowlah and Balgowlah to limit increases in road traffic noise to no more than 2 dB(A).
- On average the project is predicted to result in reduced traffic noise for about 59 per cent of receivers at the Warringah Freeway, Gore Hill Freeway Connection, the connections to and from Burnt Bridge Creek Deviation and the connections to and from the Wakehurst Parkway noise catchment areas
- An average of about 37 per cent of receivers within the noise catchment areas are predicted to experience traffic noise level increases of less than 2 dB(A), which is described by the RNP as a minor impact which is barely perceptible
- An average of about four per cent of receiver buildings within the noise catchment areas are predicted to experience increases in traffic noise of more than 2 dB(A) due to the project
- The Warringah Freeway surface road works are predicted to reduce traffic noise levels at a significant number of receiver buildings (about 81 per cent), mainly due to traffic being moved to tunnels.

For the majority of receiver buildings within the noise catchment areas there is either a reduction or relatively minor change in traffic noise levels due to the project. As such, any requirement for additional noise mitigation is likely to be a result of the high existing road traffic noise levels resulting in exceedances of the cumulative limit criterion or traffic noise levels being acute (day $L_{Aeq(15hour)} \geq 65$ dB(A) or night $L_{Aeq(9hour)} \geq 60$ dB(A)).

7.1.1.1 Receivers considered for additional noise mitigation – project only scenario

The results for the number of receiver buildings impacted upon and requiring additional noise mitigation for the design year 2037 due to the 'Do Something' scenario are summarised in Table 7-3.

Table 7-3 – Number of receiver buildings impacted due to project for design year 2037 ('Do Something')

Location	Total Number of residences assessed in area	Day period – number of receiver buildings				Night period – number of receiver buildings				Requiring additional noise mitigation[5]
		Exceed NCG noise criteria level [1]	>2 dB(A) Increase and exceed NCG criteria [2,3]	Exceed cumulative noise limit	Experience acute noise levels (≥ 65 dB(A))[4]	Exceed NCG noise criteria level[1]	>2 dB(A) Increase and exceed NCG criteria[2,3]	Exceed cumulative noise limit	Experience acute noise levels (≥ 60 dB(A))[4]	
Warringah Freeway	6764	2005	12	366	314	1799	9	315	295	387
Gore Hill Freeway Connection	1147	270	3	42	30	233	1	32	30	43
Connections to and from Burnt Bridge Creek Deviation	2352	503	9	34	21	460	108	25	21	140
Connections to and from the Wakehurst Parkway	1235	192	39	26	15	171	74	19	11	87
TOTAL	**11,498**	**2970**	**63**	**468**	**380**	**2663**	**192**	**391**	**357**	**657**

Notes:
1. NCG noise criteria level based on 'New Road', 'Redeveloped Road', 'Transition Zone' or 'Relative Increase' criteria as per RNP
2. >2 dB(A) increase based on comparison between 'Do Something' scenario and 'Do Minimum' scenario for the design year 2037
3. Exceedance of NCG noise criteria AND increase of more than 2 dB(A) are required to be eligible for noise mitigation
4. Acute noise levels due to contribution from the project only
5. A receiver building qualifies for noise mitigation if it falls under any of the three NMG noise mitigation triggers (ie >2 dB(A) increase, exceed cumulative or acute noise) or a multiple of triggers
6. An individual receiver building is considered as a single receiver for the purposes of this assessment; ie one multi-dwelling residential building = one receiver building

The above table shows that out of the 11,498 receiver buildings assessed, 657 are eligible for consideration for additional noise mitigation in accordance with the NMG requirements as presented in Section 4.7.

The 657 receiver buildings were identified based on the following:

- The predicted 'Do Something' (Build) traffic noise levels in the design year (2037) would exceed the NCG project road noise criteria and would also increase by more than 2 dB(A) as a result of the project at 63 and 192 receiver buildings during the day and night periods, respectively
- The cumulative limit (5 dB(A) above the NCG project road criterion) would be exceeded at 468 and 391 receiver buildings during the day and night periods, respectively
- There are 380 and 357 receiver buildings predicted to experience acute (day $L_{Aeq(15hour)} \geq$ 65 dB(A) or night $L_{Aeq(9hour)} \geq 60$ dB(A)) noise levels due to the project during the day and night periods, respectively.

It is noted that some receiver buildings eligible for consideration for additional noise mitigation might fall into more than one of the NMG noise mitigation triggers and have multiple triggers. The most common multiple trigger is when an eligible receiver building exceeds the cumulative noise limit and is also exposed to acute noise levels.

7.1.2 Cumulative scenario

Traffic generated by other major road projects has the potential to increase traffic along the project surface roads, resulting in higher noise levels at affected receivers. To address this, an assessment of traffic noise from the 'Do Something - Cumulative' (Build) scenario compared to the 'Do Minimum' (No Build) scenario has been carried out. Cumulative traffic from the following major road projects was included in the 'Do Something - Cumulative' scenario:

- Western Harbour Tunnel and Warringah Freeway Upgrade
- WestConnex
- Sydney Gateway
- M6 Motorway (Stage 1 in 2027; full project in 2037).

Detailed noise modelling results for the 'Do Something - Cumulative' scenario and the 'Do Minimum' scenario and the assessment against the NCG requirements are presented in Annexure O. The results of the assessment identify the sensitive receivers that would qualify for consideration of additional noise mitigation as a result of the project ('Do Something - Cumulative'). Furthermore, noise contours representing the traffic noise impacts to ground floor levels (ie 1.5 metres above ground) of receivers within the noise catchment areas are presented in Annexure P.

Table 7-4 presents the number of receiver buildings that have been predicted to exceed the NCG noise criteria levels for the 'Do Minimum' and 'Do Something - Cumulative' scenarios for the opening year and design year without any mitigation measures implemented. It is noted that if a receiver is predicted

to exceed the NCG noise criteria, it may not necessarily be eligible for additional noise mitigation. Eligibility for additional noise mitigation measures is subject to the processes and criteria discussed in Section 4.7

Table 7-4 – Number of receiver buildings exceeding the NCG noise criteria without mitigation

Noise catchment area[1]	2027 'Do Minimum' (No Build)[2]		2027 'Do Something - Cumulative' (Build)[2]		2037 'Do Minimum' (No Build)[2]		2037 'Do Something - Cumulative' (Build)[2]	
	Day	Night	Day	Night	Day	Night	Day	Night
Warringah Freeway								
15.1	0	0	0	0	0	0	0	0
15.2	0	0	0	0	0	0	0	0
15.3	22	9	22	9	24	9	24	9
15.4	5	3	6	1	5	3	7	1
16.1	34	35	35	32	35	36	35	35
16.2	0	0	0	0	0	0	0	0
16.3	20	7	20	8	20	9	20	9
17.1	89	75	69	47	95	82	83	56
17.2	22	23	20	21	23	27	22	21
17.3	156	172	104	98	166	179	115	105
17.4	117	130	63	44	137	149	71	45
18.1	1	2	1	1	2	2	2	2
18.2	7	10	3	3	8	11	4	5
18.3	200	215	23	21	214	226	23	21
19.1	22	21	22	21	22	21	22	21
20.1	10	10	10	10	10	10	10	10
21.1	12	12	12	11	12	12	13	12
21.2	27	18	27	18	27	18	27	18
22.1	107	87	106	88	107	88	107	88
22.2	45	34	45	35	46	35	46	37
22.3	182	178	182	178	182	178	182	178
23.1	140	138	123	119	143	142	127	119
23.2	24	22	22	20	24	22	23	21
24.1	126	124	124	122	128	126	126	122
25.1	46	46	43	41	48	47	45	42
26.1	31	30	24	22	33	32	26	23
26.2	0	0	0	0	0	0	0	0
27.1	0	0	0	0	0	0	0	0
28.1	25	35	6	5	38	40	9	5
29.1	50	50	49	47	51	51	50	49
30.1	196	178	193	169	200	182	206	172

Noise catchment area[1]	2027 'Do Minimum' (No Build)[2]		2027 'Do Something - Cumulative' (Build)[2]		2037 'Do Minimum' (No Build)[2]		2037 'Do Something - Cumulative' (Build)[2]	
	Day	Night	Day	Night	Day	Night	Day	Night
30.2	69	67	63	52	72	73	69	58
30.3	70	75	66	59	76	76	69	62
30.4	8	8	8	8	8	8	8	8
31.1	29	29	28	27	30	30	28	28
31.2	38	23	32	22	38	26	34	22
31.3	131	130	125	117	137	134	131	122
32.1	146	147	149	136	154	157	161	148
36.1	42	41	42	41	42	41	42	41
37.1	16	14	14	10	16	15	15	11
38.1	0	0	0	0	0	0	0	0
38.3	0	0	0	0	0	0	0	0
TOTAL	**2265**	**2198**	**1881**	**1663**	**2373**	**2297**	**1982**	**1726**
Gore Hill Freeway Connection								
33.1	141	118	141	110	143	121	145	114
33.2	8	1	8	1	8	1	8	1
59.1	50	50	51	48	51	50	51	48
33.4	27	27	27	27	28	27	27	27
34.1	1	1	1	1	1	1	2	1
35.1	19	20	20	19	20	20	21	20
36.1	20	20	21	20	21	21	21	21
TOTAL	**266**	**237**	**269**	**226**	**272**	**241**	**275**	**232**
Connections to and from Burnt Bridge Creek Deviation								
45.1	0	0	0	0	0	0	0	0
46.1	37	37	25	25	38	38	26	26
46.2	15	14	14	12	15	14	15	12
47.1	47	46	45	42	48	48	46	43
48.1	81	74	82	73	85	79	84	74
49.1	59	49	60	50	66	52	62	50
50.1	133	95	156	144	141	103	166	152
51.1	132	133	142	147	139	137	153	155
52.1	48	49	49	52	49	50	50	55
TOTAL	**552**	**497**	**573**	**545**	**581**	**521**	**602**	**567**
Connections to and from the Wakehurst Parkway								
53.1	35	26	35	33	36	29	36	35
53.2	5	5	5	5	5	5	5	5
53.3	8	8	8	8	9	8	8	8
53.4	1	1	1	1	1	1	1	1

Noise catchment area[1]	2027 'Do Minimum' (No Build)[2]		2027 'Do Something - Cumulative' (Build)[2]		2037 'Do Minimum' (No Build)[2]		2037 'Do Something - Cumulative' (Build)[2]	
	Day	Night	Day	Night	Day	Night	Day	Night
54.1	38	14	42	36	42	17	44	41
55.1	9	7	32	25	14	8	33	28
55.4	0	0	0	0	0	0	0	0
56.1	43	41	43	42	44	41	44	44
57.1	19	7	19	9	19	9	20	9
58.1	0	0	0	0	0	0	0	0
58.2	2	1	2	1	2	1	2	1
TOTAL	**160**	**110**	**187**	**160**	**172**	**119**	**193**	**172**

Notes:
1. Refer to Annexure B for location of noise catchment areas
2. Refer to Table 4-13 for a description of the 'Do Minimum' and 'Do Something - Cumulative' operational road traffic noise scenarios
3. The eligibility requirements for a receiver to qualify for additional noise mitigation is based on the processes and criteria discussed in Section 4.7
4. An individual receiver building is considered as a single receiver for the purposes of this assessment; ie one multi-dwelling residential building = one receiver building.

The number of receivers predicted to experience a decrease in traffic noise; experience a minor increase in traffic noise of no more than 2 dB(A); or experience an increase in traffic noise by more than 2 dB(A) due to the project, are presented in Table 7-5 for the Warringah Freeway, Gore Hill Freeway Connection, the connections to and from Burnt Bridge Creek Deviation and the connections to and from the Wakehurst Parkway. The results are based on no additional mitigation measures being implemented.

Table 7-5 – Predicted changes in noise levels (2037 'Do Something - Cumulative' – 'Do Minimum')

Study area	Number of receiver buildings					
	<0 dB(A)		0 dB(A) – 2 dB(A)		>2 dB(A)	
	Day	Night	Day	Night	Day	Night
Warringah Freeway	5140	5923	1588	808	36	33
Gore Hill Freeway Connection	79	1002	1056	142	12	3
Connections to and from Burnt Bridge Creek Deviation	813	901	1500	1301	39	150
Connections to and from the Wakehurst Parkway	36	22	868	790	331	423

Notes:
1. Based on no mitigation measures implemented, except existing noise barriers
2. Includes other sensitive receivers (OSRs) that are non-residential, where applicable
3. An individual receiver building is considered as a single receiver for the purposes of this assessment; ie one multi-dwelling residential building = one receiver building

From the results presented in Table 7-4 and Table 7-5 above, the following outcomes are identified:

- When considering cumulative traffic from the project and other major road projects, the number of receiver buildings exceeding the NCG noise criteria when compared to the 'Do Minimum' scenario during the day and night periods is predicted to typically decrease at the Warringah Freeway and the Gore Hill Freeway Connection

- The decrease in the number of receiver buildings would be due to the reduction in forecast cumulative traffic volumes as a result of the project and other major road projects, as traffic along existing surface roads move to the proposed tunnels
- At the connections to and from the Burnt Bridge Creek Deviation and connections to and from the Wakehurst Parkway, when considering cumulative traffic from the project and other major road projects, the overall number of receiver buildings exceeding the NCG noise criteria when compared to the 'Do Minimum' scenario during the day and night periods is predicted to increase. This is due to the widening of the Burnt Bridge Creek Deviation and the Wakehurst Parkway and the predicted increase in traffic volumes along Wakehurst Parkway due to the project and other major road projects
- On average, the project is predicted to result in a reduction in traffic noise to about 61 per cent of receivers at the Warringah Freeway, Gore Hill Freeway Connection, the connections to and from Burnt Bridge Creek Deviation and the connections to and from the Wakehurst Parkway noise catchment areas
- An average of about 35 per cent of receivers within the study areas are predicted to experience traffic noise level increases of less than 2 dB(A), which is described by the RNP to be a minor impact and considered to be barely perceptible
- An average of about four per cent of receivers within the study areas are predicted to experience increases in traffic noise of more than 2 dB(A) due to cumulative traffic from the project and other major road projects
- Traffic noise levels on the Warringah Freeway are predicted to reduce at a significant number of receiver buildings (average of around 82 per cent), mainly due to traffic moving to tunnels.

For the majority of receiver buildings within the study areas, there would be either a reduction or relatively minor change in traffic noise levels due to the project. As such, any requirement for additional noise mitigation is likely to be a result of the high existing road traffic noise levels resulting in exceedances of the cumulative limit criterion or traffic noise levels being acute (day $L_{Aeq(15hour)} \geq 65$ dB(A) or night $L_{Aeq(9hour)} \geq 60$ dB(A)).

7.1.2.1 Receivers considered for additional noise mitigation – cumulative scenario

The results for the number of receiver buildings impacted upon for the design year 2037 due to the 'Do Something - Cumulative' scenario are summarised in Table 7-6.

Aerial maps identifying the receivers considered for additional noise mitigation are presented in Annexure N.

The difference between the 2037 'Do Minimum' (without the project) and the 2037 'Do Something - Cumulative' (with the project) assessments has been used to determine the additional noise mitigation measures (eg noise barriers, at-property treatment) required as part of the project.

Table 7-6 – Number of receiver buildings impacted due to project for design year 2037 ('Do Something - Cumulative')

Location	Total Number of residences assessed in area	Day period – number of receiver buildings				Night period – number of receiver buildings				Requiring additional noise mitigation[5]
		Exceed NCG noise criteria level [1]	>2 dB(A) Increase and exceed NCG criteria [2,3]	Exceed cumulative noise limit	Experience acute noise levels (≥ 65 dB(A))[4]	Exceed NCG noise criteria level[1]	>2 dB(A) Increase and exceed NCG criteria[2,3]	Exceed cumulative noise limit	Experience acute noise levels (≥ 60 dB(A))[4]	
Warringah Freeway	6764	1982	25	359	301	1726	25	294	270	407
Gore Hill Freeway Connection	1147	275	9	45	31	232	1	32	30	47
Connections to and from Burnt Bridge Creek Deviation	2352	602	23	34	21	567	113	25	20	135
Connections to and from the Wakehurst Parkway	1235	193	40	30	18	172	75	19	11	90
TOTAL	11,498	3052	97	468	371	2697	214	370	331	679

Notes:
1. NCG noise criteria level based on 'New Road', 'Redeveloped Road', 'Transition Zone' or 'Relative Increase' criteria as per RNP
2. >2 dB(A) increase based on comparison between 'Do Something - Cumulative' scenario and 'Do Minimum' scenario for the design year 2037
3. Exceedance of NCG noise criteria AND increase of more than 2 dB(A) are required to be eligible for noise mitigation
4. Acute noise levels due to contribution from the project only
5. A receiver building qualifies for noise mitigation if it falls under any of the three NMG noise mitigation triggers (ie >2 dB(A) increase, exceed cumulative or acute noise) or a multiple of triggers
6. An individual receiver building is considered as a single receiver for the purposes of this assessment; ie one multi-dwelling residential building = one receiver building

The above table shows that out of the 11,498 receiver buildings assessed, 679 were identified as eligible for consideration for additional noise mitigation in accordance with the NMG requirements as presented in Section 4.7, due to cumulative traffic from the project and other major road projects.

The 679 receivers were identified based on the following:

- The predicted Do Something - Cumulative (Build) traffic noise levels in the design year (2037) would exceed the NCG project road noise criteria and would also increase by more than 2 dB(A) as a result of the project at 97 and 214 receiver buildings during the day and night periods, respectively
- The cumulative limit (5 dB(A) above the NCG project road criterion) would be exceeded at 468 and 370 receiver buildings during the day and night periods, respectively
- There are 371 and 331 receivers predicted to experience acute (day $L_{Aeq(15hour)} \geq 65$ dB(A) OR night $L_{Aeq(9hour)} \geq 60$ dB(A)) noise levels due to the project during the day and night periods, respectively.

It is noted that some receiver buildings eligible for consideration for additional noise mitigation might fall into more than one of the NMG noise mitigation triggers and have multiple triggers. The most common multiple trigger is when an eligible receiver building exceeds the cumulative noise limit and is also exposed to acute noise levels.

Figures showing the location of the receivers identified as eligible for additional noise mitigation are presented in Annexure N. However, for the connections to and from the Wakehurst Parkway and Burnt Bridge Creek Deviation areas it is noted that the receivers along Judith Street, Myrtle Street and Woodbine Street identified for additional noise mitigation are not presented in the figures as the traffic noise impacts to these receivers would be confirmed during further design development. This would include consultation with Northern Beaches Council on appropriate targeted traffic calming measures to reduce predicted increased traffic volumes on local streets.

7.1.3 Pacific Highway and Dickson Avenue intersection

The Pacific Highway and Dickson Avenue Intersection in Artarmon is to be upgraded and signalised to allow for traffic to turn right from Dickson Avenue onto the northbound carriageway of the Pacific Highway. The current intersection has a concrete median separating the northbound and southbound carriageways of the Pacific Highway, which would be removed to allow for the proposed traffic movements from Dickson Avenue.

The intersection upgrade would involve the introduction of traffic signals and road widening on the south western side of Dickson Avenue to accommodate an additional lane for the proposed traffic movements out of Dickson Avenue onto the Pacific Highway. It is noted that no road widening would occur on the Pacific Highway and traffic lanes would not move closer to residential receiver buildings located on the western side of the Pacific Highway.

A review of the traffic volume data with and without the upgraded intersection indicates that additional traffic turning right from Dickson Avenue onto the Pacific Highway would not result in an increase in traffic noise of more than 2 dB(A) due to the upgraded intersection, for residential receivers on the western side of the Pacific Highway and north of the intersection. This is in compliance with the requirements of the RNP and NCG and therefore, no traffic noise mitigation measures are required.

Maximum noise levels (L_{Amax}), can be higher near intersections compared to equivalent sections of road with continuous traffic flow. This is due to vehicles accelerating from the intersection. However, this only occurs for vehicles traveling with instantaneous speeds of less than 60 kilometres per hour. At instantaneous speeds of 60 kilometres per hour or greater, the noise level of a passing vehicle would tend to be the same whether the vehicle is travelling at a constant speed or accelerating at that instant in time. This is likely due to tyre-to-road noise dominating over engine noise at higher speeds. Furthermore, the noise level of a vehicle passing at 60 kilometres per hour is greater than the noise of a vehicle accelerating at instantaneous speeds of less than 60 kilometres per hour. This applies to light vehicles and could vary for heavy vehicles depending on gearing[1].

7.2 Operational road traffic noise predictions with mitigation

Section 7.1 documents operational road traffic noise predictions without noise mitigation. The following sections describe the operational road traffic noise mitigation measures that have been assumed for the purposes of the assessment and the receivers recommended for at-property treatment.

7.2.1 Quieter pavement surfaces

The NMG sets out that a quieter pavement surface is the preferred form of noise mitigation for road traffic noise as it reduces source noise levels and provides protection to both external and internal sensitive areas and also has the least visual impact. Quieter pavements may be considered where there are groups of four or more closely spaced receivers (ie facades are separated by less than 20 metres) that exceed the NCG criteria. Quieter pavements, however, are not always appropriate for engineering reasons (durability) based on likely traffic conditions and does not always provide reasonable attenuation based on likely traffic speeds. Quieter pavements are not, therefore, appropriate in all locations and situations.

For the purpose of this assessment, quieter pavements such as open grade asphalt or similar, have been assumed for all sections of the Gore Hill Freeway and Burnt Bridge Creek Deviation affected by the project. A 2 dB(A) noise reduction (compared to dense graded asphalt (DGA)) has been assumed for the quieter pavements. The resultant road traffic noise levels have been used to consider additional mitigation required.

The use of quieter pavements to reduce operational road traffic noise would be further investigated during further detailed design development. The final road pavement surfaces used for the project

[1] Makarewicz, R & Kokowski, P. 'Prediction of noise changes due to traffic speed control', p2074-2081, JASA 122(4), October 2007

would be subject to various requirements aside from acoustic benefits, including structural integrity, skid resistance, water dispersion, maintenance and design life. Well designed pavements that consider these requirements are subject to less rutting and cracking, where these typical defects can deteriorate the operational noise performance of the pavements. Pavements would ultimately be selected by balancing performance, design life, durability, serviceability and noise emissions.

7.2.2 Noise barriers

A combination of noise barriers and at-property noise treatments can provide the most reasonable overall reduction for an affected community when consideration is given to urban design, visual impact and engineering constraints. It is noted that while most types of at-property noise treatment do not provide any external noise reduction benefits; the achievable internal noise reduction may be higher than for most external noise barrier solutions. The process of deriving the most effective combination of noise barrier height and at-property noise treatment is given in the NMG, whereby the process gives preference to a hierarchy of noise control measures that reduce outdoor noise levels as per the RNP.

When optimising the noise barrier height in the noise abatement design, the process described in the NMG identifies three heights. These are the maximum barrier height, initial design barrier height and design barrier height. The optimising process is completed in three steps:

- **Step 1** – identify the maximum barrier height, which is the barrier height that strives to result in external noise criteria being met at all receivers. Transport for NSW policy is that barrier heights above eight metres would not be assessed as part of the noise abatement design.
- **Step 2** - define the initial barrier height, which is a height between zero and maximum barrier height, where the trend in noise benefit is characterised by a rapid reduction in the number of properties that are eligible for consideration of additional noise mitigation.
- **Step 3** – determine the design barrier height, between the initial barrier and maximum design barrier heights. The design barrier height is identified by also taking into consideration the area of noise barrier and noise reduction benefits across the broader community.

The design barrier height forms the acoustic recommendation and is further evaluated in a multi-criteria decision making process to determine the feasible and reasonable combination of noise mitigation measures. As a guide, a noise barrier deduced from this process is considered to be a reasonable noise mitigation option where it is capable of providing a minimum insertion loss of 5 dB(A) at the most affected residential receiver building for noise barrier heights up to five metres or 10 dB(A) for heights above five metres and up to eight metres high. Where existing barriers may be increased in height, the higher barrier should provide a minimum insertion loss increase of 2 dB(A) over the existing barrier height to be considered a reasonable noise mitigation option. It is also important to note that where the predicted total diffraction attenuation exceeds 20 dB(A) for single diffraction, further increase in noise

barrier height is not considered in the aforementioned process as this level of noise reduction is nearly impossible to attain in practice[2, 3, 4].

Generally speaking, the higher the barrier, the greater the level of noise reduction. However, as identified in Transport for NSW *Noise Wall Design Guideline* (Roads and Maritime Services, 2016d), noise barriers that are excessively high can bring about the potential for visual intrusion, reduction of sunlight, loss of character and view and social alienation, compromising on urban design and resulting in unacceptable visual impacts (refer to Technical working paper: Urban design, visual and landscape impact for an assessment of visual impacts from proposed noise barriers). In addition, a noise barrier that is reasonable may not always be feasible to build, on account of roadway and stormwater flow obstruction, access requirements, space limitations as well as wind loading and unsuitable ground conditions. As such, the aforementioned non-acoustical design factors are evaluated at each assessed location and the appropriate barrier heights recommended for further consideration during further design development. Taking into account community preferences, the final design barrier height with acceptable visual impact would be confirmed during further design development for construction, conforming to Transport for NSW Design Specification QA R271 *'Design and Construction of Noise Walls'*.

Figure 7-1 to Figure 7-6 below show the noise barriers considered in the NMG analysis for the project. The exception to this is the existing barriers shown as a blue line, which were not subject to NMG analysis due to initial reasonable and feasible considerations.

The NMG analysis results and recommended alternative barrier height for each location is presented in Table 7-7. The location and extent of noise barriers was determined based on the receivers identified for additional noise mitigation (refer to Section 7.1.2.1 and Annexure N) and in accordance with the NMG barrier analysis process and the requirements of Transport for NSW *Noise Wall Design Guideline*. A reasonable and feasible assessment of each proposed barrier was carried out taking into account:

- Urban design, overshadowing and visual impacts (refer to Technical working paper: Urban design, visual and landscape impact (Appendix V of the environmental impact assessment) for an assessment of impacts from noise barriers)
- Impacts to private land
- Future uses and development of land where barrier is proposed
- Constructability and engineering constraints.

The NMG barrier analysis results for each proposed noise barrier are presented Annexure Q.

It is noted that the indicative barrier heights in Table 7-7 are based on the height above the local ground where the proposed barrier is to be located. Furthermore, receiver counts presented in Table 7-7

[2] Table 4.1, Section 4 of RTA 'Environmental Noise Management Manual' (ENMM – Roads and Traffic Authority, 2001).

[3] Attenborough, Keith & M. Li, K & Horoshenkov, Kirill. (2007). "Predicting Outdoor Sound".

[4] ISO/TR 17534-3:2015 'Acoustic – Software for the calculation of sound outdoors – Part 3: Recommendations for quality assured implementation of ISO 9613-2 in software according to ISO 17534-1'.

refer to receiver points, where a receiver point is representative of each habitable floor level of a residence. For example, a double storey residence would be represented by two receiver points.

Figure 7-1 – Noise barriers considered in the NMG analysis at the Warringah Freeway and surrounds (south)



Figure 7-2 – Noise barriers considered in the NMG analysis at the Warringah Freeway and surrounds (centre)



Figure 7-3 – Noise barriers considered in the NMG analysis at the Warringah Freeway and surrounds (north)

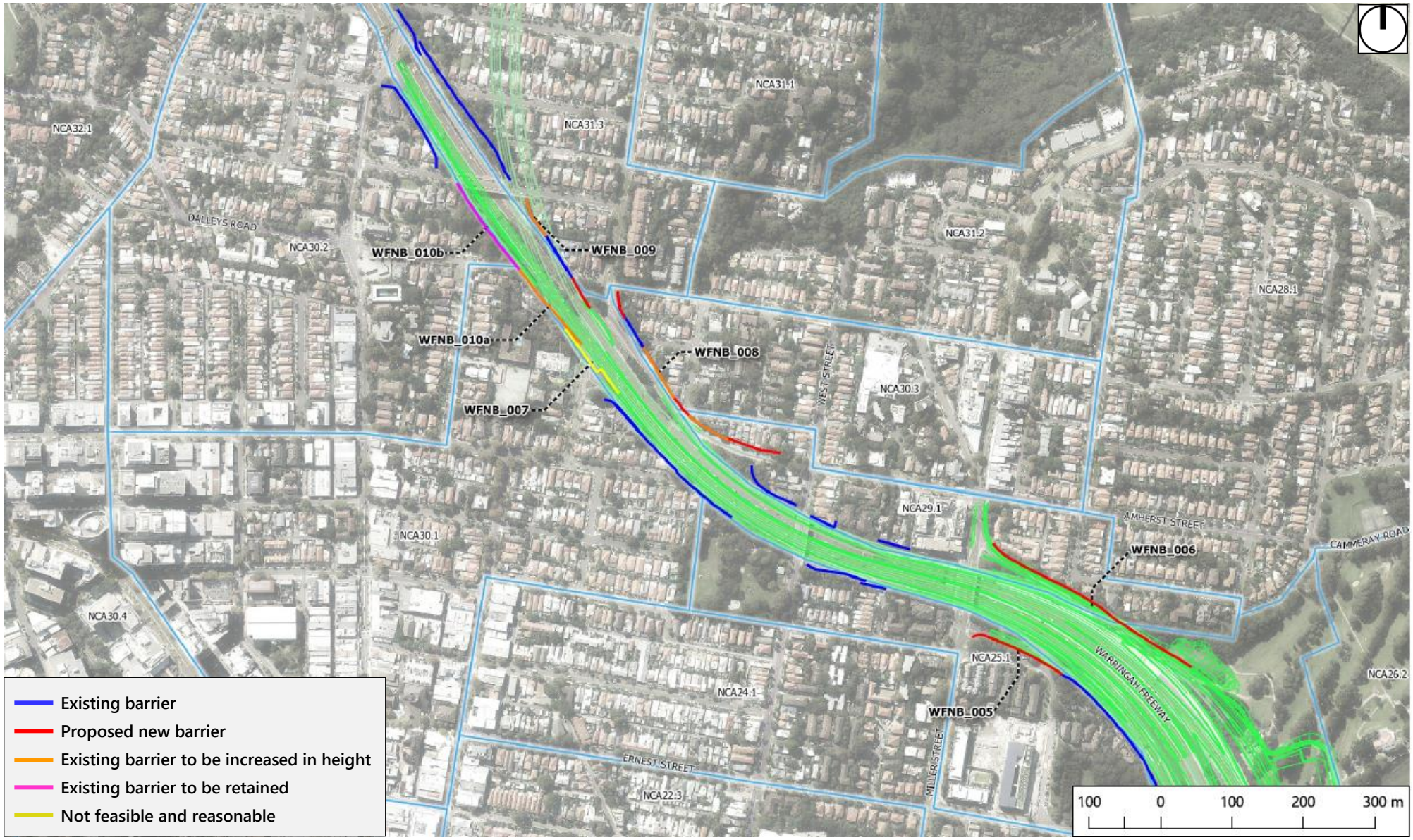


Figure 7-4 – Noise barriers considered in the NMG analysis at the Gore Hill Freeway Connection



Figure 7-5 – Noise barriers considered in the NMG analysis at the connections to and from Burnt Bridge Creek Deviation

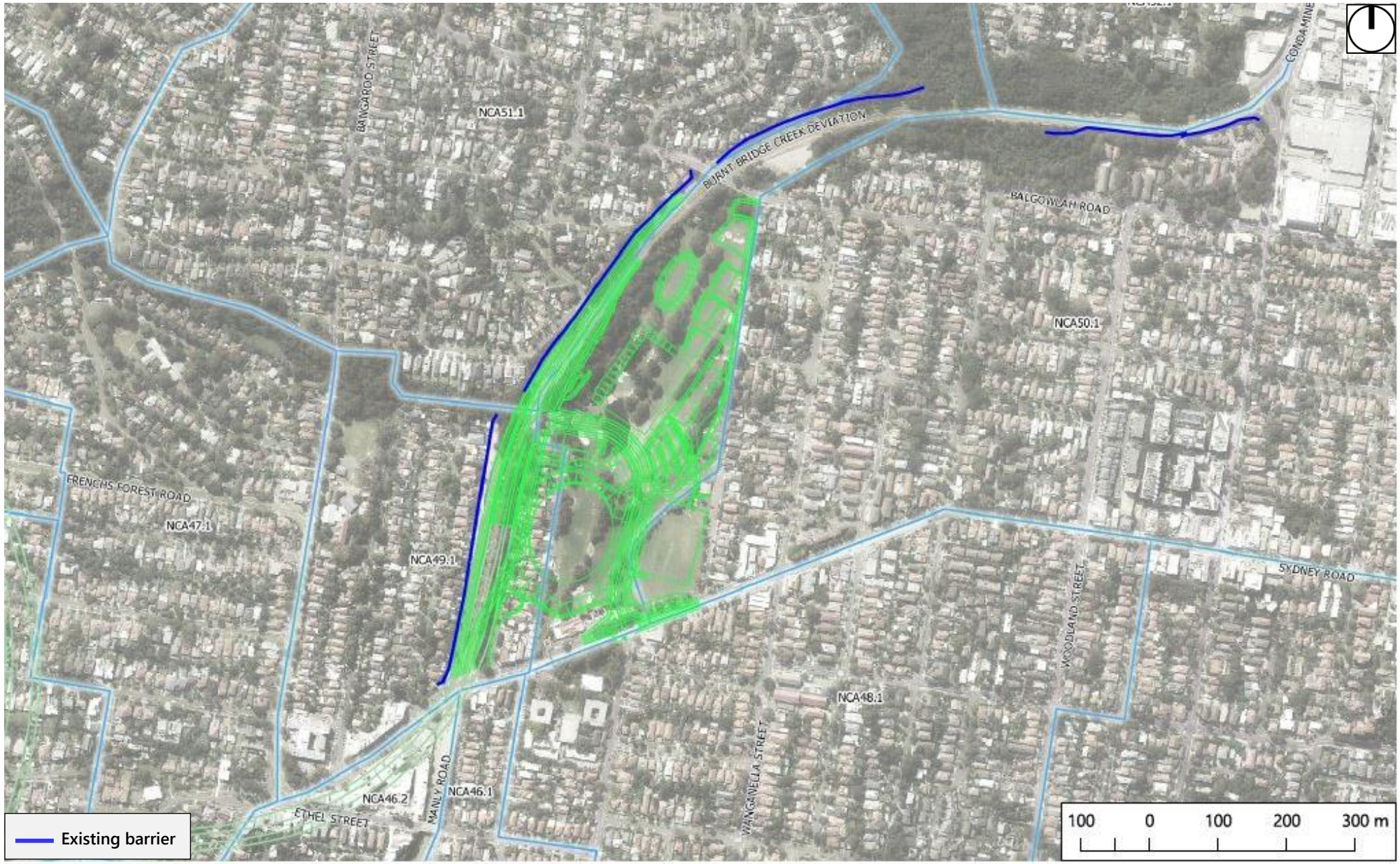


Figure 7-6 – Noise barriers considered in the NMG analysis at the connections to and from the Wakehurst Parkway

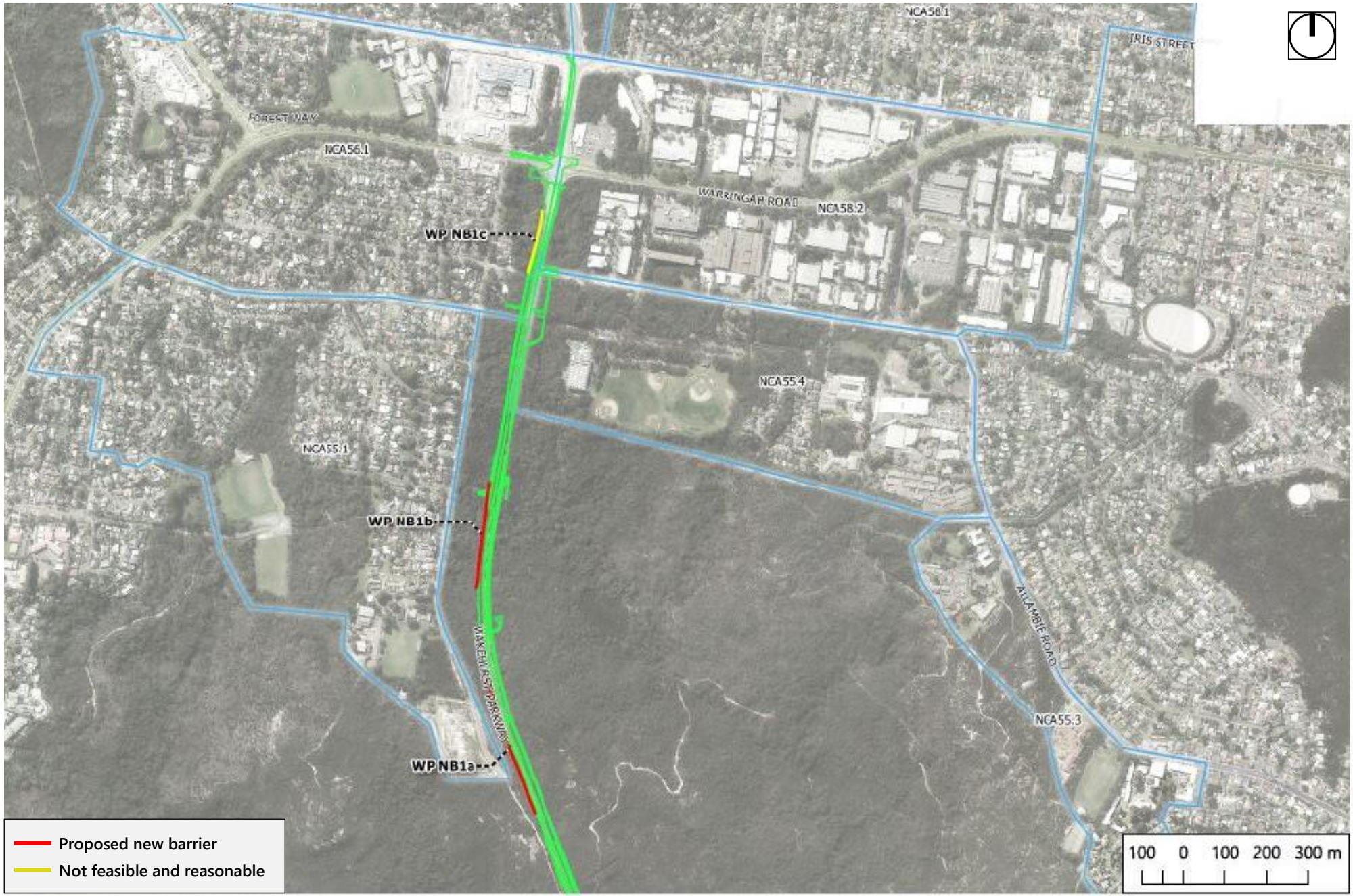


Table 7-7 – Analysis summary of indicative noise barriers

Barrier ID (see Figure 7-1 to Figure 7-6)	NMG noise barrier analysis						Proposed alternative barrier height (metres)[2,4]	Comments[3]
	Barrier considered	Approx. length (metres)	Design height (metres)[1,4]	Total number of benefitting receivers	Triggered receivers with no proposed barrier	Remaining triggered receivers with proposed barrier		
Warringah Freeway Upgrade								
WFNB_001	New	67	7.5	15	19	16	4	Acoustic design barrier height of 7.5 metres would provide more than 10 dB(A) insertion loss as required for barriers over 5 metres However, due to engineering constraints of the existing retaining wall, constructing a 7.5 metre high barrier is not a feasible option The alternative barrier height of 4 metres would provide more than 5 dB(A) insertion loss and would meet the noise performance requirements for barriers up to 5 metres in height. Therefore, the alternative barrier height of 4 metres has been adopted taking into consideration the engineering constraints. The feasibility of a 4 metres high barrier on the existing retaining wall, overshadowing and noise mitigation options at this location would be further investigated during further design development. Note: Barrier WFNB_001 would be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.
WFNB_002	New	92	8	41	26	8	5	Acoustic design barrier height of 8 metres would provide more than 10 dB(A) insertion loss as required for barriers over 5 metres. The alternative barrier height of 5 metres would provide more than 5 dB(A) insertion loss and would meet the noise performance requirements for barriers up to 5 metres in height. The insertion loss of the alternative barrier height of 5 metres would not provide substantially less than the insertion loss of the design barrier height of 8 metres (ie. less than 3 dB(A)). Therefore, the alternative barrier height of 5 metres has been adopted and would provide a reasonable balance between addressing noise impacts and visual amenity impacts for adjacent receivers. Noise mitigation options at this location would be further investigated during further design development. Note: Barrier WFNB_002 would be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

Barrier ID (see Figure 7-1 to Figure 7-6)	NMG noise barrier analysis						Proposed alternative barrier height (metres)[2,4]	Comments[3]
	Barrier considered	Approx. length (metres)	Design height (metres)[1,4]	Total number of benefitting receivers	Triggered receivers with no proposed barrier	Remaining triggered receivers with proposed barrier		
WFNB_003	New	140	6.5	23	6	5	5	Acoustic design barrier height of 6.5 metres would not achieve more than 10 dB(A) insertion loss as required for barriers over 5 metres. The alternative barrier height of 5 metres would provide more than 5 dB(A) insertion loss and would meet the noise performance requirements for barriers up to 5 metres in height. The insertion loss of the alternative barrier height of 5 metres would not provide substantially less than the insertion loss of the design barrier height of 6.5 metres (ie. less than 3 dB(A)). Therefore, the alternative barrier height of 5 metres has been adopted and would provide a reasonable balance between addressing noise impacts and visual amenity impacts for adjacent receivers. Final noise mitigation options at this location would be further investigated during further design development. Note: Barrier WFNB_003 would be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.
WFNB_004	Existing Height: 3.6 metres	115	8	15	10	5	Retain existing barrier	Acoustic design barrier height of 8 metres would provide more than 10 dB(A) insertion loss as required for barriers over 5 metres. The existing noise barrier is on top of a steep sandstone cutting and directly adjacent to receiver buildings. The proposed road widening at this location means that construction of a new noise wall at the design barrier height of 8 metres on the landform that would be left after widening, is not feasible for engineering and constructability reasons. Also, a new noise wall would not be able to be constructed until after the existing noise wall has been removed exposing the receiver buildings behind the wall to unattenuated road traffic noise. Although the existing barrier height would not provide as much insertion loss as the design barrier height, the insertion loss provided is greater than 10 dB(A). The existing barrier height is therefore considered to be a good balance between noise and visual amenity impacts. Therefore, the existing barrier is to be retained and would not be increased in height. Noise mitigation options at this location would be further investigated during further design development.

Barrier ID (see Figure 7-1 to Figure 7-6)	NMG noise barrier analysis						Proposed alternative barrier height (metres)[2,4]	Comments[3]
	Barrier considered	Approx. length (metres)	Design height (metres)[1,4]	Total number of benefitting receivers	Triggered receivers with no proposed barrier	Remaining triggered receivers with proposed barrier		
WFNB_005	New	138	6	6	25	24	5	Acoustic design barrier height of 6 metres would not achieve more than 10 dB(A) insertion loss as required for barriers over 5 metres and is not considered to be reasonable. The alternative barrier height of 5 metres would provide up to 5 dB(A) insertion loss and would meet the noise performance requirements for barriers up to 5 metres in height. The insertion loss of the alternative barrier height of 5 metres would not provide substantially less than the insertion loss of the design barrier height of 6 metres (ie. less than 3 dB(A)). Therefore, the alternative barrier height of 5 metres has been adopted and would provide a reasonable balance between addressing noise impacts and visual amenity impacts for adjacent receivers. Noise mitigation options at this location would be further investigated during further design development. Note: Barrier WFNB_005 would be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.
WFNB_006	New	326	7.5	103	8	0	4.5	Acoustic design barrier based on maximum barrier height of 7.5 metres where sufficient benefits are achieved to remove the need for at-property treatment. The barrier would provide more than 10 dB(A) insertion loss as required for barriers over 5 metres. The alternative barrier height of 4.5 metres, which is also the initial design barrier height, would provide more than 5 dB(A) insertion loss and would meet the noise performance requirements for barriers up to 5 metres in height. Although the alternative barrier height would not provide as much insertion loss as the design barrier height, the insertion loss provided is a greater than 10 dB(A). The alternative barrier height of 5 metres is therefore considered to be a good balance between noise and visual amenity impacts. Noise mitigation options at this location would be further investigated during further design development, taking into consideration noise barrier constraints such as constructability and impacts to properties would be further investigated. Note: Barrier WFNB_006 would be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

Barrier ID (see Figure 7-1 to Figure 7-6)	NMG noise barrier analysis						Proposed alternative barrier height (metres)[2,4]	Comments[3]
	Barrier considered	Approx. length (metres)	Design height (metres)[1,4]	Total number of benefitting receivers	Triggered receivers with no proposed barrier	Remaining triggered receivers with proposed barrier		
WFNB_007	New	-	-	15	30	30	Noise barrier is not recommended	A barrier in this location would not provide acoustic benefits to impacted receivers as the number of receivers identified as eligible for at-property treatment would not reduce by two thirds at any barrier height (ie no initial design barrier height). Therefore, a barrier in this location is not considered reasonable. Furthermore, a feasibility assessment has concluded that attaching a noise barrier to the existing bridge over Brook Street is not structurally feasible. Therefore, a barrier in this location is not considered structurally feasible due to the insufficient structural capacity to accommodate a noise barrier to be attached to the side of the existing bridge.
WFNB_008	New	295	8	38	31	10	4.5	Acoustic design barrier height of 8 metres would provide more than 10 dB(A) insertion loss as required for barriers over 5 metres. The alternative barrier height of 4.5 metres would provide more than 5 dB(A) insertion loss and would meet the noise performance requirements for barriers up to 5 metres in height. Although the alternative barrier height would not provide as much insertion loss as the design barrier height, the insertion loss provided is a substantially greater than 10 dB(A). The alternative barrier height of 4.5 metres is therefore considered to be a good balance between noise and visual amenity impacts. Constraints affecting the feasibility of the barrier such as the integration with existing structures, removal of vegetation (eg well established urban/native trees) as well as urban design and visual amenity impacts would be further investigated during further design development. It is noted that this noise barrier consists of existing barriers and new barriers to fill in the gaps between the existing barriers. Note: Barrier WFNB_008 would be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

Barrier ID (see Figure 7-1 to Figure 7-6)	NMG noise barrier analysis						Proposed alternative barrier height (metres)[2,4]	Comments[3]
	Barrier considered	Approx. length (metres)	Design height (metres)[1,4]	Total number of benefitting receivers	Triggered receivers with no proposed barrier	Remaining triggered receivers with proposed barrier		
WFNB_009	Existing Height: 3.6 metres Existing private barrier Height: 4.2 metres to 6.6 metres	104	8	9	26	25	Consistent with existing private barrier height	Acoustic design barrier height of 8 metres would provide more than 10 dB(A) insertion loss as required for barriers over 5 metres. Furthermore, increasing the existing barrier height to the design barrier height of 8 metres would provide more than 2 dB(A) increase in insertion loss over the existing barrier. Therefore, although the acoustic design barrier height of 8 metres would achieve the insertion loss requirements, the height of the barrier should be consistent with the lower existing private noise barrier due to urban design, visual amenity impacts such as overshadowing, removal of vegetation and impacts to properties. Final barrier height based on assessment of all potential constraints would be further investigated during further design development. Note: Barrier WFNB_009 would be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.
WFNB_010a	Existing timber fence Height: approx. 1.8 metres	137	7.5	17	15	13	4.5	Acoustic design barrier height of 7.5 metres would provide more than 10 dB(A) insertion loss as required for barriers over 5 metres. The alternative barrier height of 4.5 metres would provide more than 5 dB(A) insertion loss and would meet the noise performance requirements for barriers up to 5 metres in height. Furthermore, increasing the existing 1.8 metre high timber fence height to the alternative barrier height of 4.5 metres would provide more than 2 dB(A) increase in insertion loss over the existing fence and is considered to be reasonable. Therefore, the alternative barrier height of 4.5 metres has been adopted and would provide a reasonable balance between addressing noise impacts and visual amenity impacts for adjacent receivers. Noise mitigation options at this location would be further investigated in further design development including the feasibility of construction access to build the barrier. Note: Barrier WFNB_010a would be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.
WFNB_010b	Existing Height: 3 to 3.6 metres	-	-	15	6	6	Retain existing barrier	Increasing the existing barrier in this location would not provide acoustic benefits to impacted receivers as the number of receivers identified as eligible for at-property treatment would not reduce by two thirds at any barrier height (ie no initial design barrier height). Therefore, the existing barrier is to be retained.

Barrier ID (see Figure 7-1 to Figure 7-6)	NMG noise barrier analysis						Proposed alternative barrier height (metres)[2,4]	Comments[3]
	Barrier considered	Approx. length (metres)	Design height (metres)[1,4]	Total number of benefitting receivers	Triggered receivers with no proposed barrier	Remaining triggered receivers with proposed barrier		
Gore Hill Freeway Connection								
GF_EB1	Existing Height: 3.8 metres	323	7.5	28	12	8	Retain existing barrier	Acoustic design barrier height of 7.5 metres would provide more than 10 dB(A) insertion loss as required for barriers over 5 metres. The existing noise barrier is on top of a cutting/retaining wall and directly adjacent to receiver buildings. The construction of a new noise wall at the design barrier height of 7.5 metres on at this location would not be feasible for engineering and constructability reasons. Although the existing barrier height would not provide as much insertion loss as the design barrier height, the insertion loss provided is greater than 10 dB(A). The existing barrier height is therefore considered to be a good balance between noise and visual amenity impacts. Therefore, the existing barrier is to be retained and would not be increased in height. Final noise mitigation options at this location would be further investigated during further design development.
GF_EB2	Existing Height: 3.8 metres	391	7.5	29	22	20	Retain existing barrier	Acoustic design barrier height of 7.5 metres would provide more than 10 dB(A) insertion loss as required for barriers over 5 metres. The existing noise barrier is on top of a cutting/retaining wall and directly adjacent to receiver buildings. The construction of a new noise wall at the design barrier height of 7.5 metres on at this location would not be feasible for engineering and constructability reasons. Although the existing barrier height would not provide as much insertion loss as the design barrier height, the insertion loss provided is almost 10 dB(A). The existing barrier height is therefore considered to be a good balance between noise and visual amenity impacts. Therefore, the existing barrier is to be retained and would not be increased in height. Final noise mitigation options at this location would be further investigated during further design development.

Barrier ID (see Figure 7-1 to Figure 7-6)	NMG noise barrier analysis						Proposed alternative barrier height (metres)[2,4]	Comments[3]
	Barrier considered	Approx. length (metres)	Design height (metres)[1,4]	Total number of benefitting receivers	Triggered receivers with no proposed barrier	Remaining triggered receivers with proposed barrier		
GF_NB1	New	263	7	24	18	16	5	Acoustic design barrier height of 7 metres would not provide the required insertion loss as required for barriers over 5 metres. The alternative barrier height of 5 metres achieves the required insertion loss of 5 dB(A) for barriers 5 metres and under. The insertion loss of the alternative barrier height of 5 metres would not provide substantially less than the insertion loss of the design barrier height of 7 metres (ie. less than 3 dB(A)). Therefore, the alternative barrier height of 5 metres has been adopted and would provide a reasonable balance between addressing noise impacts and visual amenity impacts for adjacent receivers. Final barrier height would be subject to the feasibility of integrating the barrier with retaining walls and cut and cover tunnel structures and would be further investigated during further design development.
Connections to and from Burnt Bridge Creek Deviation								
• Receivers triggered on Wanganella Street and Kitchener Street are due to the predicted increase in traffic volumes along these roads. To mitigate the road traffic noise impacts would require noise barriers to be constructed on either side of these roads. Access to properties would be required through gaps in the noise barriers, resulting in barriers being ineffective. The noise barriers would also result in substantial visual impacts to the streetscape. Therefore, traffic calming measures would be a more reasonable and feasible solution (see Section 7.2.4). • Two receivers on Paris Street have been triggered due to traffic noise from the project on the Burnt Bridge Creek Deviation. However, a noise barrier to mitigate traffic noise from the Burnt Bridge Creek Deviation to these receivers is not reasonable as there are less than four closely grouped triggered receivers. • Triggered receivers on Sydney Road, opposite the intersection with the proposed access road connection are due to traffic along Sydney Road. Therefore, to mitigate traffic noise through a noise barrier would require gaps in the barrier to provide access to properties fronting Sydney Road, resulting in the barrier to be ineffective. Therefore, a noise barrier for these triggered receivers would not be reasonable. • Triggered receivers adjacent to the intersection of Sydney Road and Dudley Street have been predicted to be impacted by traffic noise along the Burnt Bridge Creek Deviation to the north of the receivers. To mitigate traffic noise impacts, a substantially long noise barrier would be required to reduce noise coming from the north from the Burnt Bridge Creek Deviation. Therefore, a barrier to protect these five triggered receivers was not considered to be a reasonable option. • The existing noise barriers on the western side of the Burnt Bridge Creek Deviation that are mitigating traffic noise to the residential receivers along Hope Street (approximately 3.6 metres high) and Serpentine Crescent / Boronia Street (between approximately 2 metres and 3.6 metres high), have been reviewed and the insertion losses provided by the barriers are 15 dB(A) and 16 dB(A), respectively. The insertion losses provided are greater than 10 dB(A) and would meet the noise performance requirements for barriers less than 5 metres high in accordance with the NMG. Furthermore, as the existing barriers are generally located on the top of a cutting, increasing the heights of the noise barriers would not provide substantial additional noise benefits, and would require the protected residences to be exposed to unattenuated road traffic noise while the replacement is occurring. Therefore, the existing barriers are to be retained and it is not considered reasonable and feasible to increase the barriers in height.							

Barrier ID (see Figure 7-1 to Figure 7-6)	NMG noise barrier analysis						Proposed alternative barrier height (metres)[2,4]	Comments[3]
	Barrier considered	Approx. length (metres)	Design height (metres)[1,4]	Total number of benefitting receivers	Triggered receivers with no proposed barrier	Remaining triggered receivers with proposed barrier		
Connections to and from the Wakehurst Parkway								
WP_NB1a	New	339	5.5	38	20	7	5	Acoustic design barrier height of 5.5 metres would not achieve more than 10 dB(A) insertion loss as required for barriers over 5 metres. The alternative barrier height of 5 metres would provide more than 5 dB(A) insertion loss and would meet the noise performance requirements for barriers up to 5 metres in height. The insertion loss of the alternative barrier height of 5 metres would not provide substantially less than the insertion loss of the design barrier height of 5.5 metres (ie. less than 3 dB(A)). Therefore, the alternative barrier height of 5 metres has been adopted and would provide a reasonable balance between addressing noise impacts and visual amenity impacts for adjacent receivers. Noise mitigation options at this location would be further investigated during further design development.
WP_NB1b	New	253	4	62	21	0	4	Acoustic design barrier based on maximum barrier height of 4 metres where sufficient benefits are achieved to remove the need for at-property treatment. The barrier would provide more than 5 dB(A) insertion loss as required for barriers up to 5 metres in height. Therefore, the acoustic design barrier height of 4 metres has been adopted as the need for at-property treatment would not be required for the residences protected by this barrier. Noise mitigation options at this location would be further investigated during further design development.
WP_NB1c	New	-	-	0	5	5	Noise barrier is not recommended	A barrier in this location would not provide acoustic benefits to impacted receivers as the number of receivers identified for at-property treatment would not reduce by two thirds at any barrier height (ie no initial design barrier height). Therefore, a barrier in this location is not reasonable and feasible and is not recommended.

Notes:
1. Calculated noise barrier height following the process described in Section 8 of the NMG without considering urban design, visual impacts and/or engineering constraints
2. Alternative noise barrier height determined based on urban design, visual impacts and/or engineering constraints
3. Refer to *Technical working paper: Urban design, visual and landscape impact* for an assessment of visual impacts from noise barriers
4. Height of barrier based on the height above the local ground where the proposed barrier is to be located
5. Receiver counts based on receiver points, where a receiver point is representative of each habitable floor level of a residence. For example, a double storey residence would be represented by two receiver points.

7.2.3 Receiver buildings potentially eligible for consideration of additional noise mitigation

Following the NMG noise barrier analysis presented in Table 7-7 any residual receivers triggered for additional noise mitigation and still exceeding the relevant traffic noise criteria would be mitigated through at-property treatment. A summary of the number of receiver floors and buildings identified as being eligible for consideration of at-property treatment is presented in Table 7-8. Details of each receiver building is presented in Annexure R.

For non-residential noise sensitive receivers such as schools, hospitals, places of worship and childcare centres equivalent external noise goals based on a 10 dB(A) reduction from external noise levels to internal noise levels when windows are left 20 per cent open, have been conservatively adopted to allow external assessments. Therefore, residual non-residential receivers triggered for additional noise mitigation because they still exceed the equivalent external traffic noise criteria, have been identified for at-property treatment based on this conservative assessment. These non-residential receivers would require further investigation during further design development to confirm the extent of noise impact and eligibility for consideration of noise mitigation since the difference in noise from outside to inside can increase to more than 30 dB depending on the building type, location of the room within the building, window type and whether the use of the space requires the window to be fully opened, slightly opened or closed.

It is noted that the number of receiver floors represent individual floor levels of a receiver building. For example, a 10-storey apartment block would have 10 receiver floors and one receiver building. Receiver buildings identified as potentially eligible for at-property treatment are presented on aerial maps in Annexure R.

Receiver buildings potentially eligible for consideration of additional noise mitigation along the Warringah Freeway and surrounds would be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

Table 7-8 – Receiver buildings potentially eligible for consideration of additional noise mitigation

Noise catchment area[1]	Number of receiver floors[2]	Number of receiver buildings[3]
Warringah Freeway and surrounds		
15.4	1	1
16.1	193	17
16.3	43	5
17.1	22	12
17.2	37	10
17.3	86	37
17.4	67	30
18.1	2	1
19.1	55	16
20.1	37	10
21.1	26	11

Noise catchment area[1]	Number of receiver floors[2]	Number of receiver buildings[3]
21.2	49	13
22.1	41	23
22.3	14	5
23.1	64	43
23.2	48	16
24.1	13	5
25.1	43	27
28.1	2	1
29.1	33	20
30.1	35	24
30.2	12	11
30.3	11	11
31.2	3	2
31.3	21	18
Total – Warringah Freeway and surrounds	**958**	**369**
Gore Hill Freeway Connection		
33.1	79	42
33.2	13	3
Total – Gore Hill Freeway Connection	**92**	**45**
Connections to and from Burnt Bridge Creek Deviation		
46.1	4	2
48.1	23	10
49.1	16	13
50.1	63	47
51.1	72	62
Total – Connections to and from Burnt Bridge Creek	**178**	**134**
Connections to and from the Wakehurst Parkway		
53.1	15	11
53.4	1	1
54.1	36	30
55.1	14	11
56.1	14	12
57.1	15	2
58.2	6	1
Total – Connections to and from the Wakehurst Parkway	**101**	**68**
TOTAL	**1329**	**616**

Notes:
1. Refer to Annexure B for location of noise catchment areas
2. Receiver floors represent the individual floor levels of a multi-level receiver building
3. A receiver building represents the individual building outlines as shown in Annexure R

The number of receivers considered for at-property treatment would be confirmed during the design development stage. During further design development, site inspections of these receivers would be carried out to confirm:

- Internal layout and location of habitable areas
- Construction type of the building structure
- Locations and sizes of windows and doors
- For multi-level apartment buildings, the number of residential dwellings per floor level and the layout of the dwellings.

Given that the predicted traffic noise levels are external levels, the above information would assist in determining a conversion from external to internal levels, which would help determine the appropriate at-property treatment.

7.2.4 Traffic management at local roads

Although not explicitly nominated in the NMG, traffic management measures to reduce traffic movements through local roads can be considered to reduce road traffic noise impact in residential areas.

During further design development appropriate traffic calming measures along local roads would be considered in consultation with the relevant council where operational traffic volumes are expected to increase leading to a large number of receivers being triggered for additional noise mitigation measures as a result of predicted traffic noise levels increasing by more than 2 dB(A) due to the project.

7.3 Maximum road traffic noise levels

The maximum noise level results and assessment are presented in Annexure S and a summary is presented in Table 7-9. The results are based on the noise monitoring carried out at the locations listed in Table 2-3, where road traffic noise dominated the noise environment.

Table 7-9 – Summary of measured maximum noise level events

Monitoring location (see Annexure B)	Monitoring period	Total L_{Amax} events during monitoring period	Measured maximum noise level (L_{Amax}), dB(A)	
			Range	Average
L2 - 6 McDougall Street, Kirribilli	25/08/2017 - 4/09/2017	563	71-74	72
L4 - 91 Ridge Street, North Sydney	21/06/2017 - 1/07/2017	65	68-73	70
L3 - 1/191-195 Walker Street, North Sydney	21/06/2017 - 30/06/2017	24	83-91	86
L6 - 306 Miller Street, North Sydney	20/06/2017 - 2/07/2017	837	74-78	76
L7 - 1/1 Bardsley Gardens, Crows Nest	21/06/2017 - 1/07/2017	608	78-85	80
L8 - 288 Falcon Street, Neutral Bay	25/08/2017 - 4/09/2017	293	83-86	84

Monitoring location (see Annexure B)	Monitoring period	Total L_{Amax} events during monitoring period	Measured maximum noise level (L_{Amax}), dB(A)	
			Range	Average
L9 - 5 Military Road, Neutral Bay	25/08/2017 - 4/09/2017	631	84-86	85
L10 - 317 Ernest Street, Cammeray	25/08/2017 - 4/09/2017	840	74-77	75
L11 - 225 Ernest Street, Cammeray	25/08/2017 - 4/09/2017	756	73-76	75
L12 - 77 Rosalind Street, Cammeray	8/09/2017 - 19/09/2017	169	70-77	74
L13 - 53 Bellevue Street, Cammeray	8/09/2017 - 19/09/2017	25	73-82	79
L16 - 18/22-24 Donnelly Road, Crows Nest	8/09/2017 - 19/09/2017	152	70-74	72
L17 - 79 Brook Street, Naremburn	20/06/2017 - 2/07/2017	1120	77-81	79
L18 - 20/2 Parkes Road, Artarmon	7/09/2017 - 19/09/2017	208	72-84	79
L19 - 3/2 Cleland Road, Artarmon	8/09/2017 - 19/09/2017	134	70-75	72
L20 - 1 Chelmsford Avenue, Naremburn	8/09/2017 - 19/09/2017	153	71-75	72
L34 - 1/6 Whittle Avenue, Balgowlah	2/06/2017 - 16/06/2017	346	74-82	77
L35 - 469 Sydney Road, Balgowlah	13/06/2017 - 26/06/2017	1034	79-84	82
L36 - 14 Pickworth Avenue, Balgowlah	13/06/2017 - 26/06/2017	102	67-73	69
L37 - 22 Hope Street, Seaforth	29/05/2017 - 12/06/2017	225	67-73	69
L38 - 49 Hope Street, Seaforth	29/05/2017 - 12/06/2017	398	66-74	69
L39 - 2 Pitt Street, Balgowlah	13/06/2017 - 26/07/2017	117	66-72	69
L40 - 3A Jacaranda Place, Manly Vale	14/06/2017 - 26/06/2017	147	67-72	70
L41 - 81 Wakehurst Parkway, Seaforth	31/05/2017 - 12/06/2017	1133	71-79	74
L42 - 96 Kirkwood Street, Seaforth	29/05/2017 - 12/06/2017	216	67-73	70
L43 - 118 Bantry Bay Road, Frenchs Forest	29/05/2017 - 13/06/2017	551	68-76	71

The results presented in Table 7-9 show that maximum noise levels range from 66 dB(A) up to 91 dB(A) at the noise monitoring locations. The higher maximum noise levels were typically at locations near or adjacent to Manly Road and the Warringah Freeway on Walker Street, Falcon Street and Military Road.

Maximum noise levels are typically observed from a passing vehicle with the high levels generally due to heavy vehicles passing the monitoring location.

Future changes in the maximum noise levels and the number of events would depend on changes in traffic volumes and compositions forecast for the project. Changes in road alignment or width, leading to traffic moving closer to or further from the assessment location, introduction of new signalised intersections or new bus stops would also result in the maximum noise levels and number of events to increase or decrease, accordingly.

The project is predicted to increase maximum noise levels and events at the following noise catchment areas (see Annexure B for NCA locations):

- NCA 23.1 – receivers to the east of the Warringah Freeway would experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the widening of the Warringah Freeway resulting in the southbound carriageway moving closer to receivers in this NCA
- NCAs 49.1 and 50.1 – receivers to the west and east of the new access road which forms part of the connections to and from Burnt Bridge Creek Deviation would experience an increase in maximum noise levels and the number of events compared to the existing levels due to traffic along the new access road between Sydney Road and the Burnt Bridge Creek Deviation. The new access road would include signalised intersections at Sydney Road and the Burnt Bridge Creek Deviation, which would contribute to the increase in maximum noise levels and the number of events. Furthermore, new bus stops along the new access road would also introduce maximum noise levels and events to these receivers
- NCA 48.1 – receivers to the south of the new access road intersection with Sydney Road would experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the new signalised intersection on Sydney Road impacting receivers in this NCA
- NCA 55.1 – receivers to the west of the new access road intersection with the Burnt Bridge Creek Deviation would experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the new signalised intersection on the Burnt Bridge Creek Deviation impacting receivers in this NCA
- NCAs 54.1 and 55.1 – receivers to the east and west of Wakehurst Parkway would experience an increase in maximum noise levels and the number of events compared to the existing situation, represented by the noise monitoring at Locations L41, L42 and L43. This is due to the widening of Wakehurst Parkway resulting in both the northbound and southbound carriageways moving closer to receivers in these NCAs, which in turn increases maximum noise levels and the number of events at the affected receivers.

For the noise catchment areas where maximum noise levels and the number of events would increase due to the project, the affected receivers would likely be considered for additional noise mitigation measures including noise barriers and/or at-property treatment. With the implementation of noise mitigation measures, overall traffic noise levels would reduce, including L_{Amax} noise levels.

Maximum noise levels are not expected to significantly change as a result of the project at other NCAs because no major road realignments or widening are proposed at these areas.

7.4 Operational fixed facilities assessment

Noise impacts from the proposed fixed facilities associated with the project have been determined through noise modelling of the typical plant and equipment likely to be implemented. The noise prediction model is based on calculation methods presented in the international standard ISO 9613-2, which incorporates moderately adverse meteorological conditions (ie wind and temperature inversions) implemented in accordance with the international standard ISO/TR 17534-3.

The fixed facilities are proposed at the following locations:

- Warringah Freeway Upgrade – Ventilation outlet and motorway facilities at the Warringah Freeway, including substations and fire pump buildings located within Cammeray Golf Course on Ernest Street. It is noted that the ventilation outlet would be located in the centre road reserve of the Warringah Freeway, adjacent to the Ernest Street overpass
- Gore Hill Freeway Connection – Ventilation outlet and motorway facilities at the Gore Hill Freeway, including wastewater treatment plant, substations and fire pump station located on the eastern end of Punch Street in Artarmon
- Connections to and from Burnt Bridge Creek Deviation – Ventilation outlet and motorway facilities at the Burnt Bridge Creek Deviation, including substations located within the Balgowlah Golf Course site
- Connections to and from the Wakehurst Parkway – Ventilation outlet and motorway facilities at the Wakehurst Parkway, including substations and fire pump building located above the tunnel portals and in-tunnel jet fans near the tunnel portal.

The assessment has been done in accordance with the NPfI and results are presented in Table 7-10 and noise contour maps are presented in Annexure T.

Table 7-10 – Predicted $L_{Aeq,15\ min}$ noise levels from fixed facilities, dB(A)

Location	NCA	$L_{Aeq,15\ min}$ Project noise levels[1, 2]		Predicted noise level	Exceedance
		Intrusiveness	Amenity		
Warringah Freeway	NCA 23.1	*49*	***43***	39	-
	NCA 23.2	***42***	*43*	39	-
	NCA 24.1	***42***	*43*	37	-
	NCA 25.1	*48*	***43***	36	-
	NCA 26.1	*46*	***43***	38	-
	NCA 26.2	***42***	*43*	40	-
	NCA 29.1	***52***	***43***	35	-

Location	NCA	$L_{Aeq,15\ min}$ Project noise levels[1, 2]		Predicted noise level	Exceedance
		Intrusiveness	Amenity		
Gore Hill Freeway Connection	NCA 32.1	*45*	***43***	<35	-
	NCA 33.1	*51*	***43***	38	-
	NCA 33.2[3]	*N/A*	***68***	45	-
Connections to and from Burnt Bridge Creek Deviation	NCA 49.1	***36***	*43*	35	-
	NCA 50.1	***40***	*43*	<35	-
	NCA 51.1	***41***	*43*	37	-
Connections to and from the Wakehurst Parkway	NCA 54.1	***35***	*43*	<35	-

Notes:
1. Project noise levels based on night time period
2. **Bold** font represents the project Noise Trigger Level used for assessment
3. NCA comprises industrial premises only.

The results presented in the above table indicate that noise emissions from the proposed fixed facilities would comply with the relevant project noise levels established in accordance with the NPfI.

Final noise predictions and assessment of operational fixed facilities would occur during further design development for the project, when actual types, makes and models of the plant and equipment are decided on and finalised. The assessments would be done in accordance with the requirements of the NPfI and where exceedances are predicted, noise mitigation measures would be designed and installed.

For the motorway control centre located in Artarmon, due to its location and separation distance to residences across the Gore Hill Freeway, shielding from buildings, and relatively low noise emissions from mechanical plant, noise levels from the facility are expected to be barely perceivable at the nearest residential premises amongst the prevailing ambient noise. This would also be applicable for the nearby commercial and industrial premises.

7.5 Balgowlah open space and recreation facilities assessment

The design of the new and improved open space and recreation facilities at Balgowlah are subject to further consultation with stakeholders. A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council will take place to give the community an opportunity to have input on the final layout of the new and improved open space and recreation facilities. This consultation will be separate to the consultation for the environmental impact statement.

For assessment purposes, noise impacts from the open space and recreation facilities at Balgowlah have been determined through noise modelling of typical activities associated with the different areas of the facility. The noise prediction model is based on calculation methods presented in the international standard ISO 9613-2, which incorporates moderately adverse meteorological conditions (ie wind and temperature inversions) implemented in accordance with International Standard ISO/TR 17534-3.

The assessment has been done in accordance with the requirements of the NGLG and results are presented in Table 7-10 with noise contour maps presented in Annexure U. The noise predictions are based on all the playing fields, courts, playgrounds and car parking areas operating concurrently.

Table 7-11 – Predicted $L_{Aeq,15\ min}$ noise levels from open space and recreation facilities, dB(A)

Noise catchment area	Noise criteria	Predicted noise level, $L_{Aeq\ 15\ minute}$[1]	Exceedance
NCA 48.1	*55*	52	-
NCA 50.1	*50*	**56**	6

Notes: 1. Predicted noise level represents the highest noise level predicted for the corresponding NCA
2. **Bold** font represents exceedance of the established noise criterion

The results presented in the above table indicate that noise emissions from the proposed open space and recreation facilities would comply with the noise criterion at sensitive receivers in NCA 48.1. However, some sensitive receivers in NCA 50.1 may potentially experience noise exceedances during periods where all activities at the facility are occurring concurrently.

At this stage of the project, the final layout and design of the open space and recreation facilities are not confirmed. This would occur following further consultation and further design development for the project. The final layout would be subject to the requirements of the NGLG and where exceedances are predicted, noise mitigation measures would be considered. Such noise mitigation measures may include:

- Designing the layout of the recreation facilities so that they are located further from noise sensitive receivers, where possible
- Implementing noise barriers to provide noise shielding to the noise sensitive receivers in NCA 50.1 and to the east of the open space and recreation facilities.

7.6 Operational vibration impacts

The potential for operational ground-borne noise and tactile vibration impacts on nearby sensitive receivers from traffic on project surface roads and tunnels has been reviewed. Vibration emissions from traffic travelling on roads typically occur where there are significant irregularities in the road surface (eg potholes). As the new and upgraded roads on the surface and in the tunnels associated with the project would be designed and constructed to avoid road irregularities, operational ground-borne noise and tactile vibration impacts from operation traffic are not expected.

Therefore, vibration impacts from traffic travelling on the proposed surface roads, through tunnels and portals are considered negligible and are unlikely to result in ground-borne noise or tactile vibration impacts to sensitive receivers directly adjacent to surface roads, tunnels and portals.

Similarly, vibration from operational fixed facilities is not anticipated to exceed objectives given the distance between these facilities and the nearest sensitive receivers. Therefore, operational vibration impacts have not been considered further in the assessment.

8 Mitigation and management measures

Mitigation and management measures to control noise and vibration impacts of sensitive receivers and structures for both the construction and operational stages of the project have been reviewed, identified and developed. These mitigation and management measures which are presented in Table 8-1 should be incorporated into the project.

Table 8-1 – Recommended noise and vibration mitigation and management measures during the construction and operational stages of the project

No.	Impact	Environmental mitigation or management measure	Location
NV1	Construction noise and vibration impacts	A construction noise and vibration management plan will be developed for the project. This plan will: a) Identify relevant criteria and management levels in relation to noise and vibration b) Identify noise and vibration sensitive receivers and features in the vicinity of the project c) Include standard and additional mitigation from the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) and detail how and when these will be applied in the project d) Describe the approach that will be adopted for carrying out location and activity specific constructing noise and vibration impact assessments to assist with designing and selecting of the appropriate mitigation and management measures e) Include protocols that will be adopted to manage works required outside standard construction hours f) Detail the methodology and approach for managing residual construction noise impacts g) Detail the process for managing construction vibration, including heritage structures considering all types of vibration generating works, including blasting h) Outline the procedures and approach for noise and vibration monitoring to be carried out to confirm construction noise and vibration levels in relation to noise and vibration management levels i) Where feasible and reasonable, detail how construction noise impacts from concurrent or consecutive nearby construction works associated with the project will be managed. The construction noise and vibration management plan will be implemented for the duration of construction of the project.	Project wide

No.	Impact	Environmental mitigation or management measure	Location
NV2	Construction noise and vibration impacts	Detailed location and activity specific Construction Noise and Vibration Impact Statements will be prepared and implemented to cover: • Construction support sites • Works outside standard construction hours (OOHW) • Works with the potential to result in highly noise affected residential receivers (ie exposed to noise levels that exceed 75 dB(A)) • Works with the potential to exceed the relevant human response and cosmetic damage criteria for vibration • Subsurface tunnelling activities. The statements will consider the proposed site layouts and noise and vibration generating activities that would take place, assess predicted noise and vibration levels against the relevant management levels, and incorporate feasible and reasonable mitigation and management measures in accordance with the requirements of the *Interim Construction Noise Guideline* (DECC, 2009) and the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a).	Project wide
NV3	Construction noise and vibration impacts during out of hours work	An out of hours works protocol will be developed for the construction of the project. The protocol will include: a) Details of works required outside standard construction hours, including acceptable justifications for works outside of standard construction hours, what types of works are allowed to take place outside of construction hours, and justifications of why the activities are required outside standard construction hours b) Details of the assessment and approval process (internal and external) for works proposed outside standard construction hours c) Noise and vibration mitigation and management measures that are to be considered and implemented where appropriate to manage potential impacts associated with works outside standard construction hours d) The noise and vibration impact assessment processes that will be followed to identify potentially affected receivers, clarify potential impacts and determine appropriate mitigation and management measures The protocol will be prepared in consultation with DPIE and the NSW EPA. The project protocol will be implemented during the duration of the construction of the project.	Project wide
NV4	Construction noise and vibration impacts during out of hours work	For works outside standard construction hours on and adjacent to major roadways, the elevated existing ambient and background noise levels during the following shoulder periods will be investigated and confirmed: • Shoulder period (night-day) – between 5.00am and 7.00am • Shoulder period (evening-night) – between 10.00pm and 12.00am. Where appropriate, these shoulder periods will be utilised where feasible and reasonable to minimise potential amenity impacts associated with project activities outside standard construction hours.	Project wide
NV5	Construction noise and vibration impacts	Construction noise and vibration impacts will be monitored periodically throughout all stages of construction to ensure that: a) Noise and vibration levels are consistent with the predictions detailed in the relevant Construction Noise and Vibration Impact Statements b) Noise and vibration impacts are being appropriately managed c) Mitigation measures are effective.	Project wide

No.	Impact	Environmental mitigation or management measure	Location
NV6	Construction noise and vibration impacts	Where feasible and reasonable, unless compliance with the relevant traffic noise criteria can be achieved, or alternative arrangements have been agreed with affected receivers, construction vehicle movements will not occur on local roads beyond those required for direct access to construction sites.	Project wide
NV7	Construction noise and vibration impacts	Vibration generating activities will be managed through the establishment of minimum working distances to achieve vibration screening levels. Where vibration levels are predicted to exceed the screening levels, a more detailed assessment of the impacted structure and attended vibration monitoring will be carried out to ensure vibration levels remain below appropriate limits for that structure or impacts are managed in line with an approach agreed with the owner of the potentially impacted structure. For heritage items, the more detailed assessment will specifically consider the heritage values of the structure in consultation with a heritage specialist to ensure sensitive heritage fabric is adequately monitored and managed.	Project wide
NV8	Construction ground-borne noise impacts	Feasible and reasonable measures will be implemented to minimise ground-borne noise where exceedances are predicted.	Project wide
NV9	Construction impacts from surface road works	Mitigation measures will be implemented for surface road works, local area and utility works, where construction activities are predicted to exceed noise management levels at receivers. Where feasible and reasonable the approaches that will be used include: a) Carrying out works during the daytime period when near residential receivers b) Selection of plant and equipment to minimise noise and vibration impacts c) Management of plant and equipment to minimise the generation of noise and vibration impacts d) Community consultation, engagement and notification e) Detailed programming and respite protocols f) Where out of hours works are required, programming the noisiest activities to occur during the less sensitive time periods g) Out of hours works protocols h) Limiting timing of noise intensive work i) Use of portable noise barriers around particularly noisy equipment such as concrete saws and rock hammers in cases where it would effectively reduce noise levels at nearby receivers j) Management of construction traffic to minimise movements during the night periods along local roads k) Establishing minimum vibration working distances for vibration intensive works l) Vibration and blasting trials and/or monitoring along with building condition surveys m) Construction support sites that support surface road works will be design to ensure that primary noise sources are located with the maximum distance from the nearby noise sensitive receivers (where feasible and reasonable), with solid structures (shed, containers, barriers, etc) placed between the noise sensitive receiver so as to maximise acoustic shielding and block the line of site between the source and the receiver.	Project wide

No.	Impact	Environmental mitigation or management measure	Location
NV10	Construction impacts from surface road works	Where feasible and reasonable, noise barriers proposed as part of the project to address road traffic noise will be implemented as early as possible to attenuate construction noise.	Project wide
NV11	Increased road traffic noise levels due to noise barrier removal	Where it is necessary to relocate or remove existing noise barriers to facilitate construction of new road infrastructure, the new noise barriers will be installed before removing the existing barriers where feasible and reasonable. Where it is not possible to install the new barriers before removing the existing barriers, the duration between removing the existing and installing the new barriers will be minimised. Temporary noise barriers will be installed to ensure that road traffic noise levels do not increase by more than 2 dB(A) at the affected residential receiver buildings, where feasible and reasonable.	Project wide
NV12	Construction blasting impacts	Any blasting and associated activities will be carried out in a manner that does not generate unacceptable overpressure and vibration impacts or pose a substantial risk impact to structures and sensitive receivers. Prior to any blasting all potentially affected noise and vibration sensitive receivers and structures in the vicinity would be identified. Appropriate tests will be carried out at each proposed blasting location to develop site-specific laws that take into account relevant factors such as underlying geology and separation distance to sensitive receivers and features to determine appropriate charge sizes and blast design to ensure compliance with relevant vibration and overpressure criteria. All blasting will be carried out in accordance with the specific-laws. Monitoring will occur to determine compliance with the relevant criteria, and the site-specific laws will be adjusted as required based on the monitoring results to ensure ongoing compliance. The potentially affected community will be kept informed about proposed blasting activities.	Project wide
NV13	Cumulative construction noise impacts / construction fatigue	Construction noise from concurrent and consecutive major projects in the vicinity of construction work locations associated with the project will be managed to minimise cumulative construction noise impacts. Where feasible and reasonable the approaches that will be used include: a) Considering the potential for cumulative impacts due to other major projects in the locality during development of the detailed construction methodology. The construction methodology should be developed to minimise overall noise impacts and the need for respite for receivers potentially affected by cumulative impacts wherever feasible and reasonable b) Consulting with other major projects the vicinity with the aim of coordinating work between the different projects that will affect the same area to ensure that affected receivers get appropriate respite from high noise impact activities and works outside standard construction hours c) Implementing additional feasible and reasonable source mitigation for concurrent construction activities, where programming is not practical to avoid cumulative noise impacts d) Community consultation to seek feedback on and identify key noise and vibration issues relevant to the local community so that current or future works can be managed to limit cumulative impacts.	Project wide
NV14	Operational road traffic noise impacts	The operational noise performance of the project will be reviewed during further design development and operational noise mitigation (low noise pavement, noise barrier, at-property treatment or a combination of treatments) will be confirmed in accordance with relevant policies and guidelines.	Project wide

No.	Impact	Environmental mitigation or management measure	Location
NV15	Operational road traffic noise impacts	Within 12 months of the commencement of the operation of the project, actual operational noise performance will be compared to predicted operational noise performance (as reviewed during further design development) to analyse the effectiveness of the operational road traffic noise mitigation measures. Additional reasonable and feasible mitigation will be considered where any additional receivers are identified as qualifying for consideration of noise mitigation under the *Noise Mitigation Guideline* (Roads and Maritime Services, 2015b).	Project wide
NV16	Operational road traffic noise	For local roads in Balgowlah and Seaforth where predicted increases in traffic are likely to result in exceedances of the relevant road traffic noise criteria, traffic calming measures with the aim of limiting potential road traffic noise increases to no more than 2 dB(A) will be investigated in consultation with Northern Beaches Council and implemented. As a minimum, traffic calming measures will be investigated for Wanganella Street and Woodbine Street at Balgowlah and Judith Street at Seaforth. The need for at-property treatments will be confirmed during further design development and will consider the potential impact of the proposed traffic calming measures on traffic volumes and speeds.	Project wide
NV17	Operational fixed facility noise impacts	Operational fixed facilities will be designed to meet project specific noise criteria derived in accordance with the *Noise Policy for Industry* (EPA, 2017).	Project wide
NV18	Recreation facility noise impacts	Open space and recreation facilities at Balgowlah will be designed with the aim of meeting intrusive noise criteria derived in accordance with the *Noise Guide for Local Council* (EPA, 2013), where feasible and reasonable. Further noise investigation of the final layout will be carried out to confirm the need for any noise attenuation.	Open space and recreation facilities at Balgowlah

9 References

Asset Standard Authority (Transport for NSW) 2018, *Development Near Rail Tunnels*, Standard T HR CI 12051 ST, Version 2.0, 15 November 2018

Attenborough, Keith & M. Li, K & Horoshenkov, Kirill. 2007, *Predicting Outdoor Sound*

Australian and New Zealand Environment Council 1990, *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration*

British Standard 1993, *Evaluation and measurement for vibration in buildings Part 2: Guide to damage levels from ground-borne vibration*, BS 7385-2:1993

German Standard 2016, *Structural vibration – Effects of vibration on structures*, DIN 4150-3:2016

Colin G. Gordon '*Generic vibration criteria for vibration-sensitive* equipment' 1999, Proceedings. Society of Photo-Optical Instrumentation Engineers (SPIE) 3786, Optomechanical Engineering and Vibration Control, 28 September 1999

ICI Australia 1990, *'Environmental Effects of Blasting' in Handbook of Blasting Tables*, pp 33-35

International Organization for Standardization 1996, *Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation*, ISO 9613-2:1996

International Organization for Standardization 2015, *Acoustics - Software for the calculation of sound outdoors - Part 3: Recommendations for quality assured implementation of ISO 9613-2 in software according to ISO 17534-1*, ISO/TR 17534-3:2015

International Organization for Standardization 2007, *Acoustics - Description, measurement and assessment of environmental noise - Part 2: Determination of environmental noise levels*, ISO 1996-2:2007

J. Peng, N. Kessissoglou and J. Parnell 2017, *'Evaluation of Calculation of Road Traffic Noise in Australia'*, Proceedings of the 46th International Congress and Exposition on Noise Control Engineering, Hong Kong, 27-30 August 2017

NSW Department of Climate Change 2006, *Assessing Vibration: a technical guideline*

NSW Department of Climate Change 2009, *Interim Construction Noise Guideline* (ICNG)

NSW Department of Climate Change and Water 2011, *Road Noise Policy* (RNP)

NSW Environment Protection Authority 1999, *Environmental Criteria for Road Traffic Noise* (ECRTN)

NSW Environment Protection Authority 2013, *Noise Guide for Local Government* (NGLG)

NSW Environment Protection Authority 2017, *Noise Policy for Industry* (NPfI)

Roads and Maritime Services 2011, *Preparing an Operational Noise and Vibration Assessment*

Roads and Maritime Services 2015a, *Noise Criteria Guideline* (NCG)

Roads and Maritime Services 2015b, *Noise Mitigation Guideline* (NMG)

Roads and Maritime Services 2015c, *Northern Beaches Hospital, Connectivity and Network Enhancements, Stage 2 Noise and Vibration Assessment Construction and Operation*

Roads and Maritime Services 2016a, *Construction Noise and Vibration Guideline* (CNVG)

Roads and Maritime Services 2016b, *Model Validation Guideline*

Roads and Maritime Services 2016c, *Noise Criteria Guideline Application Notes*

Roads and Maritime Services 2016d, *Noise Wall Design Guideline*

Roads and Maritime Services 2017a, *At-Receiver Noise Treatment Guideline - Draft*

Roads and Maritime Services 2017b, *M4-M5 Link environmental impact statement – Technical Paper: Noise and Vibration*

Roads and Maritime Services 2017c, *M4-M5 Link, submissions and preferred infrastructure report – Technical Paper: Noise and Vibration*

Roads and Maritime Services 2019, *Western Harbour Tunnel and Warringah Freeway Upgrade Technical working paper: Noise and Vibration*

Roads and Traffic Authority 2001, *Environmental Noise Management Manual* (ENMM)

Standards Australia 1995, *Computer accommodation*, AS 2834:1995

Standards Australia 2004, *Electroacoustics - Sound level meters - Part 1: Specifications*, AS IEC 61672.1:2004

Standards Australia 2006, Explosives - Storage and use - Part 2 Use of explosives, AS 2187.2:2006

Standards Australia 2016, *Acoustics - Recommended design sound levels and reverberation times for building interiors*, AS/NZS 2107:2016

Standards Australia 2016, *Guide to Noise Control on Construction, Demolition and Maintenance Sites*, AS 2436:2010 (R2016)

Transport for NSW 2016, *Sydney Metro City & Southwest environmental impact statement – Technical Paper 2: Noise and Vibration*

Transport for NSW 2017, *Sydney Metro Chatswood to Sydenham – Victoria Cross Station and Artarmon Substation modification submission report*

UK Department of Transport 1988, *Calculation of Road Traffic Noise* (CORTN)

Annexure A Technical terms and concepts

A.1 Glossary of terminology

The following is a brief description of the technical terms used to describe noise to assist in understanding the technical issues presented.

Adverse weather	Weather effects that enhance noise (that is, wind and temperature inversions) that occur at a site for a significant period of time (that is, wind occurring more than 30 per cent of the time in any assessment period in any season and/or temperature inversions occurring more than 30 per cent of the nights in winter).
Ambient noise	The all-encompassing noise associated within a given environment at a given time, usually composed of sound from all sources near and far.
Assessment period	The period in a day over which assessments are made.
Assessment point	A point at which noise measurements are taken or estimated.
A-weighted	See dB(A) below
Background noise	Background noise is the term used to describe the underlying level of noise present in the ambient noise, measured in the absence of the noise under investigation, when extraneous noise is removed. It is described as the average of the minimum noise levels measured on a sound level meter and is measured statistically as the A-weighted noise level exceeded for ninety percent of a sample period. This is represented as the L_{A90} noise level (see below).
CNVMP	Construction noise and vibration management plan
CNVIS	Construction noise and vibration impact statement
CNVG	Construction Noise and Vibration Guideline (Roads and Maritime Services, 2016a)
Decibel (dB)	The units that sound is measured in. The following are examples of the decibel readings of every day sounds: 0dB The faintest sound we can hear 30dB A quiet library or in a quiet location in the country 45dB Typical office space. Ambience in the city at night 60dB CBD mall at lunch time 70dB The sound of a car passing on the street 80dB Loud music played at home 90dB The sound of a truck passing on the street 100dB The sound of a rock band 110dB Operating a chainsaw or jackhammer 120dB Deafening
dB(A)	A-weighted decibels. The A- weighting noise filter simulates the response of the human ear at relatively low levels, where the ear is not as effective in hearing low frequency sounds as it is in hearing high frequency sounds. That is, low frequency sounds of the same dB level are not heard as loud as high frequency sounds. The sound level meter replicates the human response of the ear by using an electronic filter which is called the "A" filter. A sound level measured with this filter switched on is denoted as dB(A). Practically all noise is measured using the A filter.
dB(C)	C-weighted decibels. The C-weighting noise filter simulates the response of the human ear at relatively high levels, where the human ear is nearly equally effective at hearing from mid-low frequency (63Hz) to mid-high frequency (4kHz), but is less effective outside these frequencies.
ECRTN	Environmental Criteria for Road Traffic Noise (EPA, 1999)
Frequency	Frequency is synonymous to pitch. Sounds have a pitch which is peculiar to the nature of the sound generator. For example, the sound of a tiny bell has a high pitch and the sound of a bass drum has a low pitch. Frequency or pitch can be measured on a scale in units of Hertz or Hz.
HNA	Highly noise affected

ICNG	Interim Construction Noise Guideline (DECC, 2009)
Impulsive noise	Having a high peak of short duration or a sequence of such peaks. A sequence of impulses in rapid succession is termed repetitive impulsive noise.
Intermittent noise	The level suddenly drops to that of the background noise several times during the period of observation. The time during which the noise remains at levels different from that of the ambient is one second or more.
km/h	Kilometres per hour
L_{Amax}	The maximum A-weighted sound pressure level measured over a given period.
L_{AMin}	The minimum A-weighted sound pressure level measured over a given period.
L_{A1}	The A-weighted sound pressure level that is exceeded for 1 per cent of the time for which the given sound is measured.
L_{A10}	The A-weighted sound pressure level that is exceeded for 10 per cent of the time for which the given sound is measured.
L_{A90}	The level of noise exceeded for 90 per cent of the time. The bottom 10 per cent of the sample is the L_{A90} noise level expressed in units of dB(A).
L_{Aeq}	The A-weighted "equivalent noise level" is the summation of noise events and integrated over a selected period of time.
MIC	Maximum instantaneous charge
m/s	Metres per second
mm/s	Millimetres per second
NCA	Noise catchment Area. Noise Catchment Areas are logical groupings of noise and vibration sensitive receivers for the project based on areas with a similar acoustic environment.
NCG	Noise Criteria Guideline (RMS, 2015a)
NMG	Noise Mitigation Guideline (RMS, 2015b)
NML	Noise management level
NPfI	Noise Policy for Industry (EPA, 2017)
OOHW or OOH	Out-of-hours works, which is construction works which take place outside of the standard construction hours specified by the NSW Environment Protection Authority (EPA) Interim Construction Noise Policy (ICNG) (2009).
RBL	Rating background level
Reflection	Sound wave changed in direction of propagation due to a solid object obscuring its path.
ROL	Road Occupancy Licence
RMS	Former Roads and Maritime Services, now part of Transport for NSW
RNP	Road Noise Policy (DECCW, 2011)
SEL	Sound Exposure Level (SEL) is the constant sound level which, if maintained for a period of 1 second would have the same acoustic energy as the measured noise event. SEL noise measurements are useful as they can be converted to obtain L_{Aeq} sound levels over any period of time and can be used for predicting noise at various locations.
Sound	A fluctuation of air pressure which is propagated as a wave through air.
Sound absorption	The ability of a material to absorb sound energy through its conversion into thermal energy.
Sound level meter	An instrument consisting of a microphone, amplifier and indicating device, having a declared performance and designed to measure sound pressure levels.
Sound pressure level (SPL or L_p)	The level of noise, usually expressed in decibels, as measured by a standard sound level meter with a microphone. Reference for sound pressure level is conventionally chosen as 20 µPa (20 x 10^{-6} Pa) for airborne sound.

Sound power level (SWL or L_w)	Ten times the logarithm to the base 10 of the ratio of the sound power of the source to the reference sound power. Reference for sound power level is conventionally chosen as 1pW (10^{-12} watts) for airborne sound.
Tonal noise	Containing a prominent frequency and characterised by a definite pitch.
TfNSW	Transport for NSW, the proponent

A.2 Acoustic concepts

A.2.1 Sound and noise

The terms 'sound' and 'noise' are almost interchangeable, except that in common usage 'noise' is often used to refer to unwanted sound. Sound is a vibration that travels as an audible wave of pressure through the air from a source to a receiver location such as the human ear. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (abbreviated as dB) is a unit of measurement used to express the ratio of a quantity to another on a logarithmic scale to make the wide range of sound pressure more manageable.

Sound power is the rate at which a source emits acoustic energy and is unaffected by the environment. It is a property of the source that is emitting acoustic energy.

In contrast, **sound pressure** is the effect, and it is affected by factors associated with the built and natural environment such as distance, direction, obstacles etc. The sound pressure is the acoustic energy or 'noise level' at a distance away from the noise source. The relationship between sound power and sound pressure can be explained by considering the analogy of an electric heater, which radiates heat into a room and temperature is the effect. Like sound pressure, temperature also reduces with distance from the source following the inverse square law.

In this technical working paper, **sound power level** is identified by the symbols **SWL** or **L_w,** while **sound pressure level** is represented by **SPL** or **L_p**, and both have the same scientific unit in dB.

A.2.2 Individual's perception of sound

The loudness of sound depends on its sound pressure level. The A-weighted decibel (dB(A)) is generally used for the purposes of environmental noise impact assessment as it has been adjusted to account for the varying sensitivity of the human ear to different frequencies of sound. 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 dB(A) is a good measure of the loudness of environmental noise to the human ear as it considers this frequency dependant sensitivity.

Different noise sources having the same dB(A) level generally sound equally loud. However, the frequency of a sound is what gives it a distinctive pitch or tone – for example, the rumble of distant thunder is an example of a low frequency sound and a whistle is an example of a high frequency sound. Most sounds we hear in our daily lives have sound pressure levels in the range of 30 to 90 dB(A). The following table provide some points of reference, measured in dB(A), of familiar sounds and those from construction activities.

Table A-1 Perception of sound - familiar sounds and construction noise

Common sounds	Construction noise	Sound pressure level
Leaf blower at operator's ear	Concrete saw or jack hammer 7 metres away	90 dB(A)
Airplane cabin during cruise (Airbus 321)	Excavator (with bucket) 7 metres away	80 dB(A)
General traffic noise kerbside next to Military Road	Towable compressor 7 metres away	75 dB(A)
Normal conversation at 1 metre		60 dB(A)
Outdoor air conditioning unit 1 metre away	Towable compressor 50 metres away	55 dB(A)
General office		50 dB(A)
Inside private office	Ground-borne noise from road header tunnel excavation between depths of 20 metres to 50 metres	40 dB(A)
Inside bedroom		30 dB(A)

In terms of sound perception, a change of 1 dB(A) or 2 dB(A) in the sound pressure level is difficult for most people to detect, while a 3 dB(A) to 5 dB(A) change corresponds to a small but noticeable change in loudness. An increase in sound level of 10 dB(A) is perceived as a doubling of loudness. However, individuals may perceive the same sound differently since many factors can influence an individual's response, including:

- The specific characteristics of the noise (eg frequency, intensity, duration of the noise event)
- Time of day noise events occur
- Individual sensitivities and lifestyle
- Reaction to an unfamiliar sound
- Understanding of whether the noise is avoidable and the notions of fairness.

A.2.3 Environmental noise assessment indicators

Environmental noise is an accumulation of noise pollution that occurs outside and is most commonly attributed to various modes of transport as well as industrial and construction activities. Environmental noise has been shown to have an adverse effect on the quality of life, especially following long-term exposure. The focus of the present technical assessment is on annoyance and sleep disturbance as they constitute most of the burden related to the impact of environmental noise on health outcomes. Noise annoyance is defined by the World Health Organization as a feeling of displeasure, nuisance, disturbance or irritation caused by a specific sound. Sleep disturbance relates to difficulty with sleep initiation, consolidation as well as awakening and reduced quality of sleep.

In New South Wales, contemporary environmental noise assessment criteria for addressing noise annoyance and sleep disturbance are specified by the NSW Environment Protection Authority (EPA). Potential road traffic noise impact is assessed in accordance with the NSW Road Noise Policy. For

motorway and ventilation facilities that are permanently fixed, and associated noise emissions are long-term in nature, noise criteria have been adopted in accordance with the Noise Policy for Industry. For enabling construction activities which are temporary in nature and highly variable, NSW EPA's Interim Construction Noise Guideline provides the underlying assessment principles for the determination of potential construction noise impact. Each policy/guideline is discussed in detail in the body of this report:

- Section 3.5.2 details the NSW Road Noise Policy
- Section 3.5.4 details the Noise Policy for Industry
- Section 3.4.1 details the NSW EPA's Interim Construction Noise Guideline.

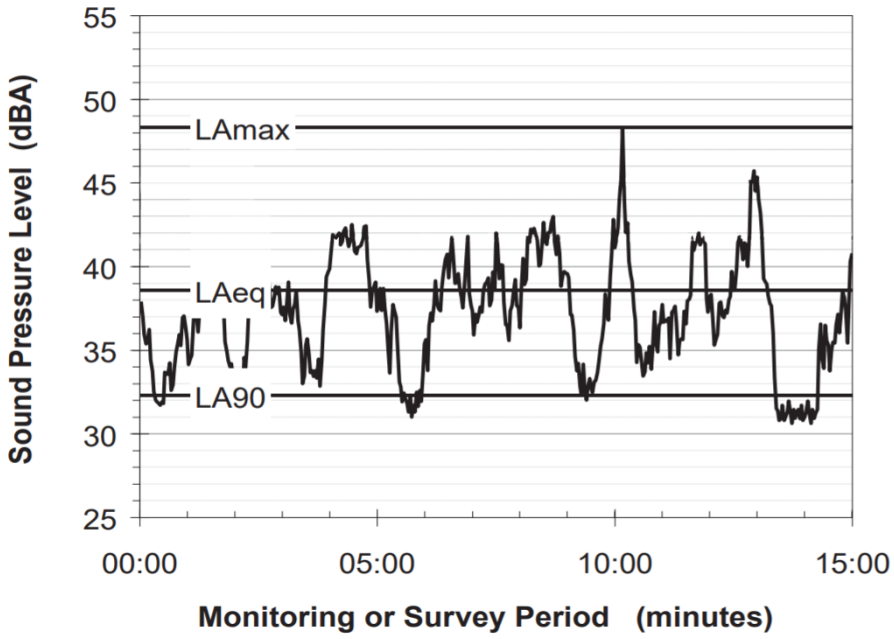
L_{Aeq} - To protect against long-term repeated noise exposure, the indicator for assessing the cumulative noise exposure level over a specific time interval is the equivalent sound pressure level, denoted as L_{Aeq}. The L_{Aeq} indicator accounts for the total energy content from all sources of sound under consideration. The fact that the L_{Aeq} is a cumulative measure means that louder activities have greater influence of the L_{Aeq} level than do quieter ones, and activities that last longer in time have greater L_{Aeq} than do shorter ones. An increase in the number of events also increases the L_{Aeq}. Further, people react to the duration of noise events, judging longer events to be more annoying than shorter ones, assuming equal maximum noise levels.

L_{Amax} - It is important to note that even though L_{Aeq} levels are numerically lower than maximum noise levels (denoted as L_{Amax}). None of the noise is ignored, just as all the rain that falls in the rain gauge in one hour counts toward the total. In the case of noisy but short-lived maximum noise events, which can sometime result in immediate short term awakening reaction, potential impact is assessed using the L_{Amax} indicator in which its emergence above the background noise environment is evaluated.

L_{A90} - The L_{A90} is the level of noise that is present almost constantly, or for 90 percent of the time and is commonly referred to as the background noise. Typical examples of what types of noise may contribute to the background noise levels are continuously flowing traffic or air conditioner noise.

These three noise indicators of L_{Amax}, L_{Aeq} and L_{A90} are presented in Figures A-1 for example noise monitoring survey period showing the sound pressure level of a varying noise environment such as environmental noise.

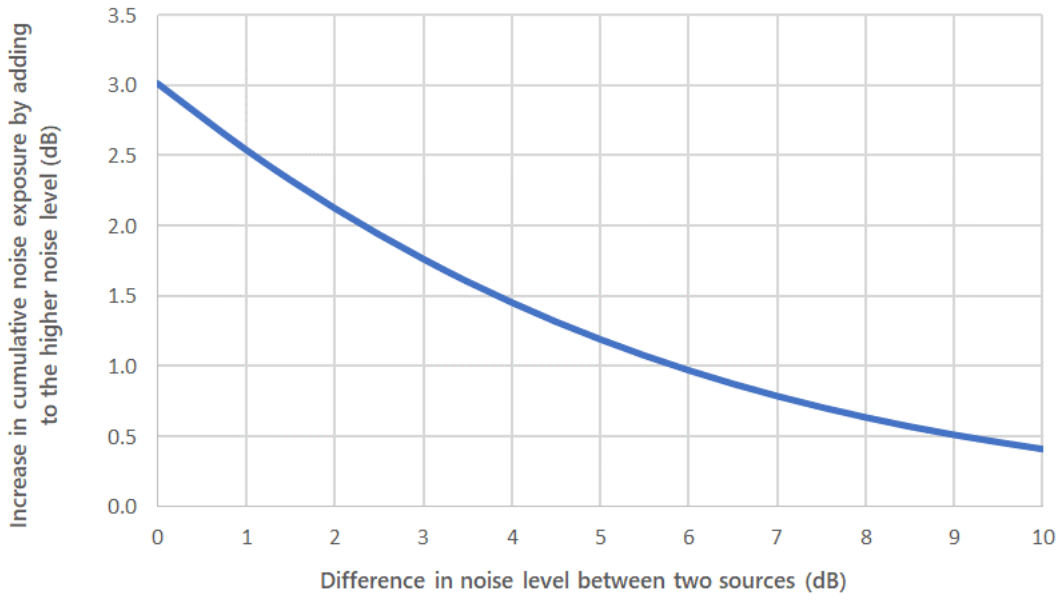
Figure A-1: Environmental noise assessment indicators



A.2.4 Cumulative sound exposure

As illustrated in Figure A-2, for two activities that result in the same amount of acoustical energy or noise level at a receiver location, the cumulative sound exposure level would be 3 dB higher than the level of just one single activity. This is because the decibel (dB) scale is logarithmic. Conversely, if the activity closer to your home results in noise exposure level that is 10 dB higher than the activity occurring further away, the quieter works would contribute very little to the cumulative noise exposure level.

Figure A-2: Difference in noise level between two sources



Annexure B Project locations, receivers and noise catchment areas

B.1 Project locations, receivers and noise catchment areas

150 0 150 300 450 600 m

NCA30.4
CROWS NEST
L6
NCA23.2
NCA22.2
NCA22.1
NCA23.1
MILITARY ROAD
WOLLSTONECRAFT
MILLER STREET
NCL4.0.1
L5
CREMORNE
NCA21.2
L3
NCA19.1
NCA17.4
NEUTRAL BAY
MOSMAN
NCA15.1
WARRINGAH FREEWAY
NORTH SYDNEY
NCA16.3
NCA18.3
NCA15.3
PACIFIC HIGHWAY
WAVERTON
NCA16.2
NCA17.3
CREMORNE POINT
KURRABA POINT
L2
NCA18.2
NCA17.2
L45
LAVENDER BAY
NCA15.2
HIGH STREET
NCA18.1
L1
MCMAHONS POINT
NCA15.4
NCA16.1
MILSONS POINT
KIRRIBILLI
NCA17.1
BRADFIELD HIGHWAY
SYDNEY HARBOUR TUNNEL

Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Warringah Freeway - South

Consultant:

RENZO TONIN & ASSOCIATES
inspired to achieve
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150 0 150 300 450 600 m

NCA33.2
NCA30.1
NCA30.3
NCA29.1
NCA28.1
NCA27.1
NCA25.1
NCA24.1
NCA26.2
NCA30.4
NCA22.3
NCA26.1
NCA27.2
NCA23.2
NCA23.1
NCA22.1
NCA22.2
NCA40.1
NCA21.2
NCA19.1
NCA17.4
NCA15.1
NCA16.3
NCA18.3
NCA15.3
NCA16.2
NCA17.3
NCA15.2
NCA15.4
NCA16.1
NCA17.2
NCA18.2
NCA18.1
L13
L14
L15
L11
L10
L7
L9
L8
L6
L5
L4
L3
L2
L45
ST LEONARDS
CAMMERAY
MIDDLE HARBOUR
RIVER ROAD
FALCON STREET
CREMORNE
BELGRAVE STREET
GERARD STREET
MILITARY ROAD
MILLER STREET
WOLLSTONECRAFT
MOSMAN
NEUTRAL BAY
WARRINGAH FREEWAY
NORTH SYDNEY
WAVERTON
PACIFIC HIGHWAY
LAVENDER BAY
KIRRIBILLI
CREMORNE POINT
KURRABA POINT

Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Warringah Freeway - Lower Centre

Consultant:

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150 0 150 300 450 600 m

NCA37.1 NCA38.1 NCA40.1 NCA38.3 NORTHBRIDGE STRATHALLEN AVENUE GORE HILL FREEWAY NCA32.1 NCA31.3 NCA31.1 BROOK STREET L17 NAREMBURN MIDDLE HARBOUR NCA40.2 NCA30.2 NCA31.2 NCA28.1 NCA33.2 L16 NCA30.3 CAMMERAY NCA30.1 NCA29.1 NCA27.1 ST LEONARDS L13 L14 L15 NCA25.1 NCA26.2 NCA24.1 WARRINGAH FREEWAY PACIFIC HIGHWAY CREMORNE MILITARY ROAD NCA30.4 RIVER ROAD FALCON STREET NCA22.3 L11 L10 NCA26.1 GERARD STREET MOSMAN NCA21.4 L9 BELGRAVE STREET L8 L6 NCA23.2 NCA23.1 NCA22.1 WOOLSTONECRAFT NCA22.2 NORTH SYDNEY L5 NCA21.1 NCA15.1 NCA21.2 NCA17.4 NCA18.3 L3 NCA19.1 WAVERTON NCA15.3 NCA16.3

Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Cammeray Golf Course

Consultant:

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150 0 150 300 450 600 m



Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Gore Hill Freeway Upgrade

Consultant:

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150 0 150 300 450 600 m

LANE COVE TUNNEL
EPPING ROAD
LANE COVE NORTH
LANE COVE WEST
CENTENNIAL AVENUE
BURNS BAY ROAD
LONGUEVILLE ROAD
LANE COVE
RIVER ROAD
RIVERVIEW
LONGUEVILLE
NORTHWOOD
WILLOUGHBY
ARTARMON
DICKSON AVENUE
PACIFIC HIGHWAY
NAREMBURN
ST LEONARDS
WOLLSTONECRAFT

NCA33.4
NCA35.1
NCA33.1
NCA34.1
NCA36.1
NCA60.4
NCA59.1
NCA33.2
NCA32.1
NCA30.2
NCA60.1
NCA60.5
NCA60.2
NCA60.3
NCA30.1

L18
L19
L20
L21
L22
L46
L47

Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Dickson Avenue Intersection

Consultant:
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150 0 150 300 450 600 m



Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Artarmon (Punch St)

Consultant:

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150 0 150 300 450 600 m

MOWBRAY ROAD
PENSHURST STREET
WILLOUGHBY EAST
EASTERN VALLEY WAY
ALPHA ROAD
CASTLECRAG
NCA41.1
NCA34.1
WILLOUGHBY
NCA36.1
NCA38.2
NCA39.1
L21
NCA33.1
ARTARMON
NORTHBRIDGE
L25
L24
NCA38.3
L19
L22
L20
L18
NCA38.1
FLAT ROCK DRIVE
LANE COVE TUNNEL
L23
NCA37.1
DICKSON AVENUE
NCA32.1
NCA31.3
NAREMBURN
BROOK STREET
L17
NCA31.1
STRATHALLEN AVENUE
WARRINGAH FREEWAY
NCA33.2
NCA30.2
NCA31.2
NCA28.1
MIDDLE HARBOUR
PACIFIC HIGHWAY
L16
CAMMERAY
NCA59.1
NCA30.3
ST LEONARDS
NCA30.4
NCA60.2
NCA30.1
CROWS NEST
NCA29.1
NCA25.1
L13
L14
NCA26.2

Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Flat Rock Drive

Consultant:

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150 0 150 300 450 600 m

CASTLE COVE
MIDDLE COVE
EASTERN VALLEY WAY
WILLOUGHBY EAST
CASTLECRAG
NCA41.1
L28
NCA53.2
NCA53.3
NORTH BALGOWLAH
FRENCHS FOREST ROAD
NCA47.1
NCA47.2
NCA51.1
NCA50.1
L36
L38
NCA49.1
L37
SYDNEY ROAD
L35
L34
L33
SEAFORTH
NCA48.1
NCA39.2
NCA46.2
NCA46.1
NCA44.1
NCA42.1
L32
L31
NCA45.1
BALGOWLAH HEIGHTS
L30
CLONTARF
ALPHA ROAD
NCA36.1
NCA38.2
L27
NCA39.1
MIDDLE HARBOUR
L29
NCA44.2
SPIT ROAD
L25
NORTHBRIDGE
NCA38.3
NCA40.1
NCA43.1
NCA43.2
L24
NCA38.1
L26
L23
NCA37.1
STRATHALLEN AVENUE
BROOK STREET
L17
NCA31.1
NCA31.3
NCA28.1
NCA31.2
CAMMERAY
CREMORNE
NCA40.2
MOSMAN
L16
NCA30.3
NCA27.1

Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition
- New open space and recreation facilities at Balgowlah

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Middle Harbour Crossing

Consultant:

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150 0 150 300 450 600 m

CASTLECRAG
NCA41.1
L28
NCA39.2
SEAFORTH
NCA47.2
NCA47.1
L33
NCA49.1
L34
NCA48.1
BALGOWLAH
NCA46.2
MANLY ROAD
NCA46.1
NCA44.1
L32
NCA42.1
L31
NCA45.1
BALGOWLAH HEIGHTS
L27
NCA39.1
NCA44.2
L30
CLONTARF
L29
MIDDLE HARBOUR
SPIT ROAD
NORTHBRIDGE
NCA40.1
L26
NCA43.1
NCA43.2
NCA38.3
MOSMAN
NCA40.2
CREMORNE

Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Spit West Reserve

Consultant:

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150 0 150 300 450 600 m

NCA54.1
NCA53.1
NCA53.4
NCA53.2
NCA53.3
NCA51.1
NCA52.1
NCA50.1
NCA49.1
NCA48.1
NCA47.1
NCA47.2
NCA46.2
NCA46.1
NCA45.1
NCA44.1
NCA42.1
NCA39.2

L41 L40 L39 L38 L37 L36 L35 L34 L33 L32

WAKEHURST PARKWAY
CLONTARF STREET
BURNT BRIDGE CREEK DEVIATION
FRENCHS FOREST ROAD
SYDNEY ROAD
ROSEDALE AVENUE
MANLY ROAD
SPIT ROAD

ALLAMBIE HEIGHTS
NORTH BALGOWLAH
MANLY VALE
NORTH MANLY
MANLY
SEAFORTH
BALGOWLAH
FAIRLIGHT
CLONTARF
NORTH HARBOUR
BALGOWLAH HEIGHTS

Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition
- New open space and recreation facilities at Balgowlah

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Balgowlah Connection and Balgowlah Golf Course

Consultant:

RENZO TONIN & ASSOCIATES
inspired to achieve
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150 0 150 300 450 600 m

KILLARNEY HEIGHTS
NCA55.2
ALLAMBIE HEIGHTS
BROOKVALE
WAKEHURST PARKWAY
NCA54.1
L42
MIDDLE HARBOUR
L41
NCA53.1
CLONTARF STREET
SEAFORTH
NCA53.4
MANLY VALE
NORTH BALGOWLAH
NCA53.3
NCA53.2
NCA51.1
CASTLE COVE
NCA41.1
NCA47.1

Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Wakehurst Parkway east

Consultant:

RENZO TONIN & ASSOCIATES
inspired to achieve
1/418A Elizabeth Street, SURRY HILLS NSW 2010
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150 0 150 300 450 600 m

WARRINGAH ROAD
FORESTVILLE
NCA55.1
FRENCHS FOREST
L43
NCA55.4
BEACON HILL
NCA55.3
WAKEHURST PARKWAY
ALLAMBIE HEIGHTS
KILLARNEY HEIGHTS
NCA55.2
MIDDLE HARBOUR
NCA54.1
L42
SEAFORTH

Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Wakehurst Parkway Connection and Upgrade

Consultant:

RENZO TONIN & ASSOCIATES
inspired to achieve
1/418A Elizabeth Street, SURRY HILLS NSW 2010
P: 02 8218 0500 F: 02 8218 0501

Figure No: TJ500-01-6-3-1-1 020b-24
Scale: 1:12500
Date: 27.10.2020

Created by: ALE
Rev: R23
Sheet: A3

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150 0 150 300 450 600 m

BELROSE

OXFORD FALLS

WAKEHURST PARKWAY

FOREST WAY

NCA57.1

NCA58.1

NCA56.1

WARRINGAH ROAD

NCA58.2

BEACON HILL

L44

FORESTVILLE

NCA55.1

L43

NCA55.4

ALLAMBIE HEIGHTS

NCA55.3

Legend

- Construction support site layout
- Construction support site footprint
- Construction footprint
- Noise catchment boundary
- Noise monitoring location
- Beaches Link tunnel alignment

Receiver type

- Residential
- Mixed use
- Commercial/Industrial
- Childcare
- Educational
- Medical
- Place of Worship
- Other noise sensitive receivers
- Recreational - Passive
- Recreational - Active
- Non-receiver building
- Other major project acquisition

Client:
Transport for NSW

Project:
Beaches Link and Gore Hill Freeway Connection

Description:
Building use identification
Wakehurst Parkway North

Consultant:

RENZO TONIN & ASSOCIATES
inspired to achieve
1/418A Elizabeth Street, SURRY HILLS NSW 2010
P: 02 8218 0500 F: 02 8218 0501

Figure No: TJ500-01-6-3-1-1 020b-25
Scale: 1:12500
Date: 27.10.2020

Created by: ALE
Rev: R23
Sheet: A3

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B.2 Noise catchment areas details summary

NCA ID	Distance to nearest works area	Nearest works areas / construction support site	Reference suburb (- sub area)	Reference Logger	Noise management level (NML) $L_{Aeq(15\ min)}$				Screening level
					Standard Hours (RBL + 10 dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL + 5 dB)			L_{Amax} (RBL + 15 dB(A))
					Day	Day	Evening	Night	Night
15.1	1240	Warringah Freeway	Waverton	L45	52	47	46	43	53
15.2	1680	Warringah Freeway	McMahons Point	L45	52	47	46	43	53
15.3	980	Warringah Freeway	North Sydney - South West	L45	52	47	46	43	53
15.4	1450	Warringah Freeway	Lavender Bay	L45	52	47	46	43	53
16.1	1470	Warringah Freeway	Milsons Point	L1	70	65	65	55	65
16.2	1230	Warringah Freeway	North Sydney - South West	L1	70	65	65	55	65
16.3	830	Warringah Freeway	North Sydney - South West	L1	70	65	65	55	65
17.1	1760	Warringah Freeway	Kirribilli	L2	65	60	59	50	60
17.2	1420	Warringah Freeway	Kirribilli	L2	65	60	59	50	60
17.3	1010	Warringah Freeway	North Sydney - East	L2	65	60	59	50	60
17.4	260	Warringah Freeway	Neutral Bay	L2	65	60	59	50	60
18.1	1520	Warringah Freeway	Kirribilli	L5	64	59	57	48	58
18.2	1290	Warringah Freeway	North Sydney - East	L5	64	59	57	48	58
18.3	270	Warringah Freeway	Neutral Bay	L5	64	59	57	48	58
19.1	620	Warringah Freeway	North Sydney - North West	L4	62	57	57	50	60
20.1	500	Warringah Freeway	North Sydney - North West	L4	62	57	57	50	60
21.1	220	Warringah Freeway	North Sydney	L7	63	58	54	46	56
21.2	550	Warringah Freeway	North Sydney	L7	63	58	54	46	56
22.1	440	Warringah Freeway	North Sydney	L6	62	57	52	41	51
22.2	720	Warringah Freeway	Wollstonecraft	L6	62	57	52	41	51
22.3	350	Warringah Freeway	Crows Nest	L6	62	57	52	41	51
23.1	10	Warringah Freeway	Neutral Bay	L8	71	66	59	49	59

NCA ID	Distance to nearest works area	Nearest works areas / construction support site	Reference suburb (- sub area)	Reference Logger	Noise management level (NML) $L_{Aeq(15\ min)}$				Screening level
					Standard Hours (RBL + 10 dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL + 5 dB)			L_{Amax} (RBL + 15 dB(A))
					Day	Day	Evening	Night	Night
23.2	20	Warringah Freeway	North Sydney	L8	71	66	59	49	59
24.1	70	Warringah Freeway	Crows Nest	L11	66	61	57	42	52
25.1	40	Warringah Freeway	Cammeray	L12	68	63	60	48	58
26.1	10	Cammeray Golf Course (BL1)	Cremorne	L10	68	63	59	46	56
26.2	<10	Cammeray Golf Course (BL1)	Cammeray	L10	68	63	59	46	56
27.1	230	Cammeray Golf Course (BL1)	Cremorne	L15	59	54	53	44	54
28.1	70	Cammeray Golf Course (BL1)	Cammeray	L14	57	52	50	42	52
29.1	40	Cammeray Golf Course (BL1)	Cammeray	L13	74	69	68	52	62
30.1	630	Warringah Freeway	Crows Nest	L16	68	63	61	43	53
30.2	410	Flat Rock Drive (BL2)	Naremburn	L16	68	63	61	43	53
30.3	300	Cammeray Golf Course (BL1)	Cammeray	L16	68	63	61	43	53
30.4	710	Punch Street (BL3)	Wollstonecraft	L16	68	63	61	43	53
31.1	110	Flat Rock Drive (BL2)	Naremburn	L17	66	61	54	42	52
31.2	470	Cammeray Golf Course (BL1)	Cammeray	L17	66	61	54	42	52
31.3	110	Flat Rock Drive (BL2)	Naremburn	L17	66	61	54	42	52
32.1	<10	Punch Street (BL3)	Naremburn	L20	69	64	60	45	55
33.1	<10	Gore Hill Freeway	Artarmon	L19	65	60	58	45	55
33.2	<10	Gore Hill Freeway	Artarmon	L19	65	60	58	45	55
33.4	180	Gore Hill Freeway	Lane Cove North	L19	65	60	58	45	55
34.1	40	Gore Hill Freeway	Artarmon	L21	54	49	49	42	52
35.1	<10	Gore Hill Freeway	Lane Cove North	L18	77	72	68	51	61
36.1	<10	Flat Rock Drive (BL2)	Willoughby	L22	60	55	53	43	53
37.1	<10	Flat Rock Drive (BL2)	Naremburn	L23	55	50	49	39	49
38.1	40	Flat Rock Drive (BL2)	Northbridge	L24	62	57	53	42	52
38.2	270	Flat Rock Drive (BL2)	Northbridge	L24	62	57	53	42	52

NCA ID	Distance to nearest works area	Nearest works areas / construction support site	Reference suburb (- sub area)	Reference Logger	Noise management level (NML) $L_{Aeq(15\ min)}$				Screening level
					Standard Hours (RBL + 10 dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL + 5 dB)			L_{Amax} (RBL + 15 dB(A))
					Day	Day	Evening	Night	Night
38.3	360	Flat Rock Drive (BL2)	Northbridge	L24	62	57	53	42	52
39.1	70	Middle Harbour south cofferdam (BL7)	Northbridge	L27	47	42	39	35	45
39.2	20	Middle Harbour north cofferdam (BL8)	Seaforth	L27	47	42	39	35	45
40.1	20	Temporary mooring east of Clive Park	Northbridge	L26	47	42	42	38	48
40.2	270	Temporary mooring east of Clive Park	Mosman	L26	47	42	42	38	48
41.1	390	Middle Harbour south cofferdam (BL7)	Castlecrag	L28	46	41	37	35	45
42.1	10	Middle Harbour north cofferdam (BL8)	Seaforth	L31	52	47	43	41	51
43.1	160	Spit West Reserve (BL9)	Mosman	L29	55	50	48	41	51
43.2	240	Spit West Reserve (BL9)	Mosman	L29	55	50	48	41	51
44.1	260	Spit West Reserve (BL9)	Seaforth	L32	60	55	54	45	55
44.2	<10	Spit West Reserve (BL9)	Mosman	L32	60	55	54	45	55
45.1	450	Spit West Reserve (BL9)	Clontarf	L30	50	45	43	38	48
46.1	30	Balgowlah Golf Course (BL10)	Clontarf	L34	68	63	59	42	52
46.2	120	Balgowlah Golf Course (BL10)	Seaforth	L34	68	63	59	42	52
47.1	220	Balgowlah Golf Course (BL10)	Seaforth	L33	53	48	44	35	45
47.2	580	Balgowlah surface road works	Seaforth	L33	53	48	44	35	45
48.1	<10	Balgowlah surface road works	Balgowlah	L35	65	60	55	37	47
49.1	<10	Balgowlah surface road works	Seaforth	L37	55	50	47	36	46
50.1	<10	Balgowlah surface road works	Balgowlah	L36	57	52	50	40	50
51.1	<10	Balgowlah surface road works	North Balgowlah	L38	53	48	45	38	48
52.1	170	Balgowlah surface road works	Manly Vale	L40	59	54	50	41	51
53.1	<10	Wakehurst Parkway east (BL13)	Seaforth	L41	58	53	44	35	45

NCA ID	Distance to nearest works area	Nearest works areas / construction support site	Reference suburb (- sub area)	Reference Logger	Noise management level (NML) $L_{Aeq(15\ min)}$				Screening level
					Standard Hours (RBL + 10 dB)	Outside standard hours: Out of Hours Work (OOHW) (RBL + 5 dB)			L_{Amax} (RBL + 15 dB(A))
					Day	Day	Evening	Night	Night
53.2	240	Wakehurst Parkway east (BL13)	Seaforth	L41	58	53	44	35	45
53.3	280	Wakehurst Parkway east (BL13)	Seaforth	L41	58	53	44	35	45
53.4	390	Wakehurst Parkway east (BL13)	North Balgowlah	L41	58	53	44	35	45
54.1	<10	Wakehurst Parkway surface road works	Seaforth	L42	55	50	44	35	45
55.1	30	Wakehurst Parkway surface road works	Forestville	L43[1]	56	51	45	35	45
55.2	940	Wakehurst Parkway surface road works	Killarney Heights	L43[1]	56	51	45	35	45
55.3	970	Wakehurst Parkway surface road works	Allambie Heights	L43[1]	56	51	45	35	45
55.4	<10	Wakehurst Parkway surface road works	Allambie Heights	L43[1]	56	51	45	35	45
56.1	<10	Wakehurst Parkway surface road works	Frenchs Forest	L44[2]	63	58	53	39	49
57.1	<10	Warringah Road/Wakehurst Parkway	Frenchs Forest	L43[1]	56	51	45	35	45
58.1	70	Warringah Road/ Wakehurst Parkway	Frenchs Forest	L43[1]	56	51	45	35	45
58.2	<10	Wakehurst Parkway north (BL14)	Frenchs Forest	L43[1]	56	51	45	35	45
59.1	<10	Gore Hill Freeway	Lane Cove/ Greenwich	L46	70	65	60	45	55
60.1	220	Gore Hill Freeway	Lane Cove	L47	49	44	42	36	46
60.2	170	Gore Hill Freeway	Greenwich	L47	49	44	42	36	46
60.3	1000	Gore Hill Freeway	Longueville/ Northwood	L47	49	44	42	36	46
60.4	850	Gore Hill Freeway	Lane Cove	L47	49	44	42	36	46
60.5	1400	Gore Hill Freeway	Riverview	L47	49	44	42	36	46

Notes: 1. L43 has been used to represent background noise levels at the most northern NCAs, as:

- Construction work prevented reliable noise monitoring during the monitoring period of this project
- Review of monitoring for the Northern Beaches Hospital, Connectivity and Network Enhancements, Stage 2 Noise and Vibration Assessment (SLR, 2015) (Logger locations NM6, NM7 and NM11) suggested that the levels measured at L43 were appropriate for those areas

2. Noise monitoring for NCA 56.1 was adopted from the Northern Beaches Hospital, Connectivity and Network Enhancements, Stage 2 Noise and Vibration Assessment (SLR, 2015) (Logger location NM9), as construction work prevented reliable noise monitoring during the monitoring period of this project.

Annexure C Environmental noise monitoring results

Acoustics
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Structural Dynamics

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Monitoring ID: Location L1
Address: 401/102 Alfred Street, Milsons Point
Description: Noise monitor located on the eastern facade of the fourth-floor balcony. Noise environment dominated by traffic on the Warringah Freeway and Alfred Street, and rail noise.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	60	60	50	63	62	58

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

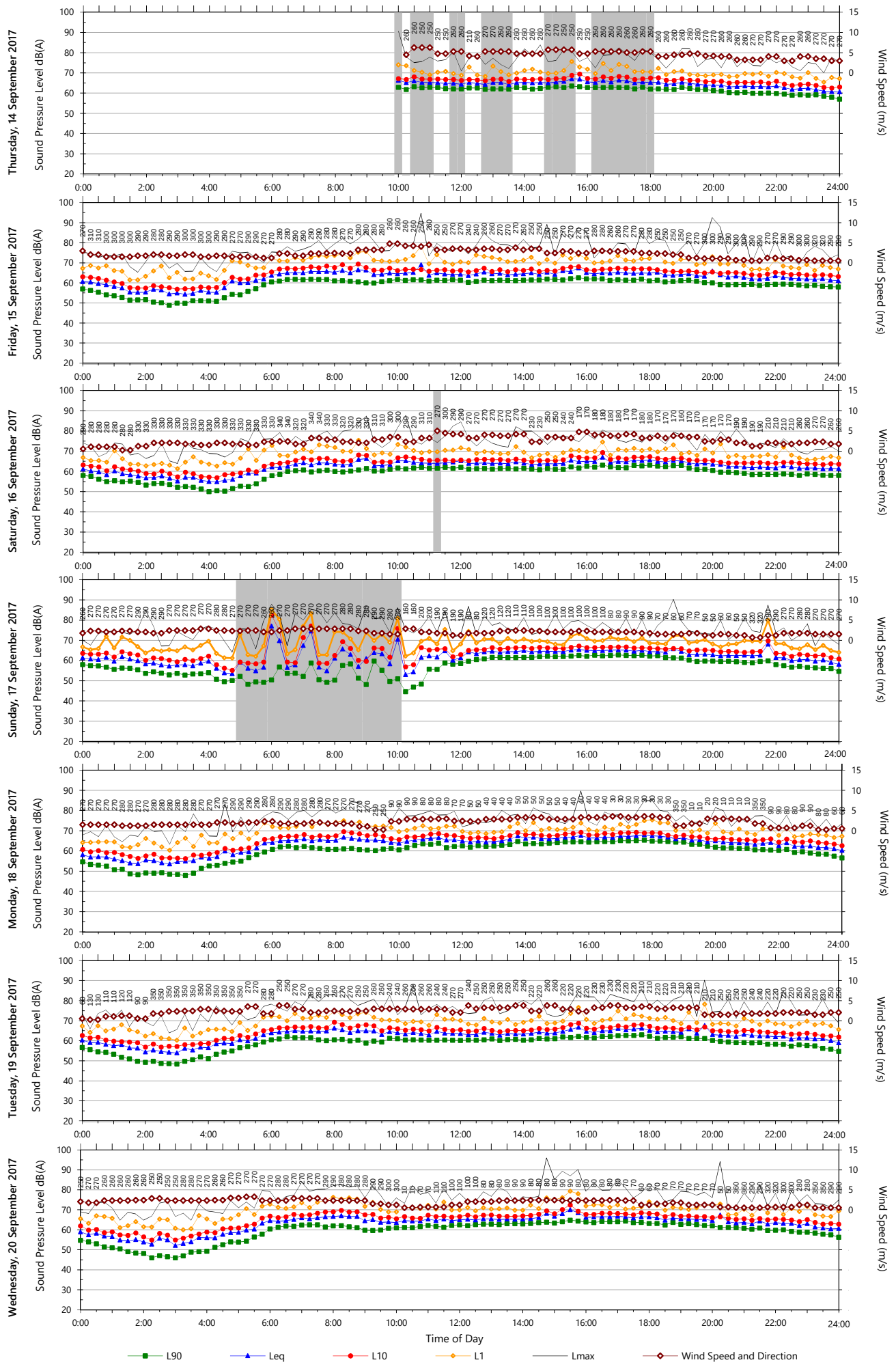
Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

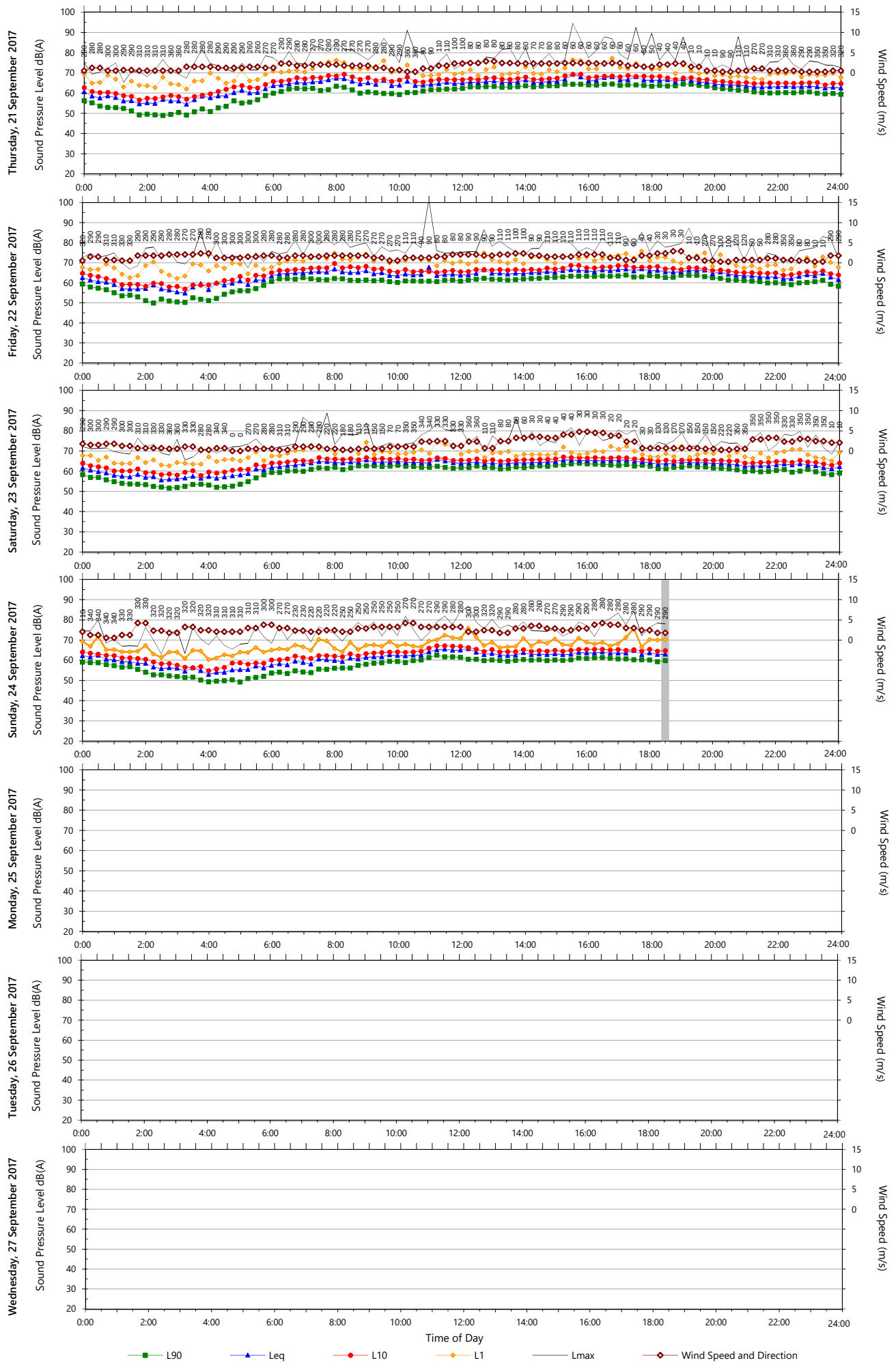
Logger Location	Aerial Photograph






Thursday, 14 September 2017
Friday, 15 September 2017
Saturday, 16 September 2017
Sunday, 17 September 2017
Monday, 18 September 2017
Tuesday, 19 September 2017
Wednesday, 20 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results **Location: Unit 401, 102 Alfred Street, Milsons Point (4F Balcony)**



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Monitoring ID: Location L2
Address: 6 McDougall Street, Kirribilli
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on the Cahill Expressway/Bradfield Highway and general neighbourhood and natural sounds.

Background & Ambient Noise Monitoring Results

	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	55	54	45	60	58	56

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)

	L_{Aeq} Noise Levels	
	Day[1]	Night[2]
Representative Week[3]	62	58

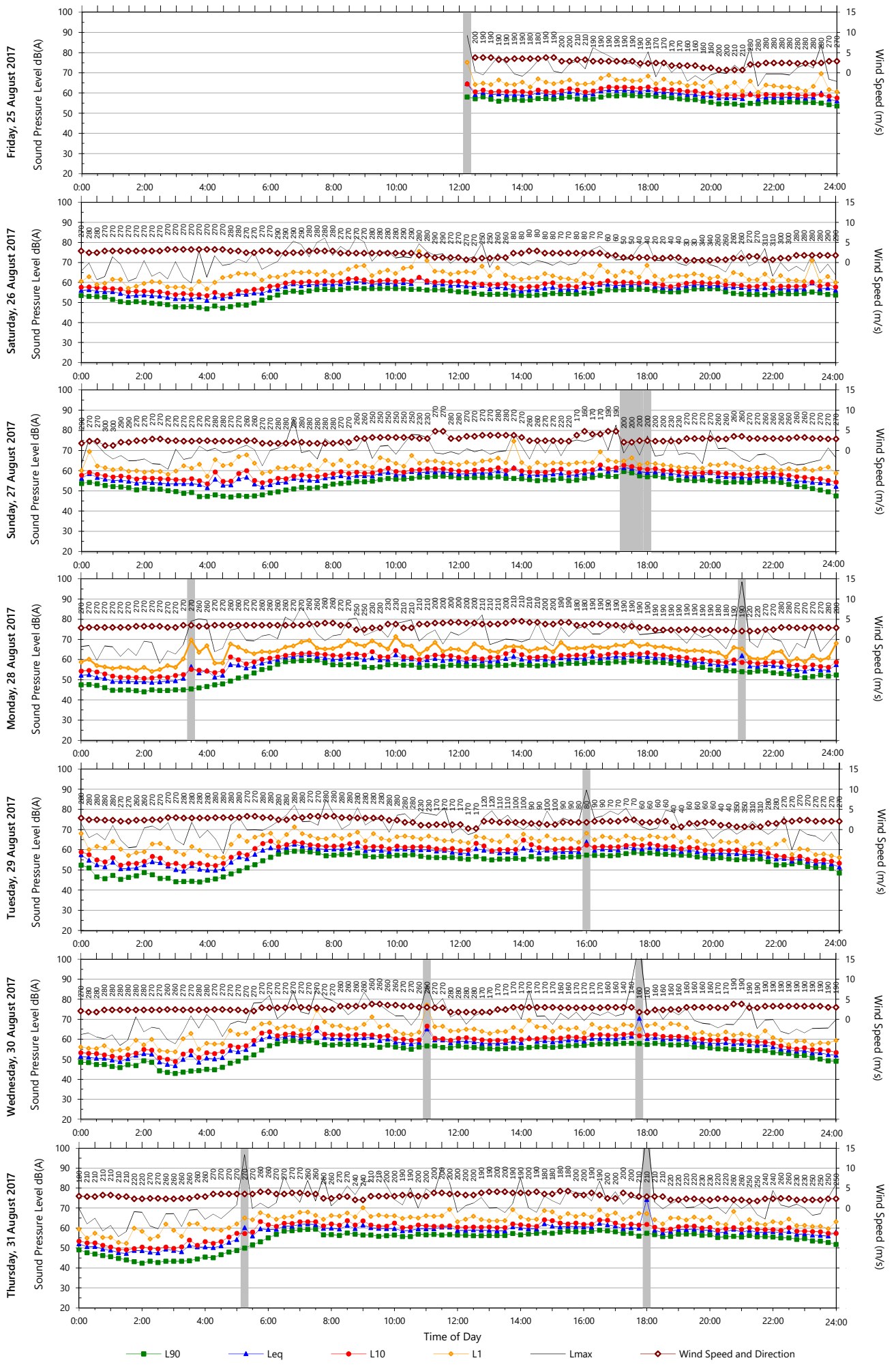
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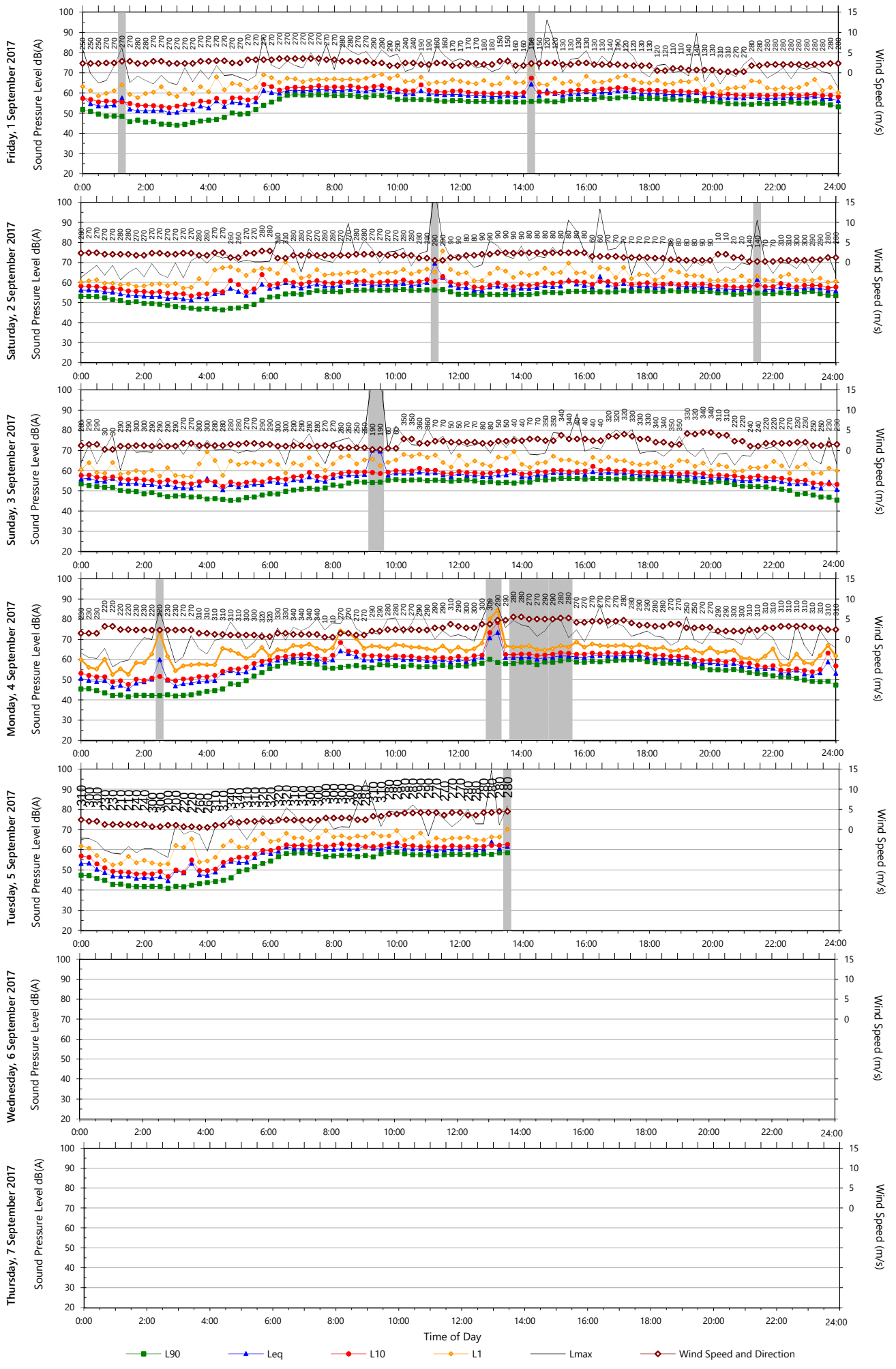
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Friday, 25 August 2017
Saturday, 26 August 2017
Sunday, 27 August 2017
Monday, 28 August 2017
Tuesday, 29 August 2017
Wednesday, 30 August 2017
Thursday, 31 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 1 September 2017
Saturday, 2 September 2017
Sunday, 3 September 2017
Monday, 4 September 2017
Tuesday, 5 September 2017
Wednesday, 6 September 2017
Thursday, 7 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L3
Address: 1/191-195 Walker Street, North Sydney
Description: Noise monitor located on the eastern side of the property, on the ground floor and positioned in the free-field. Noise environment dominated by traffic on the Warringah Freeway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	73	71	55	76	75	72

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	79	74	

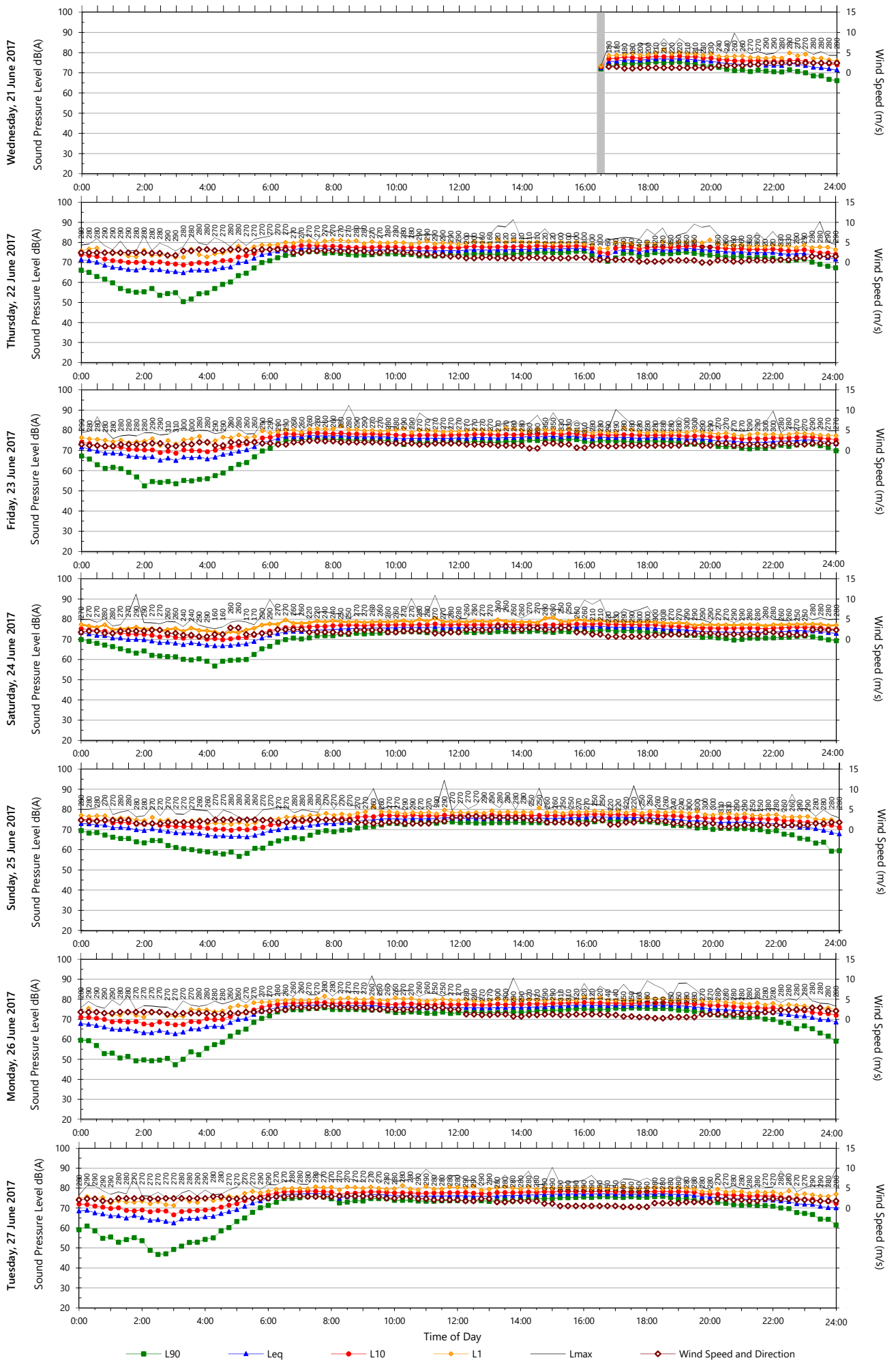
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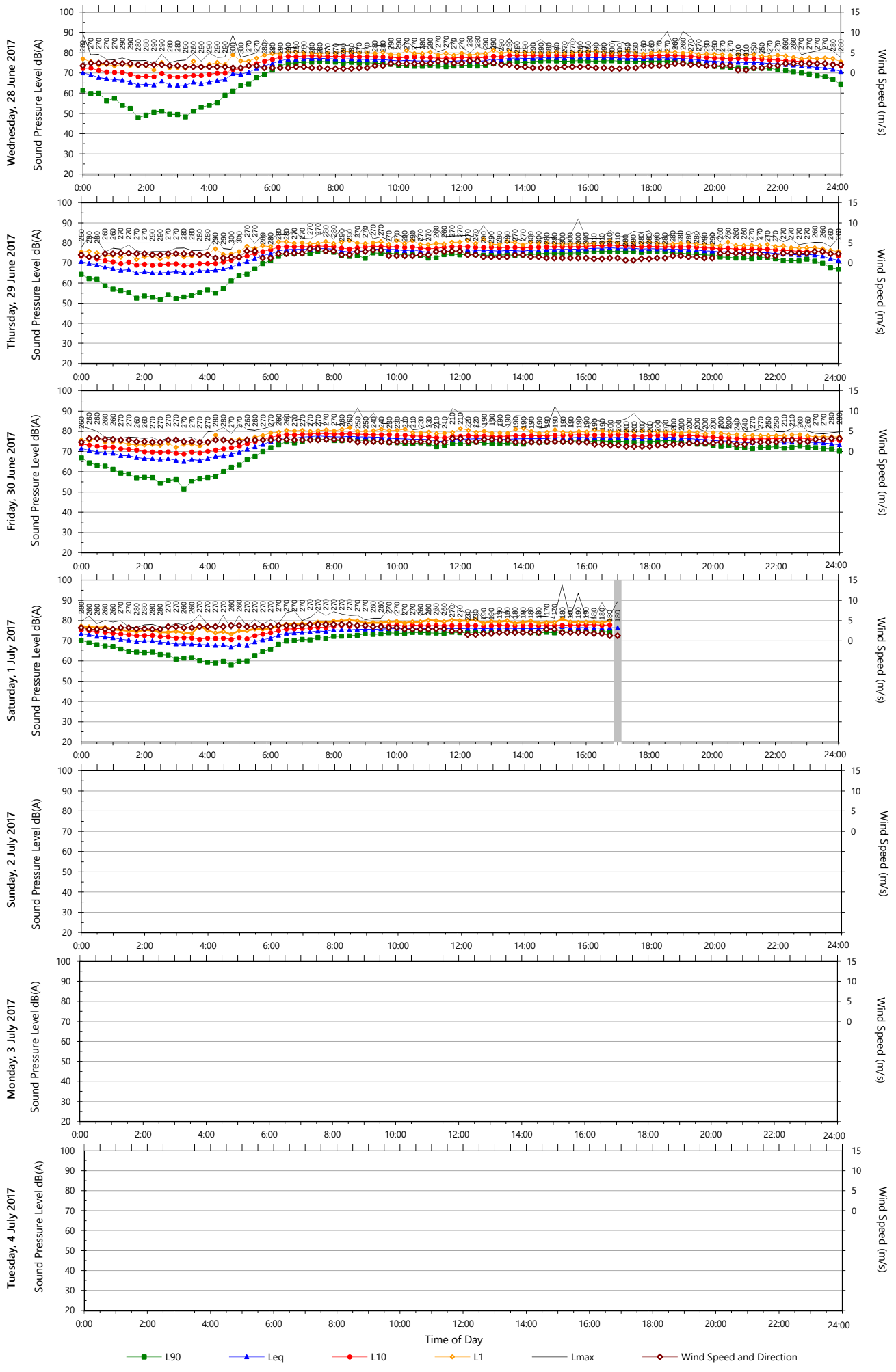
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Wednesday, 21 June 2017
Thursday, 22 June 2017
Friday, 23 June 2017
Saturday, 24 June 2017
Sunday, 25 June 2017
Monday, 26 June 2017
Tuesday, 27 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Wednesday, 28 June 2017
Thursday, 29 June 2017
Friday, 30 June 2017
Saturday, 1 July 2017
Sunday, 2 July 2017
Monday, 3 July 2017
Tuesday, 4 July 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L4
Address: 91 Ridge Street, North Sydney
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on the Warringah Freeway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	52	52	45	57	57	52

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)		
	L_{Aeq} Noise Levels	
	Day[1]	Night[2]
Representative Week[3]	60	54

Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

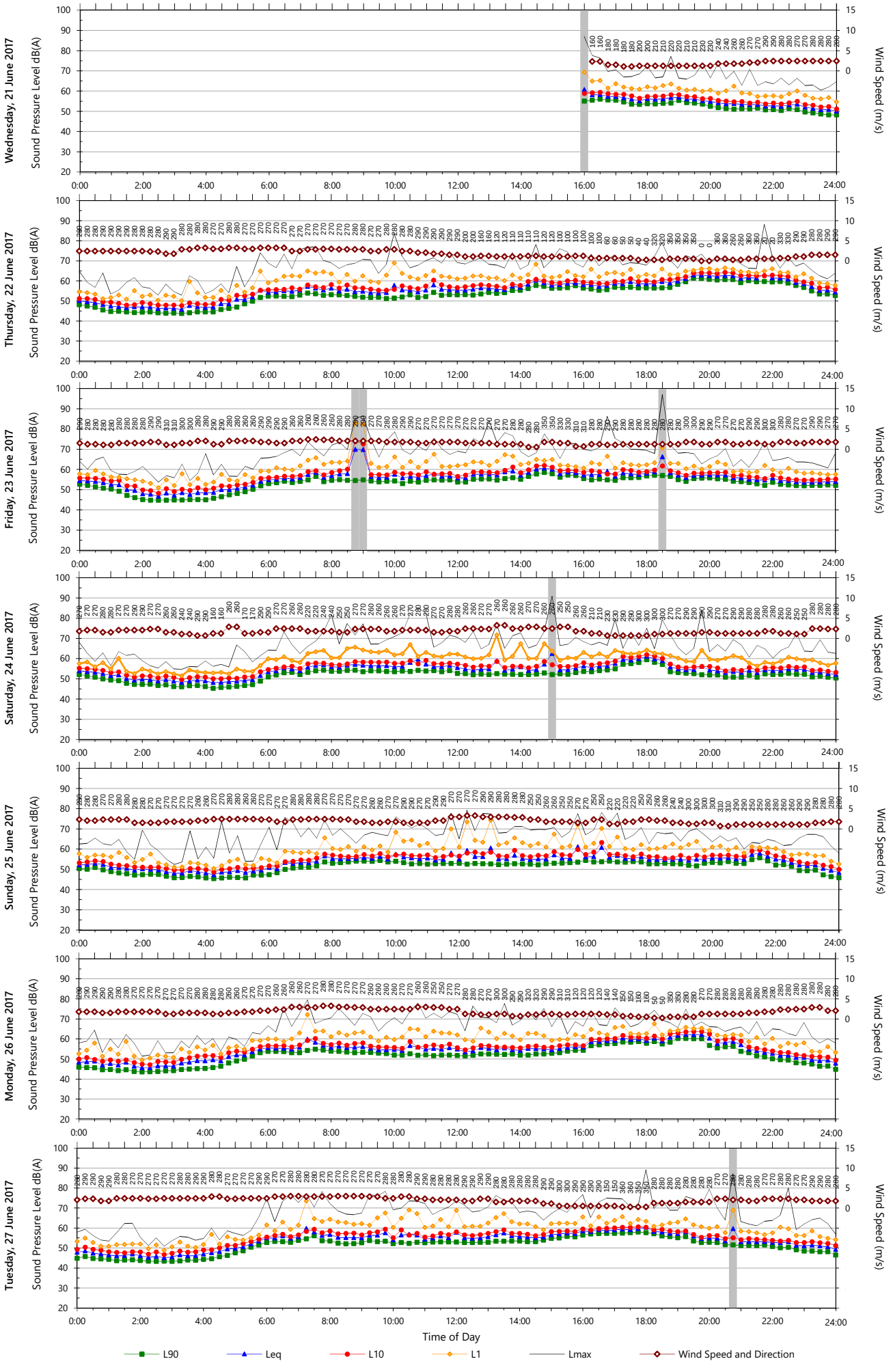
Logger Location	Aerial Photograph

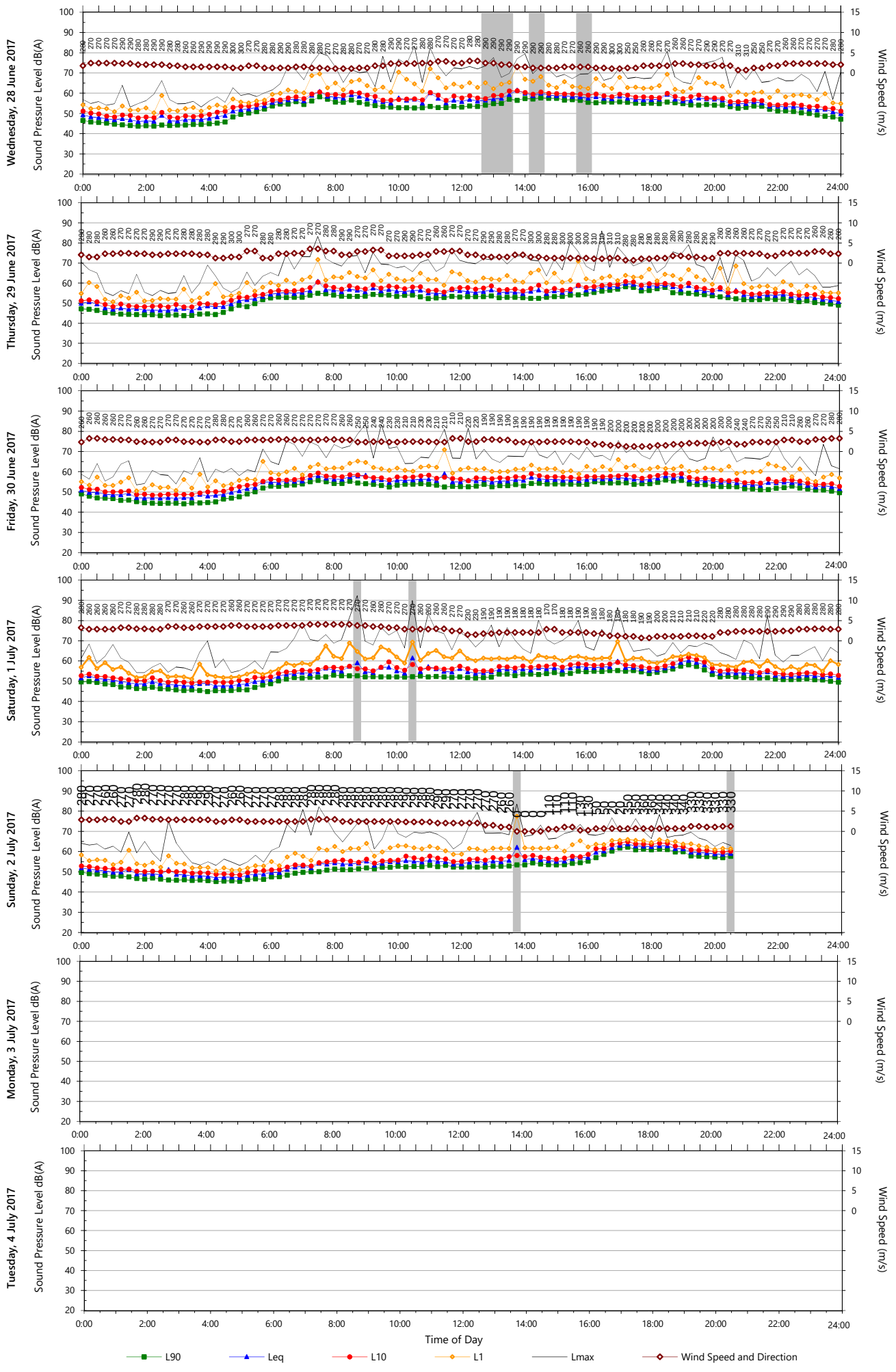




Unattended Monitoring Results

Location: 91 Ridge Street, North Sydney




Wednesday, 28 June 2017
Thursday, 29 June 2017
Friday, 30 June 2017
Saturday, 1 July 2017
Sunday, 2 July 2017
Monday, 3 July 2017
Tuesday, 4 July 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L5
Address: 14 Montpellier Road, Neutral Bay
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by general neighbourhood noise and natural sounds.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	54	52	43	59	57	53

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

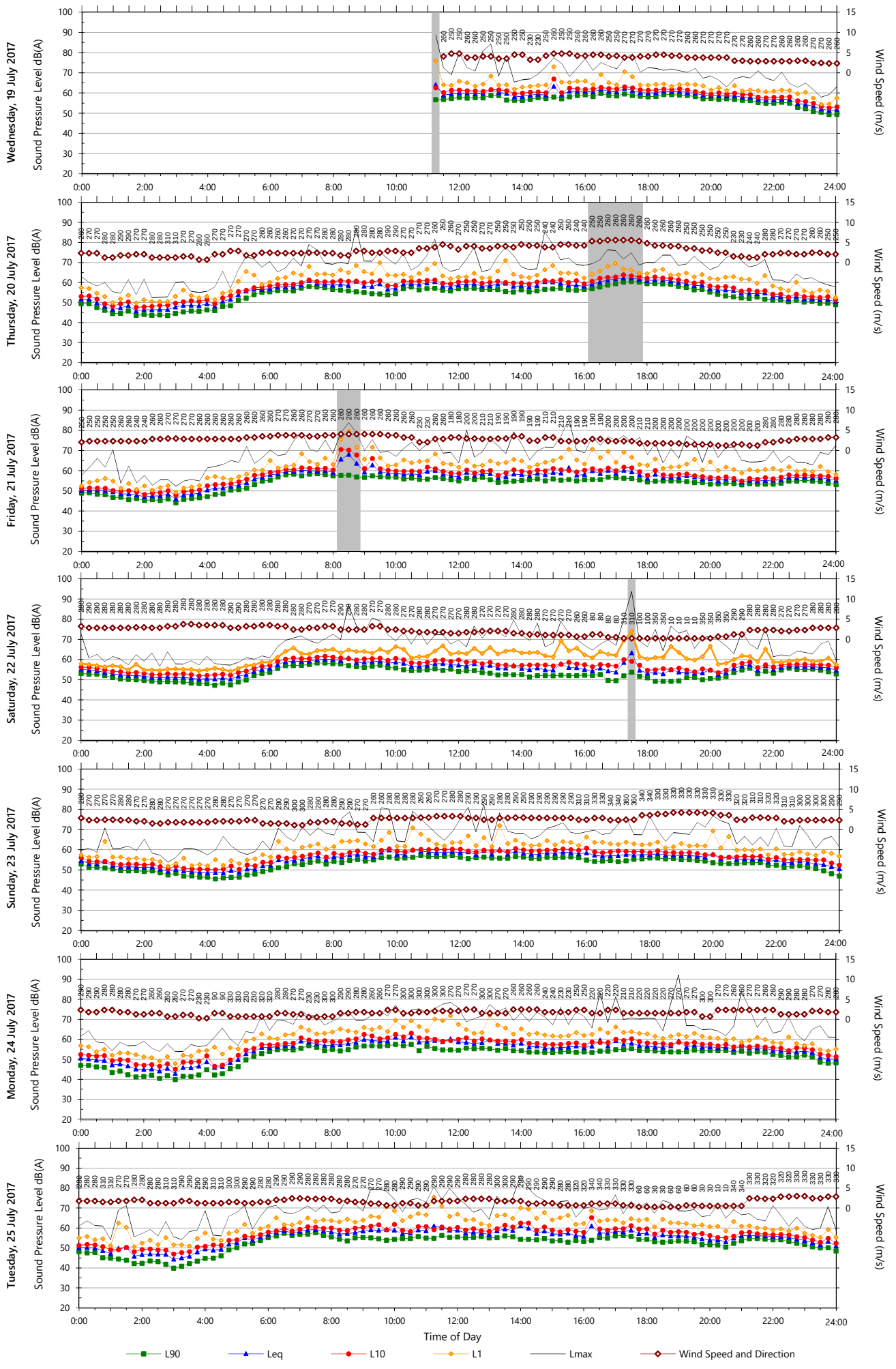
Notes:

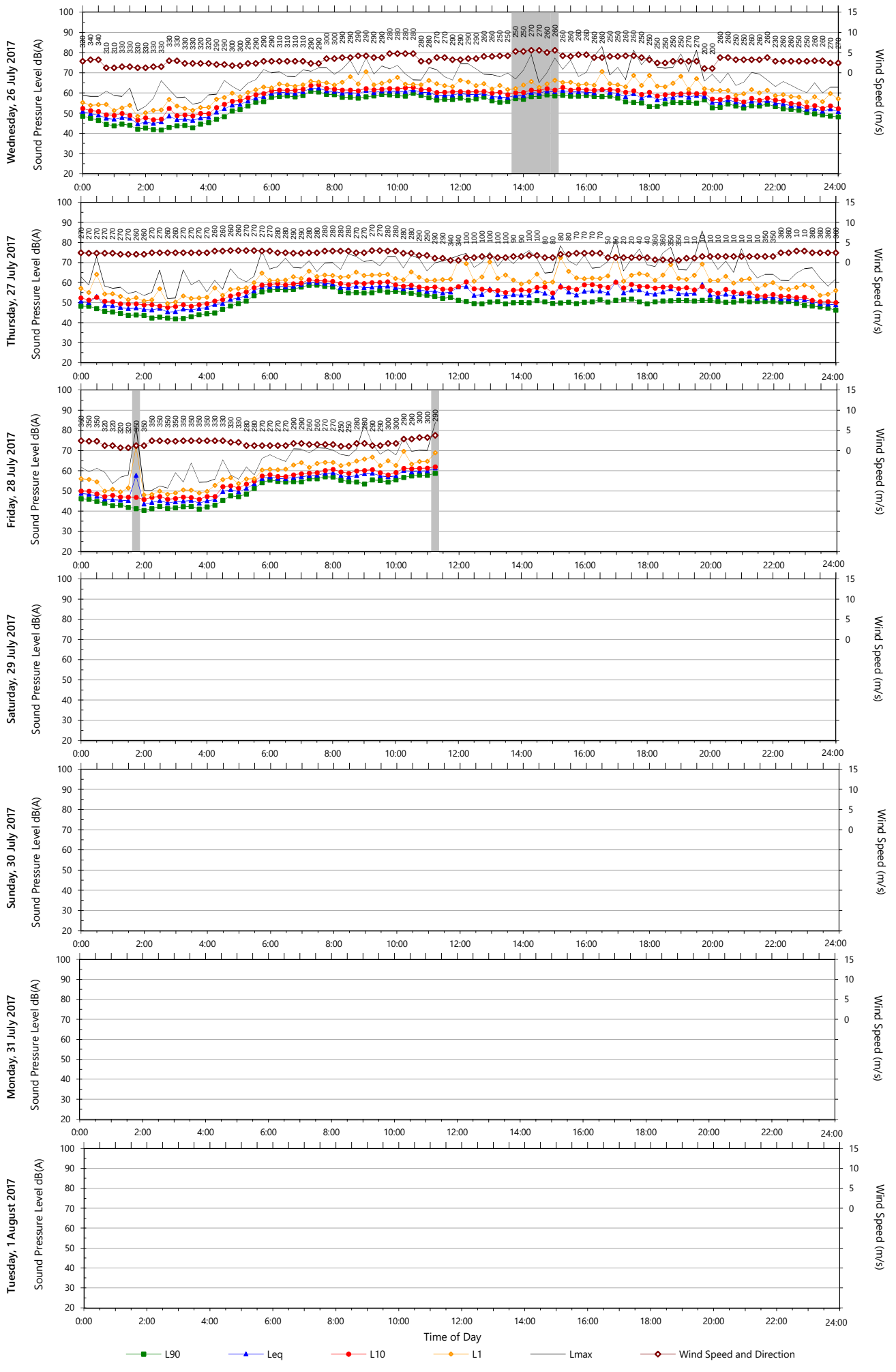
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Wednesday, 19 July 2017
Thursday, 20 July 2017
Friday, 21 July 2017
Saturday, 22 July 2017
Sunday, 23 July 2017
Monday, 24 July 2017
Tuesday, 25 July 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Wednesday, 26 July 2017
Thursday, 27 July 2017
Friday, 28 July 2017
Saturday, 29 July 2017
Sunday, 30 July 2017
Monday, 31 July 2017
Tuesday, 1 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L6
Address: 306 Miller Street, North Sydney
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on Miller Street.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	52	47	36	65	63	58

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

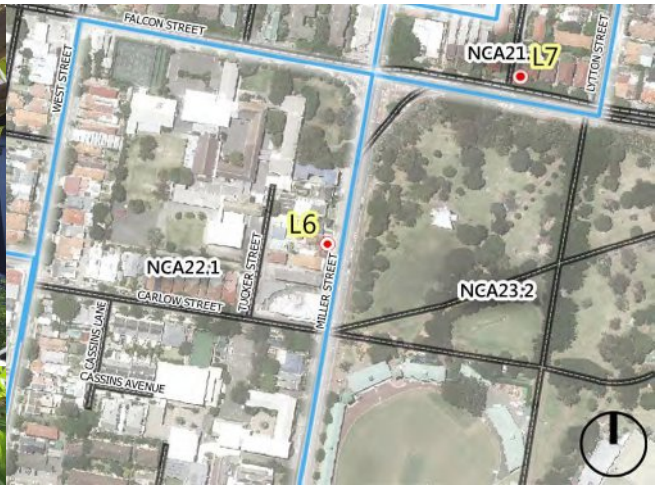
Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	67	61	

Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

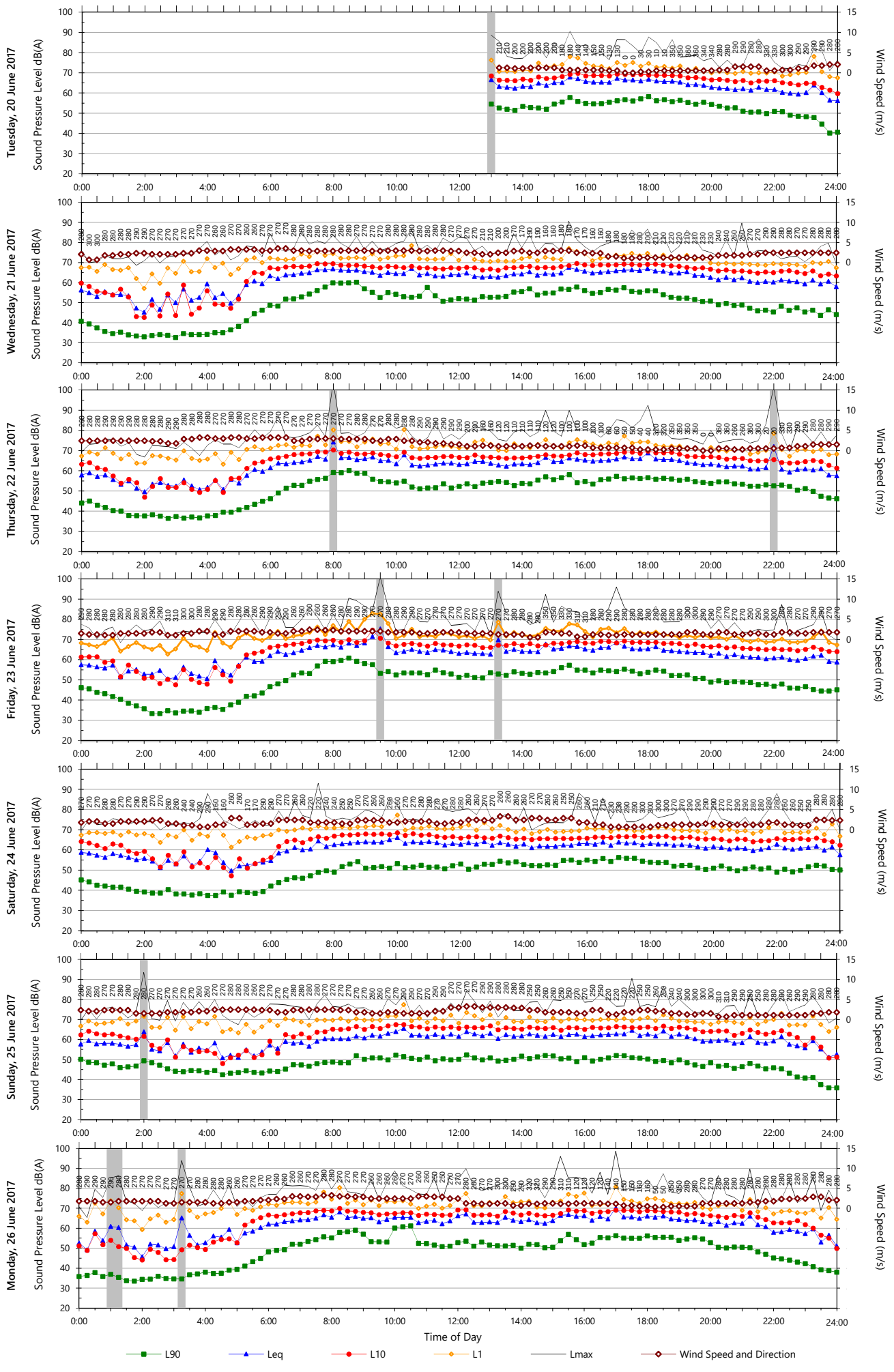
Logger Location	Aerial Photograph

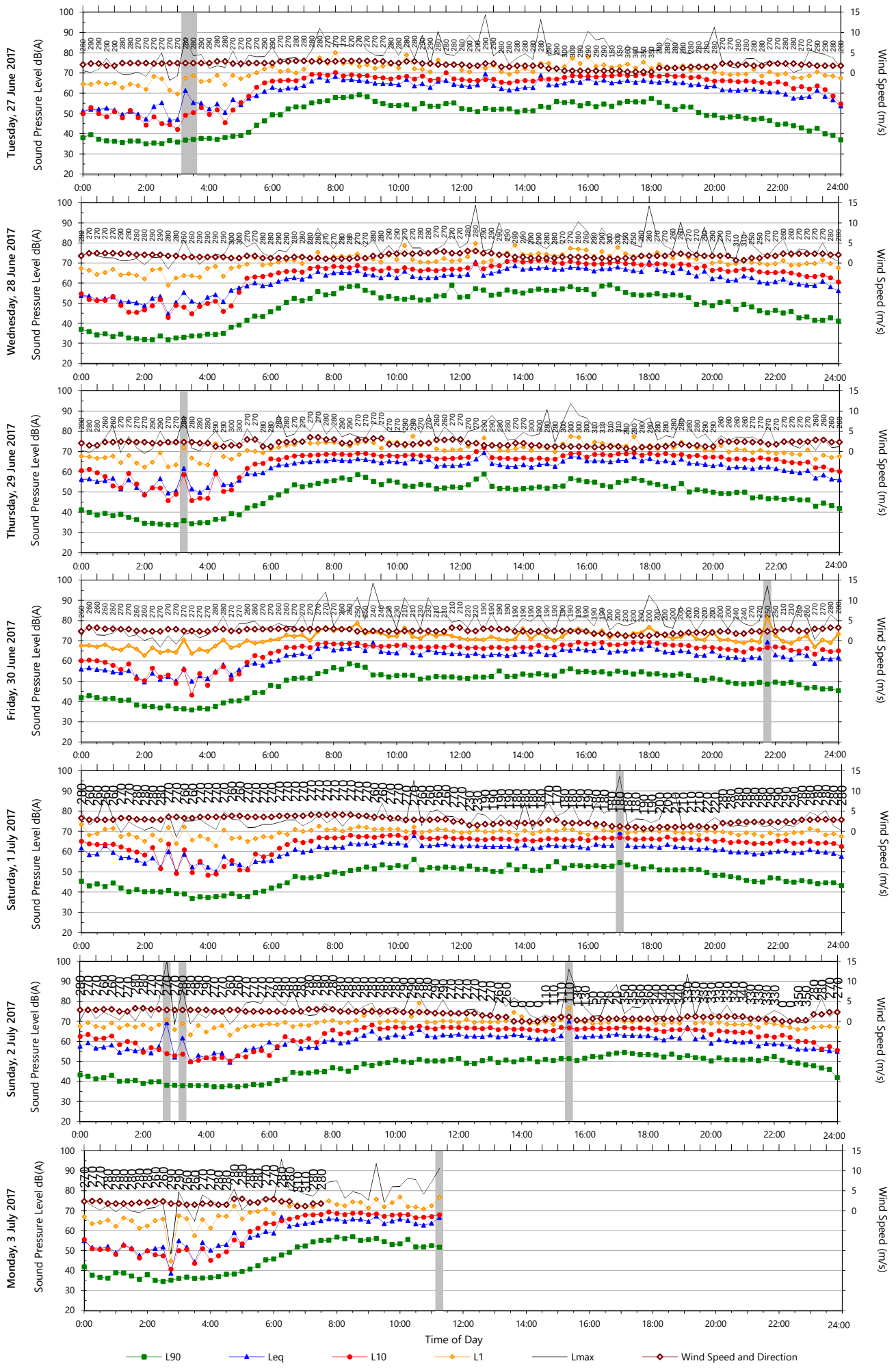




Unattended Monitoring Results

Location: 306 Miller Street, North Sydney




Tuesday, 27 June 2017
Wednesday, 28 June 2017
Thursday, 29 June 2017
Friday, 30 June 2017
Saturday, 1 July 2017
Sunday, 2 July 2017
Monday, 3 July 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L7
Address: 1/1 Bardsley Gardens, Crows Nest
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on Falcon Street.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	53	49	41	68	67	63

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	70	66	

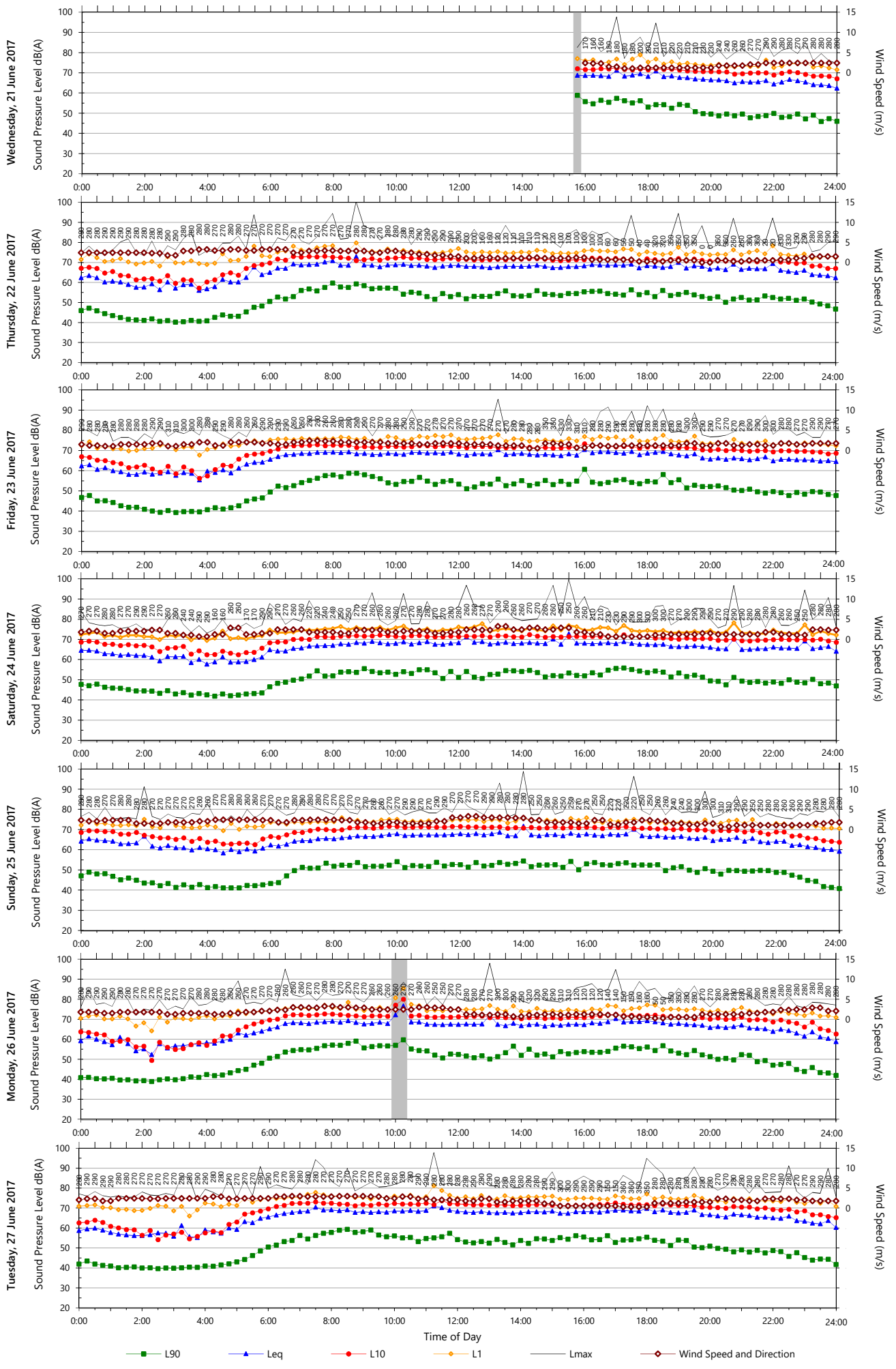
Notes:

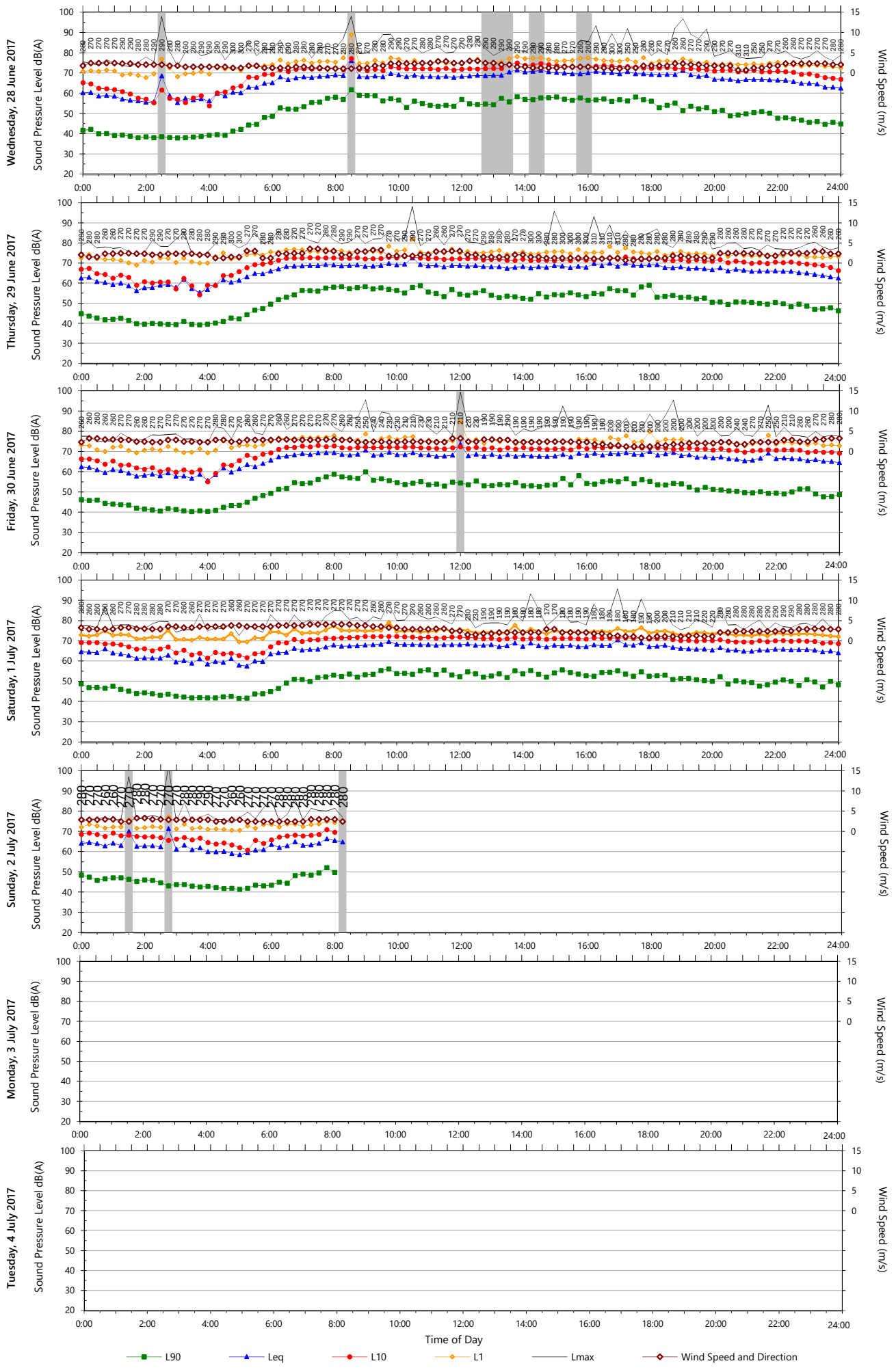
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Wednesday, 21 June 2017
Thursday, 22 June 2017
Friday, 23 June 2017
Saturday, 24 June 2017
Sunday, 25 June 2017
Monday, 26 June 2017
Tuesday, 27 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Wednesday, 28 June 2017
Thursday, 29 June 2017
Friday, 30 June 2017
Saturday, 1 July 2017
Sunday, 2 July 2017
Monday, 3 July 2017
Tuesday, 4 July 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L8
Address: 288 Falcon Street, Neutral Bay
Description: Noise monitor located in the front yard and positioned approximately 1m away from the front facade. Noise environment dominated by traffic on Falcon Street.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	**61**	**54**	**44**	**69**	**68**	**65**

Notes:

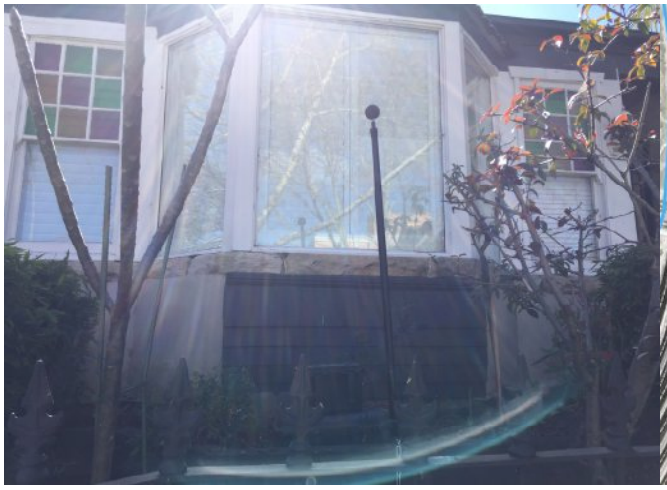
1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	**71**	**68**	

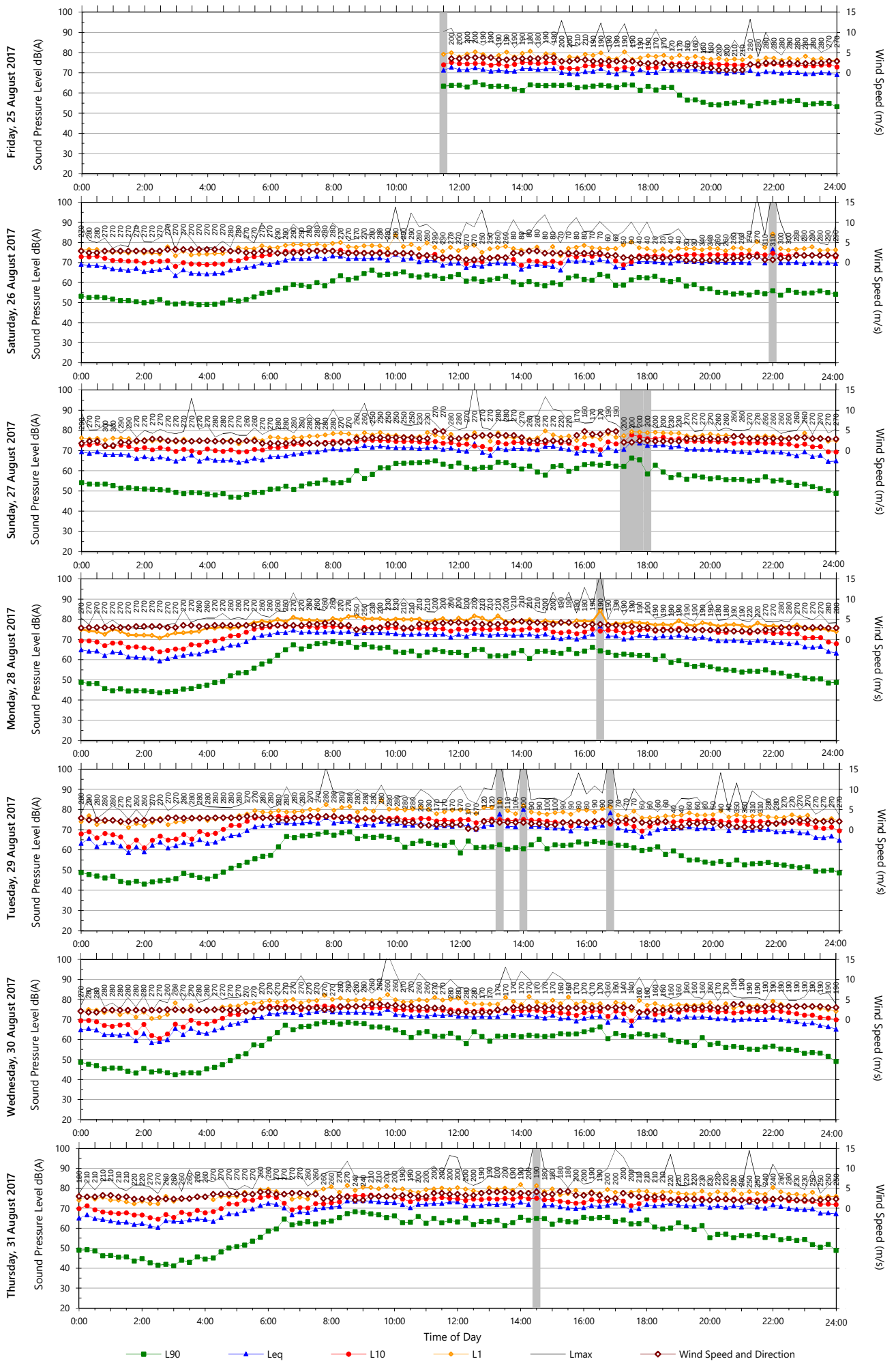
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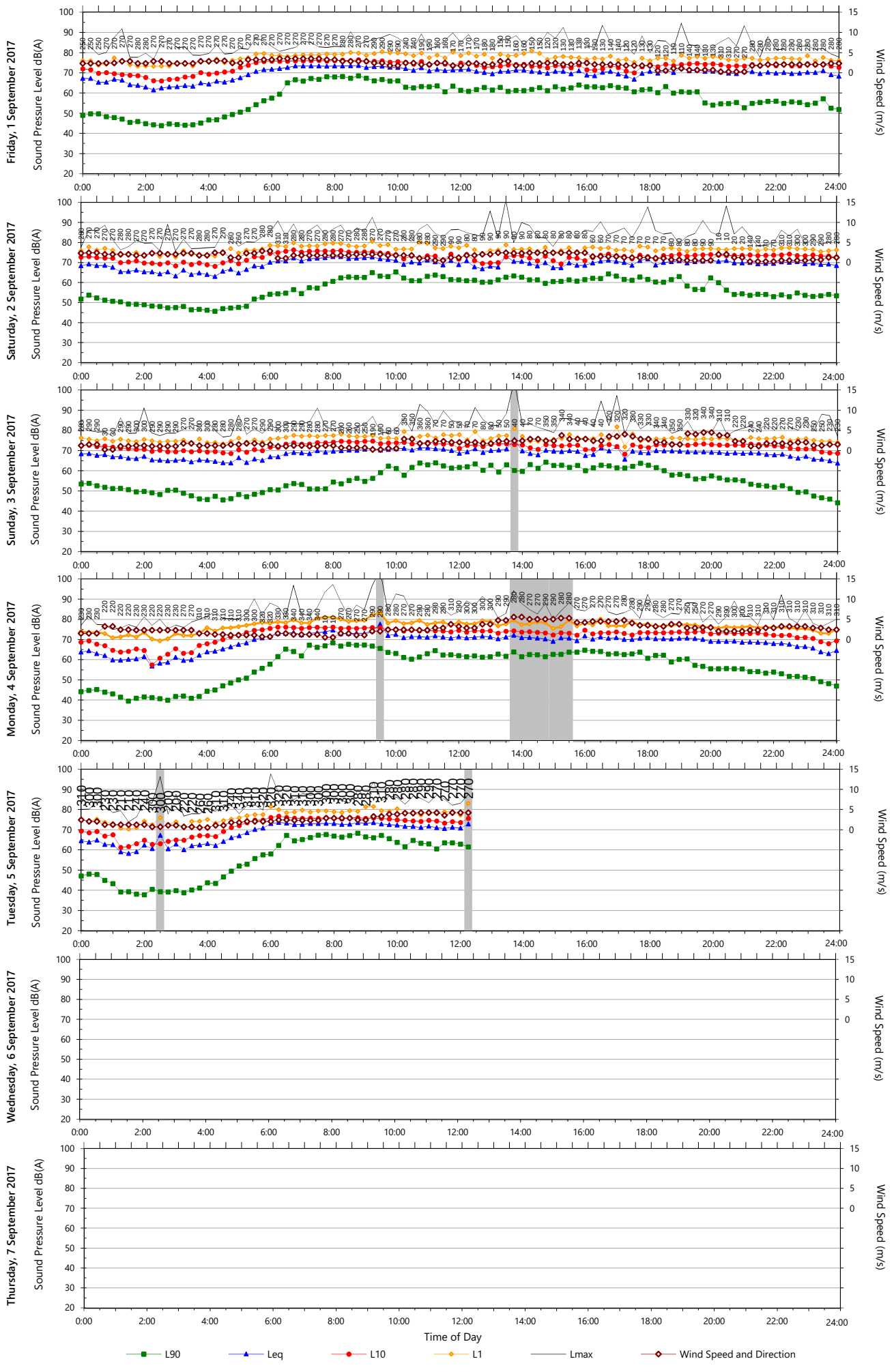
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Friday, 25 August 2017
Saturday, 26 August 2017
Sunday, 27 August 2017
Monday, 28 August 2017
Tuesday, 29 August 2017
Wednesday, 30 August 2017
Thursday, 31 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 1 September 2017
Saturday, 2 September 2017
Sunday, 3 September 2017
Monday, 4 September 2017
Tuesday, 5 September 2017
Wednesday, 6 September 2017
Thursday, 7 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L9
Address: 5 Military Road, Neutral Bay
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on Military Road.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	58	54	44	72	71	67

Notes:

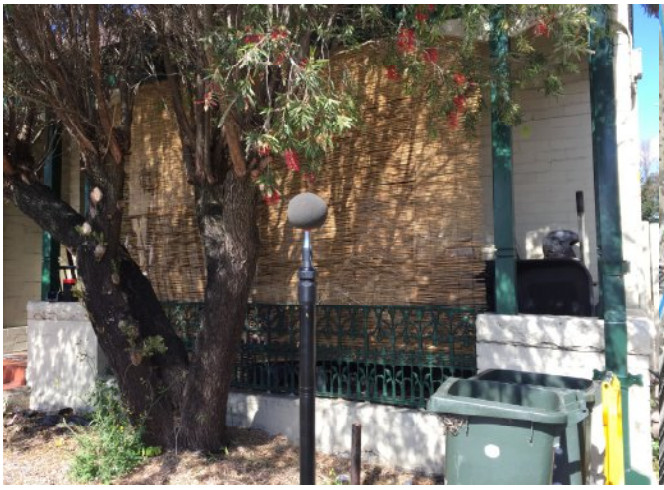
1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)		
	L_{Aeq} Noise Levels	
	Day[1]	Night[2]
Representative Week[3]	74	70

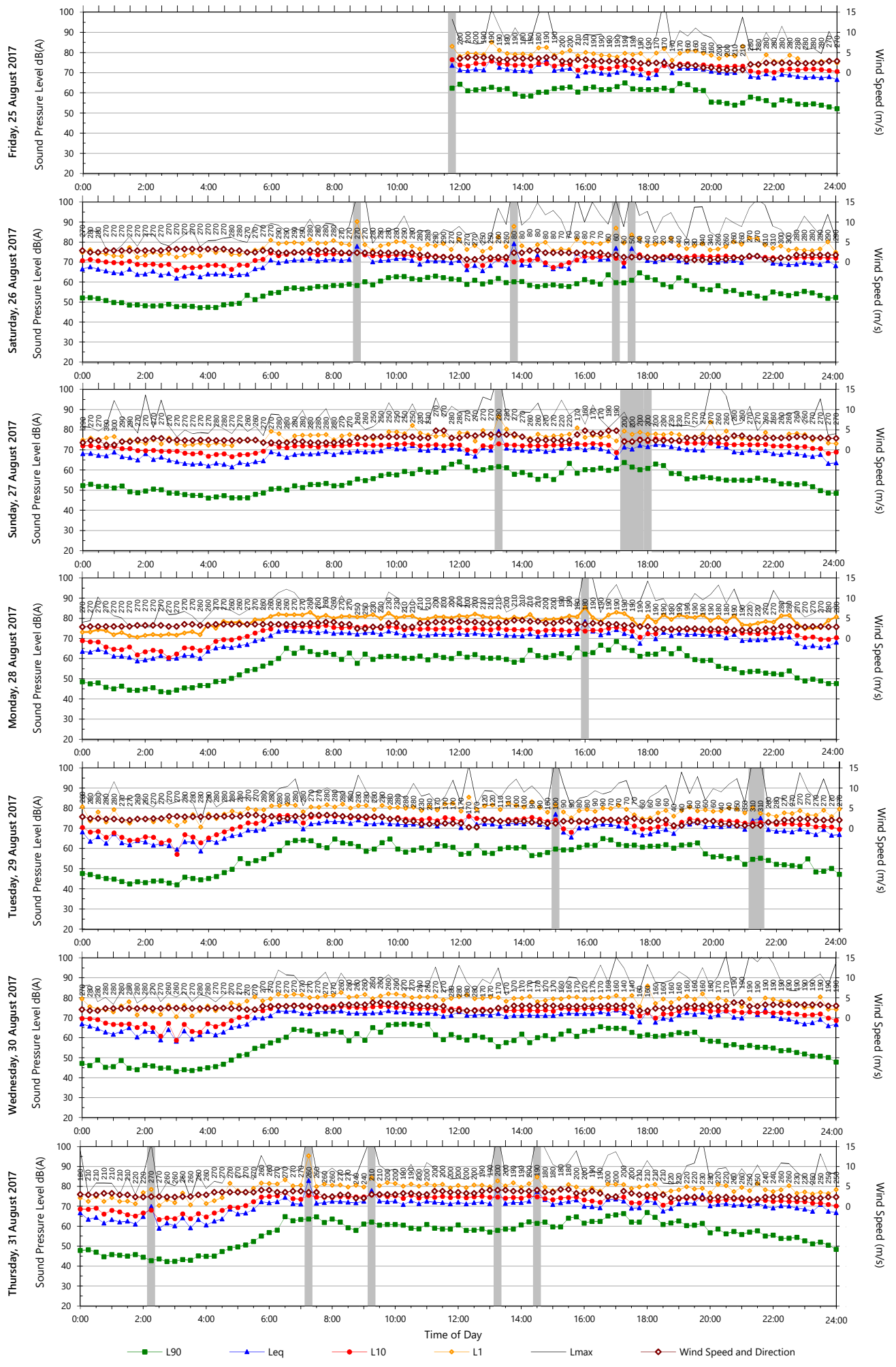
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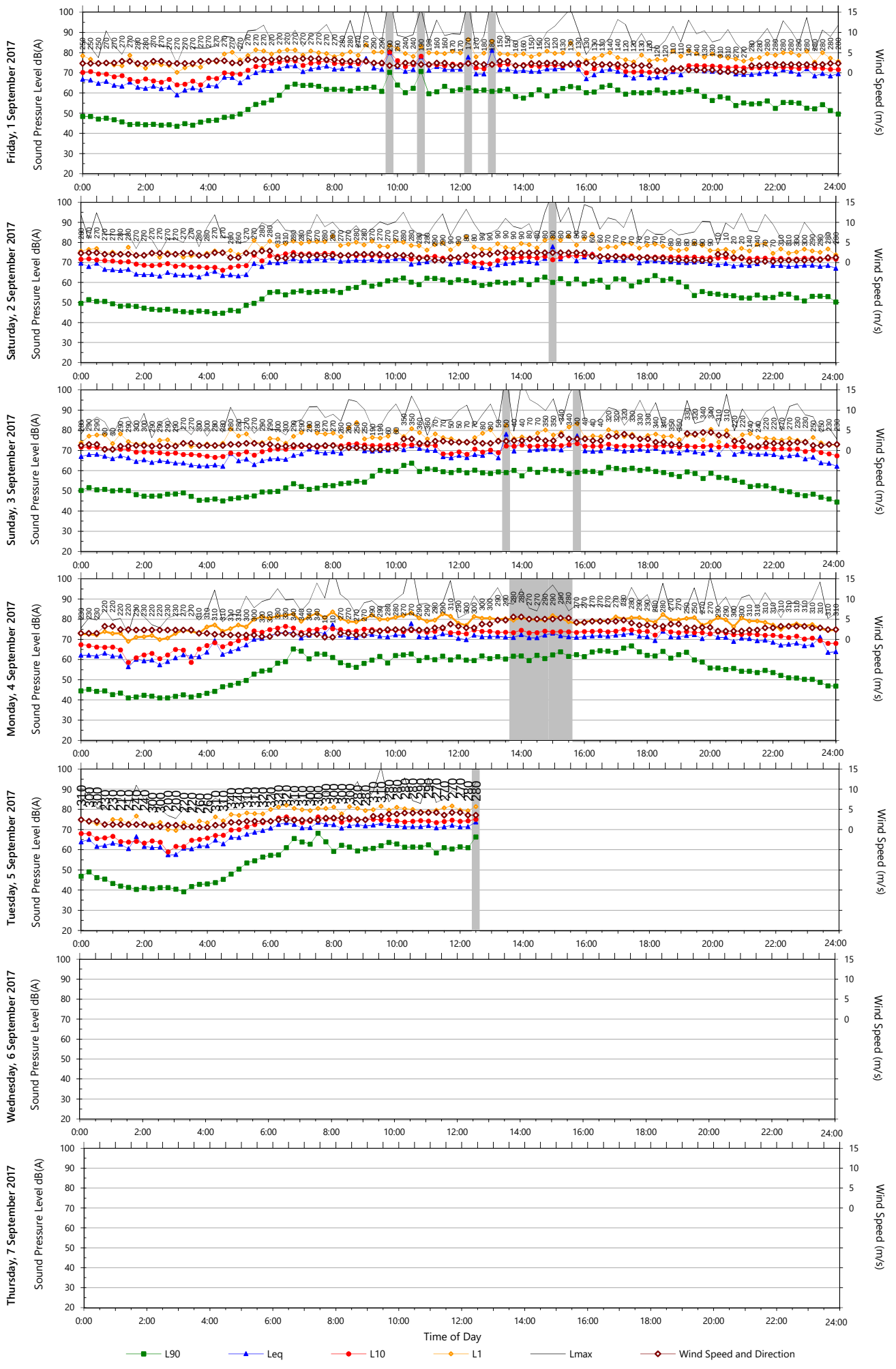
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Friday, 25 August 2017
Saturday, 26 August 2017
Sunday, 27 August 2017
Monday, 28 August 2017
Tuesday, 29 August 2017
Wednesday, 30 August 2017
Thursday, 31 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 1 September 2017
Saturday, 2 September 2017
Sunday, 3 September 2017
Monday, 4 September 2017
Tuesday, 5 September 2017
Wednesday, 6 September 2017
Thursday, 7 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L10
Address: 317 Ernest Street, Cammeray
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on Ernest Street.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	58	54	41	69	66	62

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	71	65	

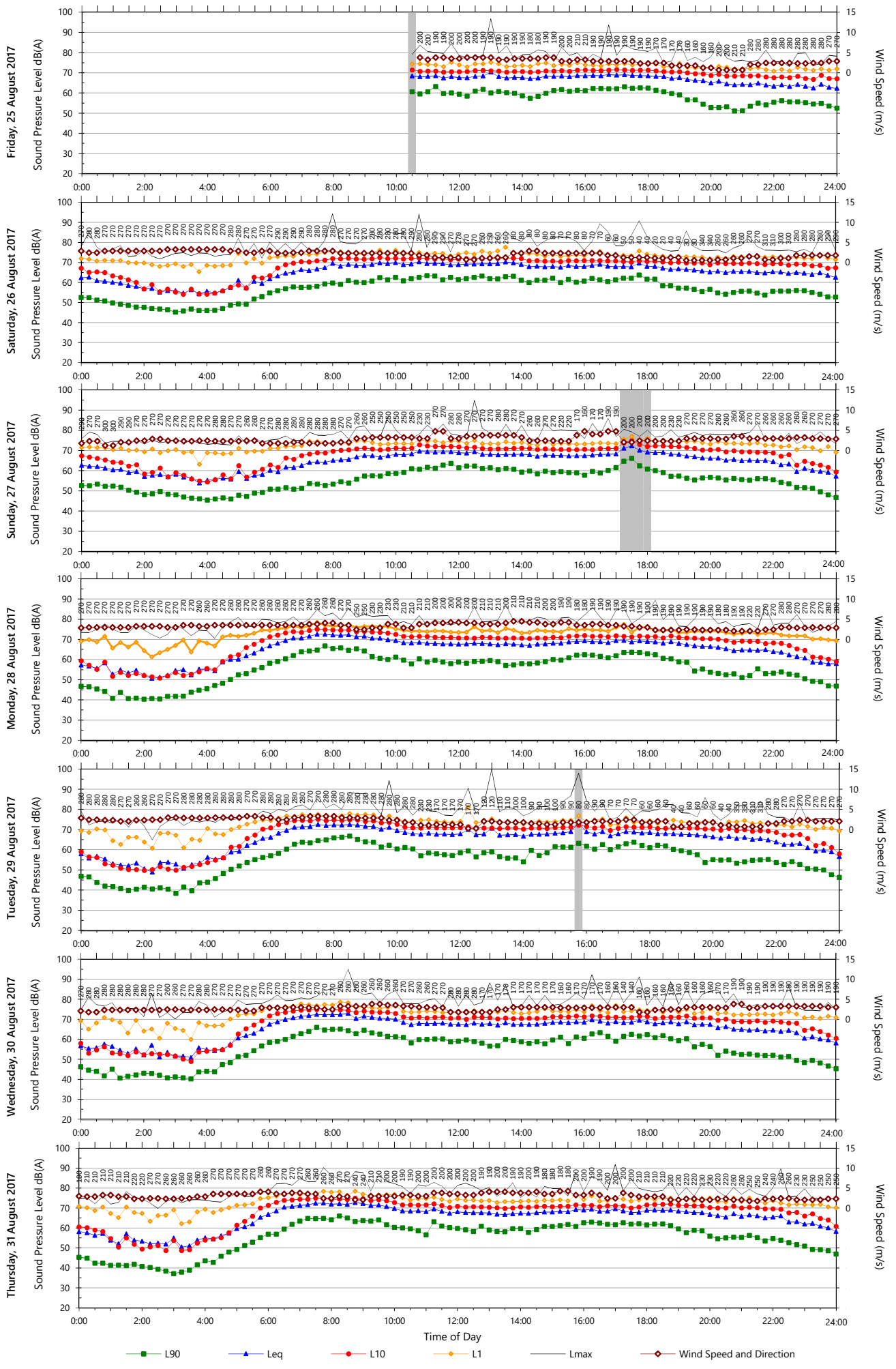
Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph

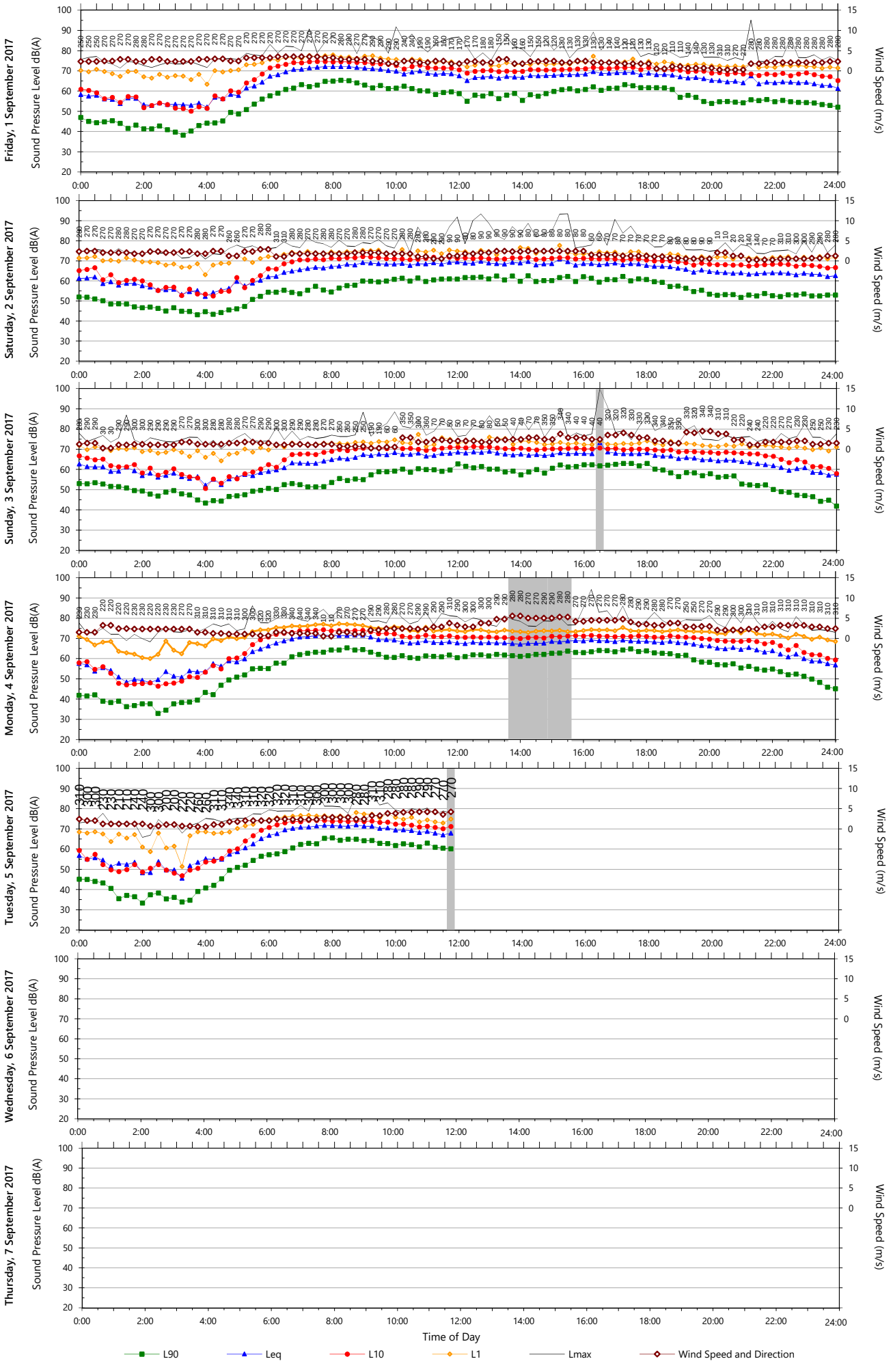





Friday, 25 August 2017
Saturday, 26 August 2017
Sunday, 27 August 2017
Monday, 28 August 2017
Tuesday, 29 August 2017
Wednesday, 30 August 2017
Thursday, 31 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results

Location: 317 Ernest St, Neutral Bay



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Monitoring ID: Location L11
Address: 225 Ernest Street, Cammeray
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on Ernest Street.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	56	52	37	68	66	61

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	70	64	

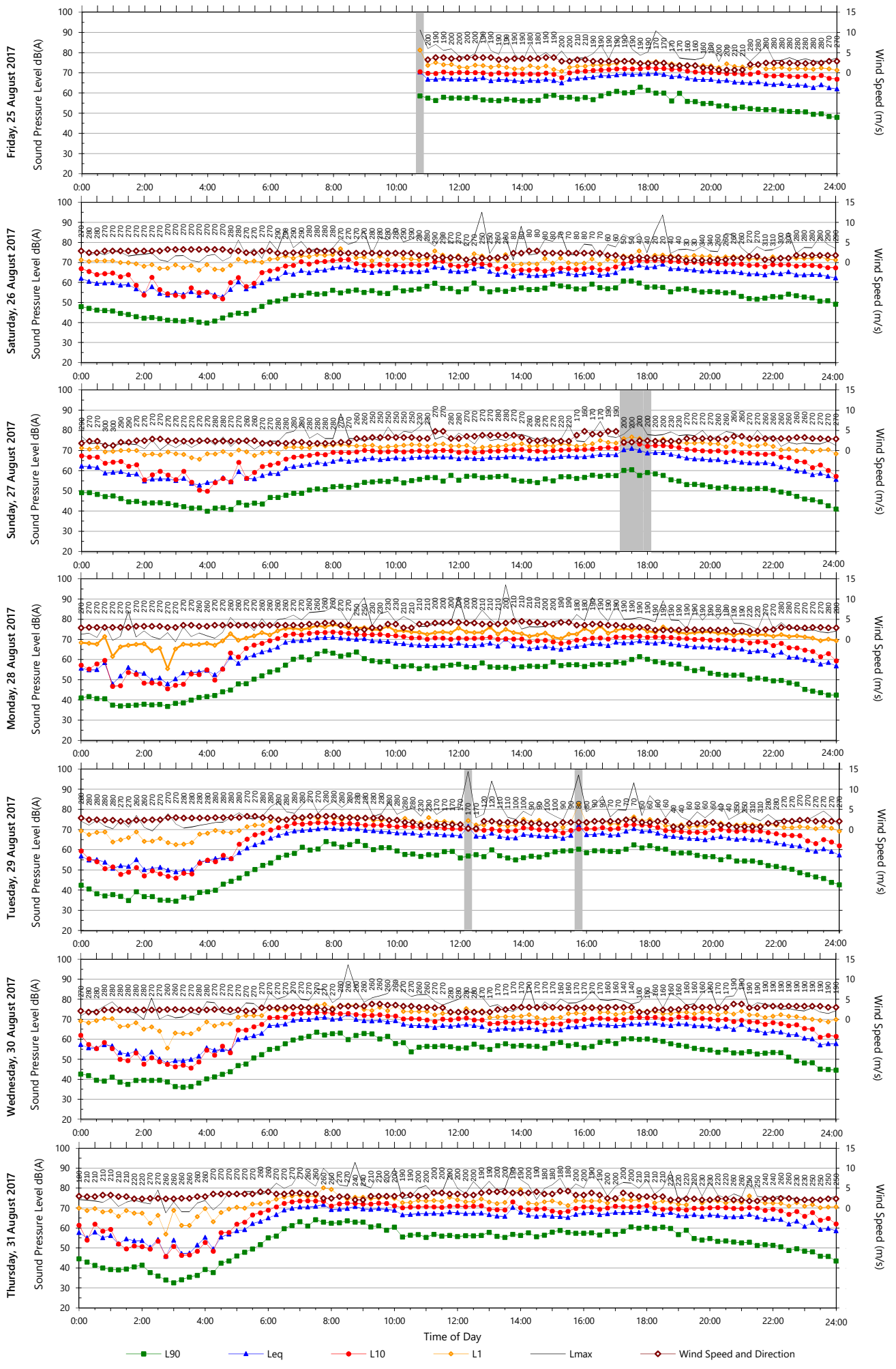
Notes:

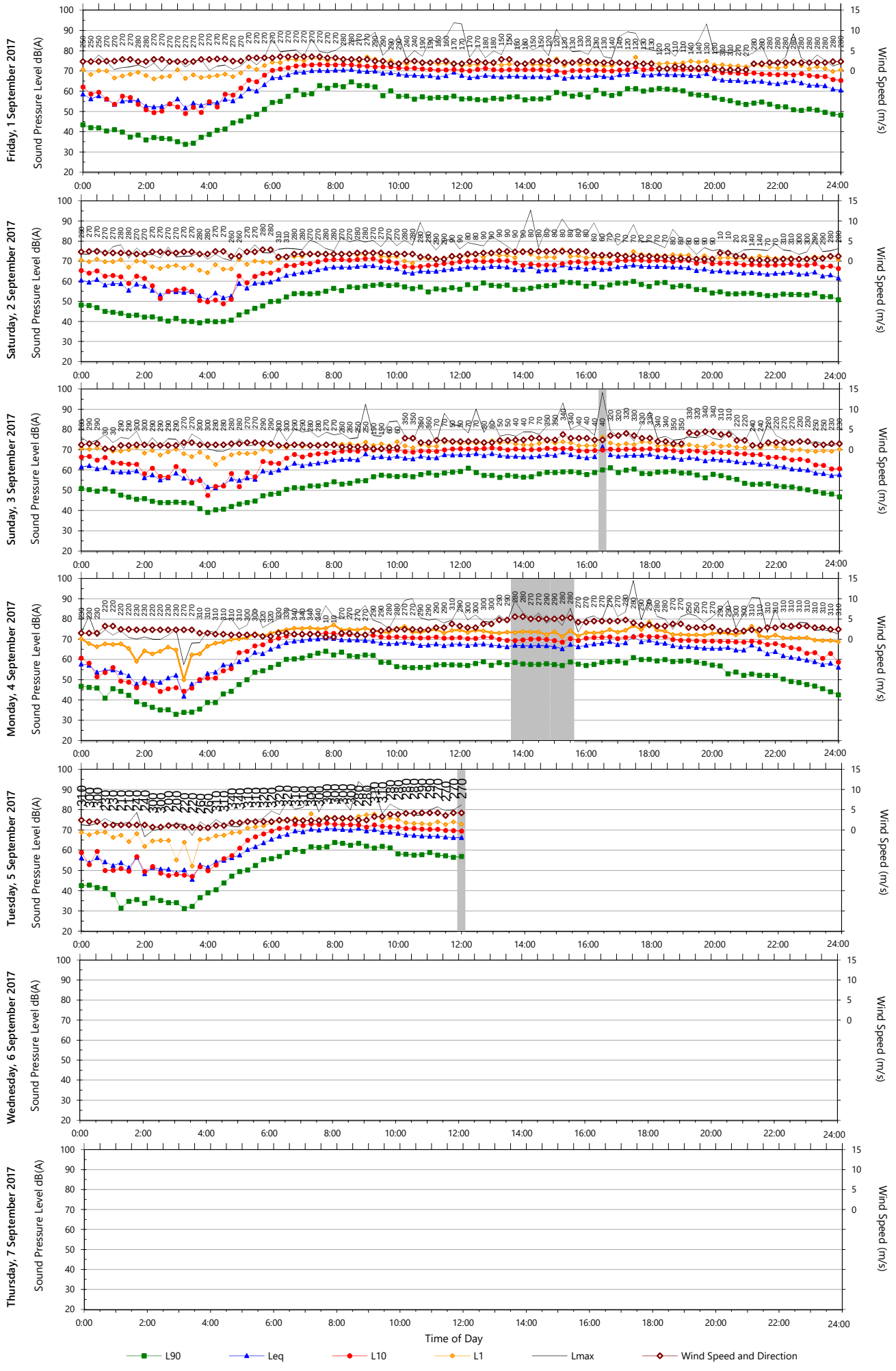
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Friday, 25 August 2017
Saturday, 26 August 2017
Sunday, 27 August 2017
Monday, 28 August 2017
Tuesday, 29 August 2017
Wednesday, 30 August 2017
Thursday, 31 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 1 September 2017
Saturday, 2 September 2017
Sunday, 3 September 2017
Monday, 4 September 2017
Tuesday, 5 September 2017
Wednesday, 6 September 2017
Thursday, 7 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L12
Address: 77 Rosalind Street, Cammeray
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on the Warringah Freeway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	58	55	43	62	60	57

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	64	59	

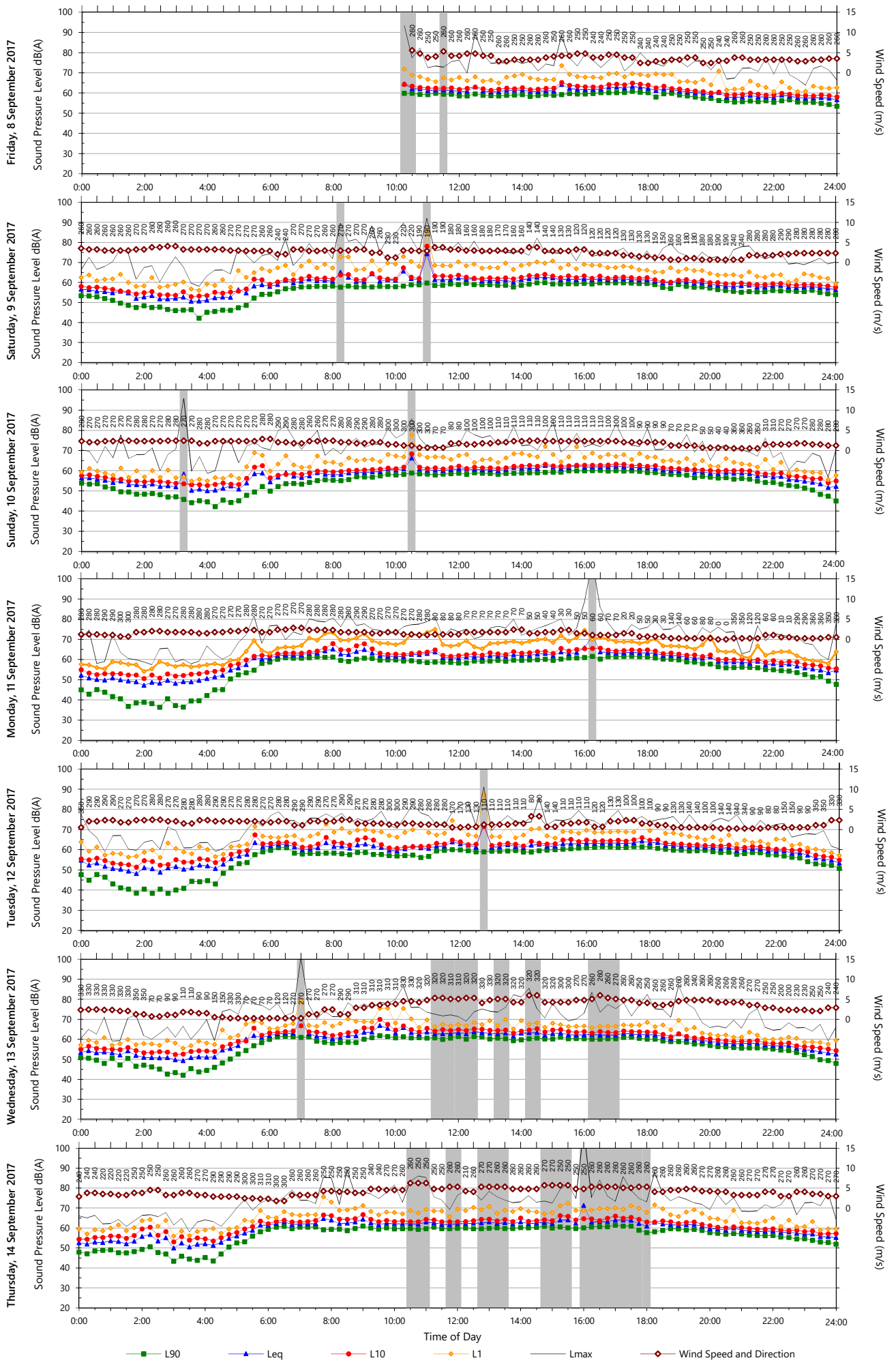
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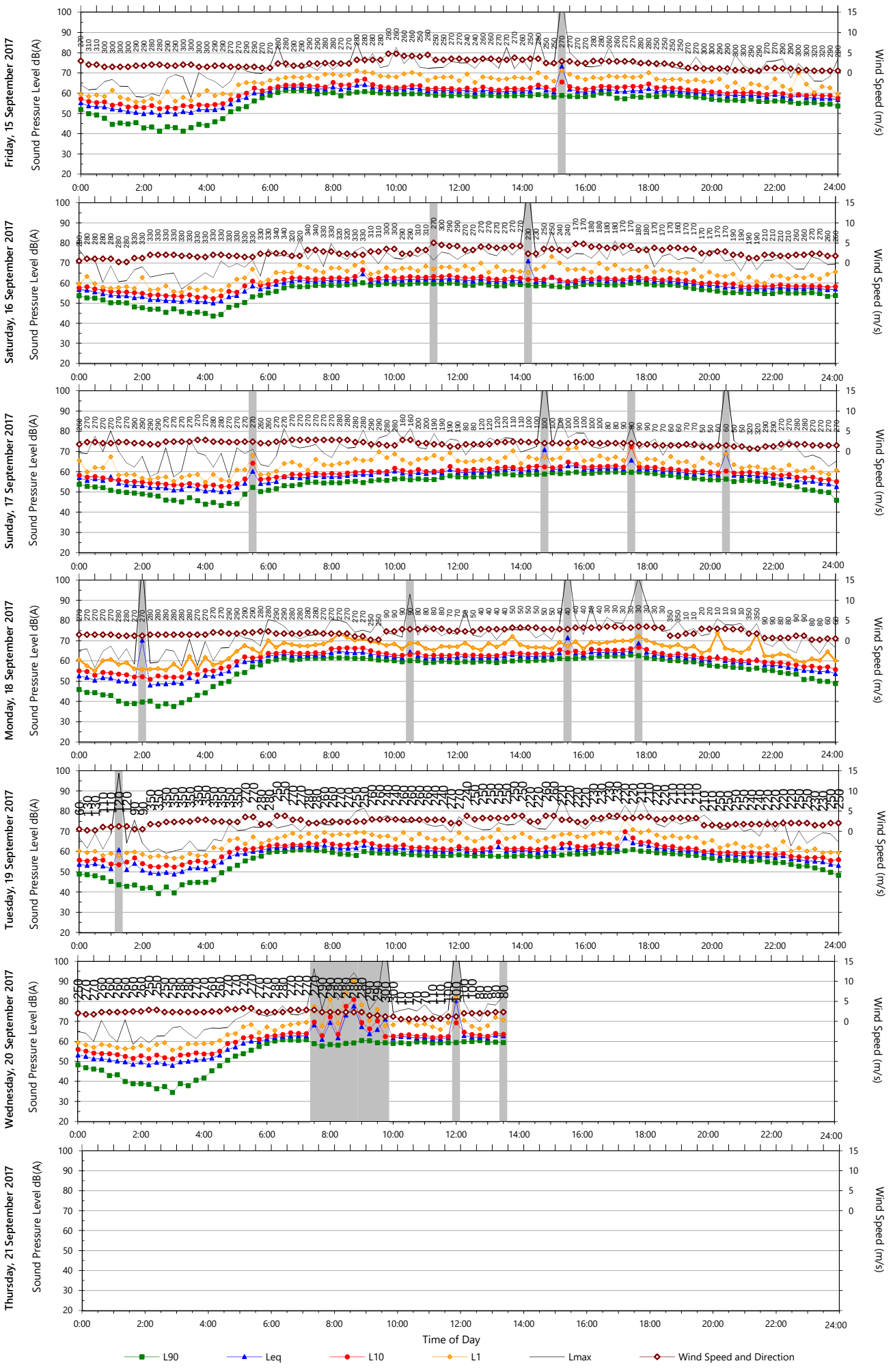
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Friday, 8 September 2017
Saturday, 9 September 2017
Sunday, 10 September 2017
Monday, 11 September 2017
Tuesday, 12 September 2017
Wednesday, 13 September 2017
Thursday, 14 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 15 September 2017
Saturday, 16 September 2017
Sunday, 17 September 2017
Monday, 18 September 2017
Tuesday, 19 September 2017
Wednesday, 20 September 2017
Thursday, 21 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L13
Address: 53 Bellevue Street, Cammeray
Description: Noise monitor located in the western side yard and positioned in the free-field. Noise environment dominated by traffic on the Warringah Freeway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	64	63	47	67	67	64

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	70	66	

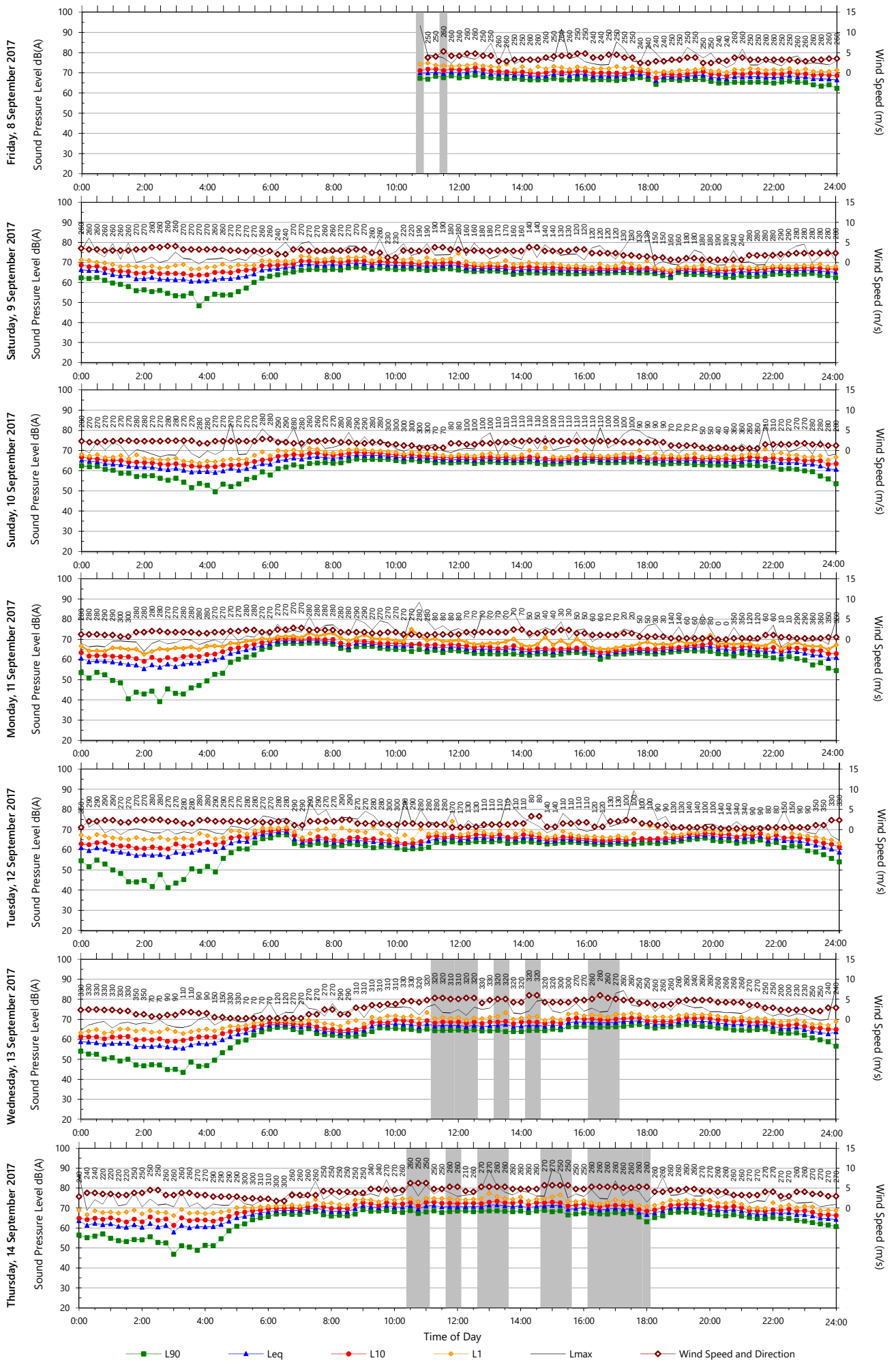
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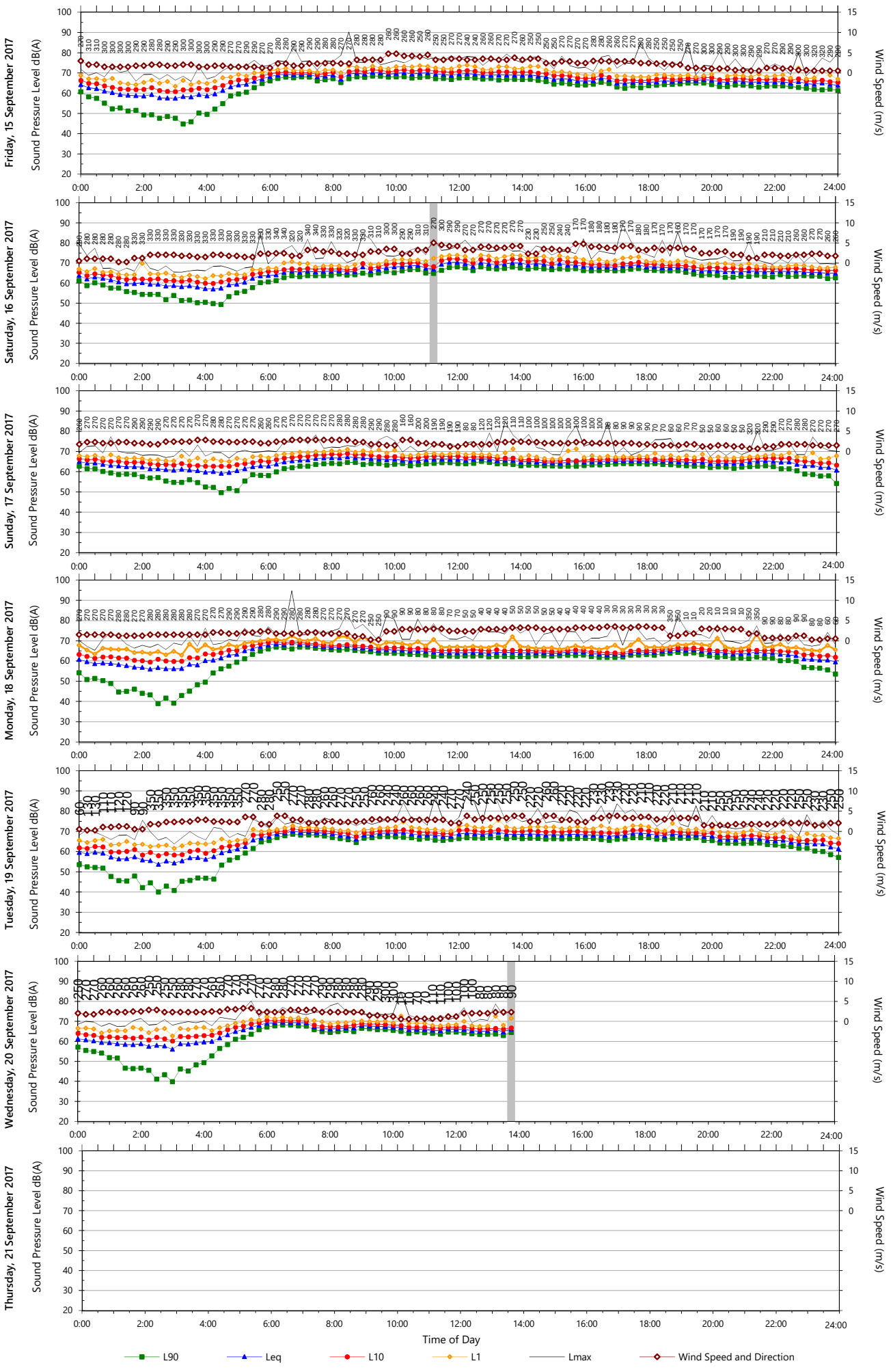
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Friday, 8 September 2017
Saturday, 9 September 2017
Sunday, 10 September 2017
Monday, 11 September 2017
Tuesday, 12 September 2017
Wednesday, 13 September 2017
Thursday, 14 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 15 September 2017
Saturday, 16 September 2017
Sunday, 17 September 2017
Monday, 18 September 2017
Tuesday, 19 September 2017
Wednesday, 20 September 2017
Thursday, 21 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L14
Address: 12 Warringa Road, Cammeray
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by general neighbourhood noise and natural sounds.

Background & Ambient Noise Monitoring Results

	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	**47**	**45**	**37**	**54**	**51**	**48**

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

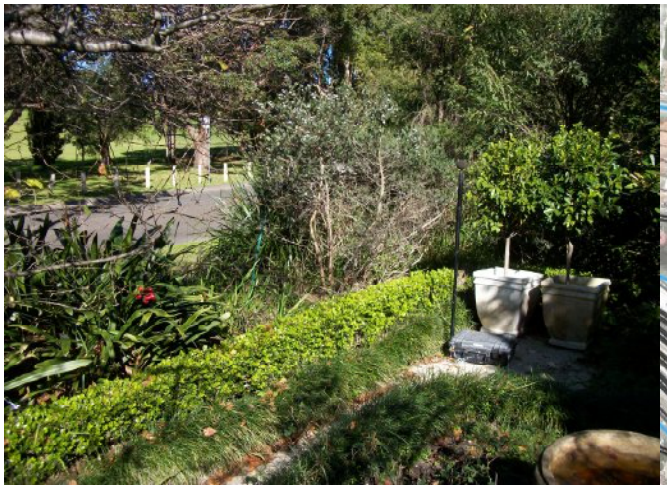
Road Monitoring Results (at one metre from façade)

	L_{Aeq} Noise Levels	
	Day[1]	Night[2]
Representative Week[3]	-	-

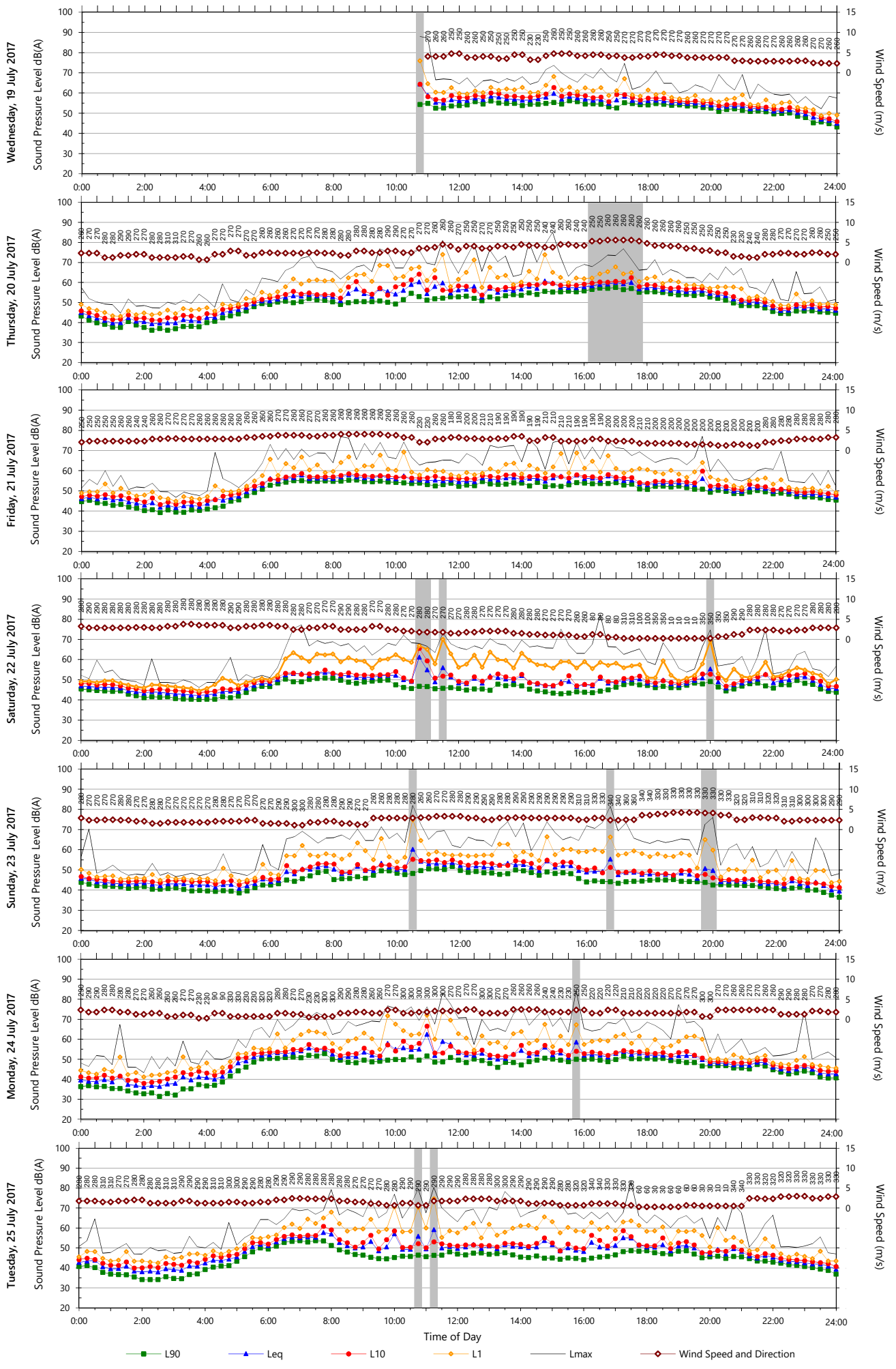
Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph

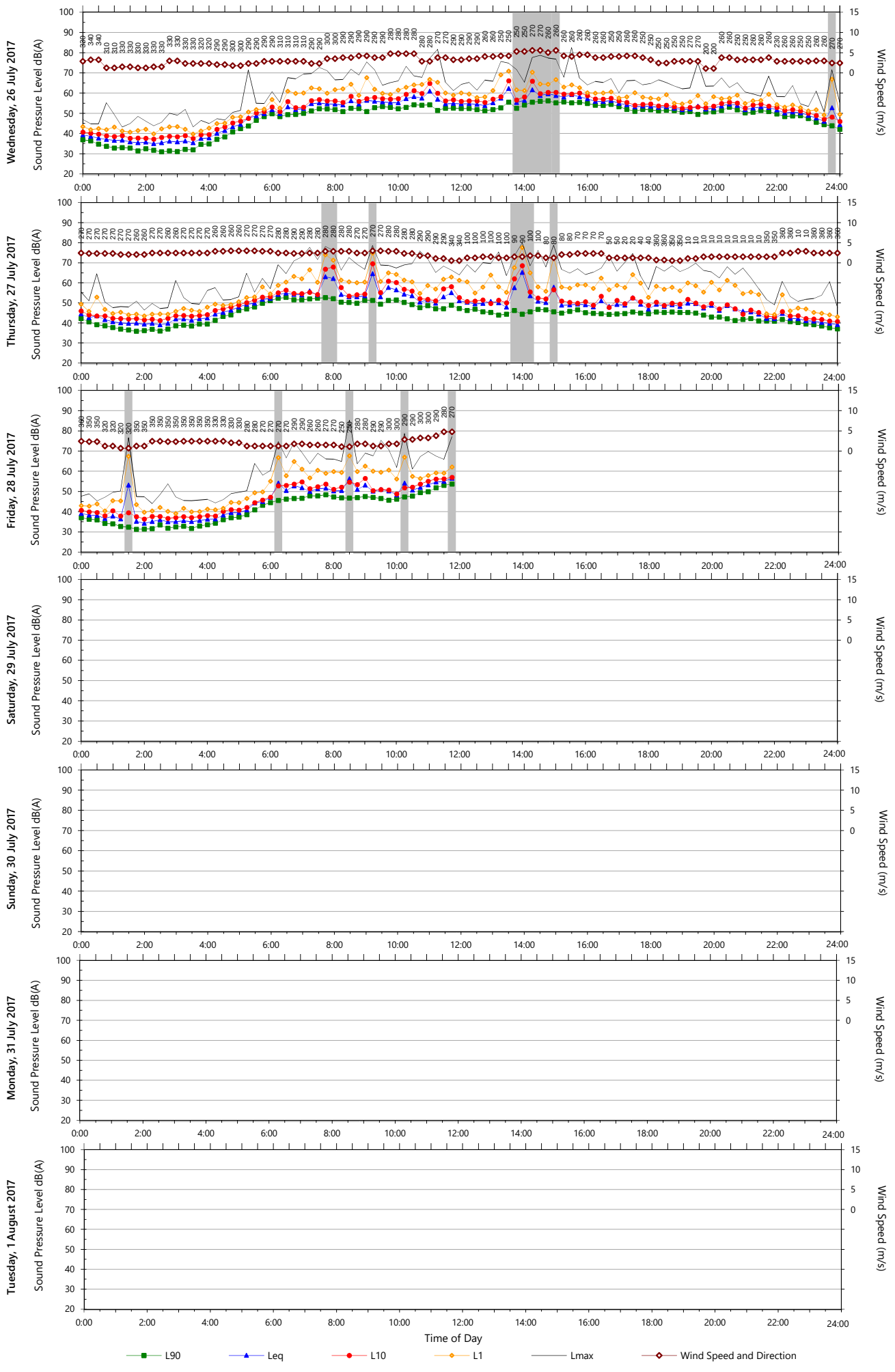





Wednesday, 19 July 2017
Thursday, 20 July 2017
Friday, 21 July 2017
Saturday, 22 July 2017
Sunday, 23 July 2017
Monday, 24 July 2017
Tuesday, 25 July 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results

Location: 12 Warringah Road, Cammeray



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Monitoring ID: Location L15
Address: 57 Park Avenue, Cremorne
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by general neighbourhood noise and natural sounds.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	49	48	39	59	57	54

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

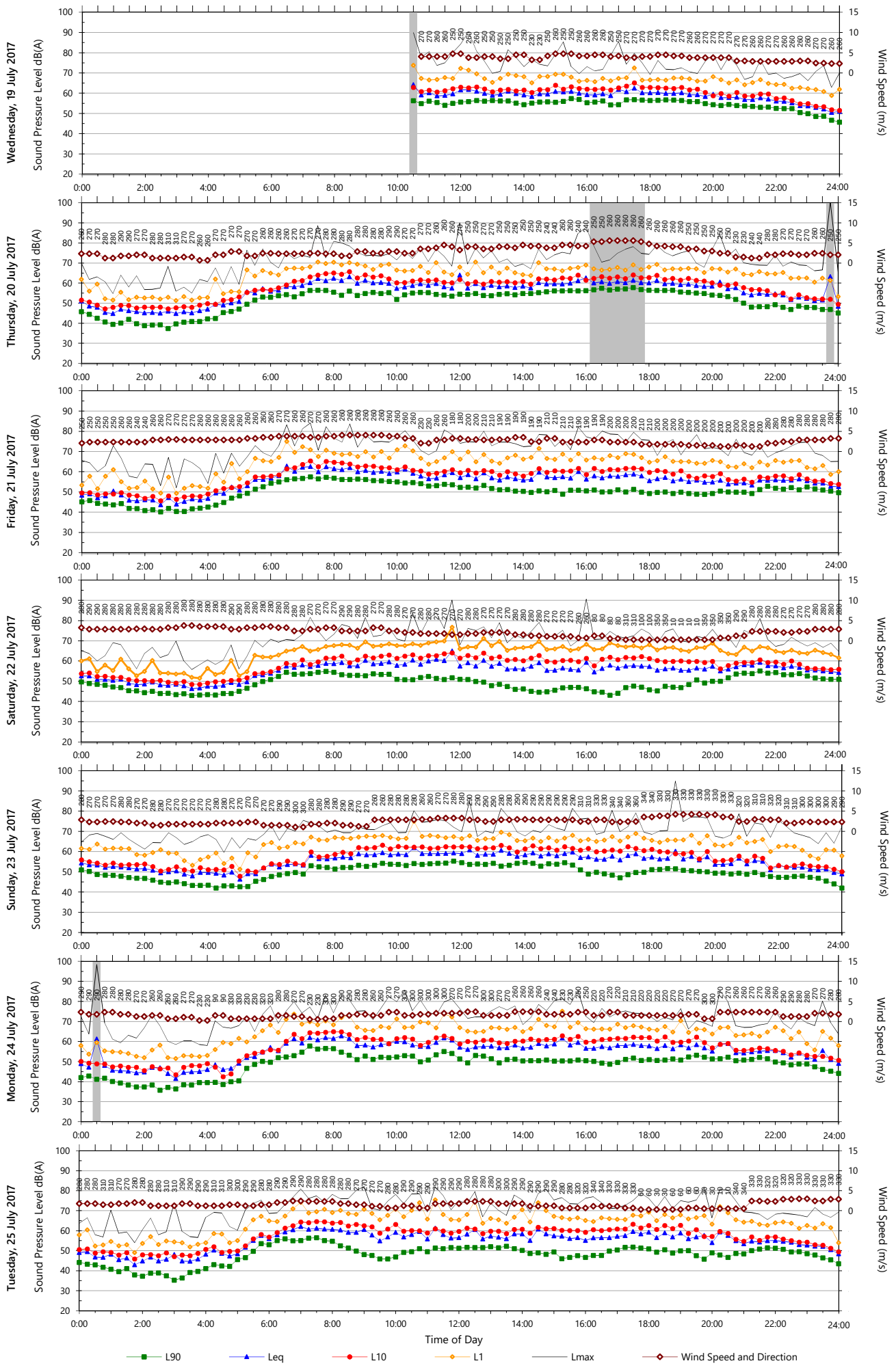
Notes:

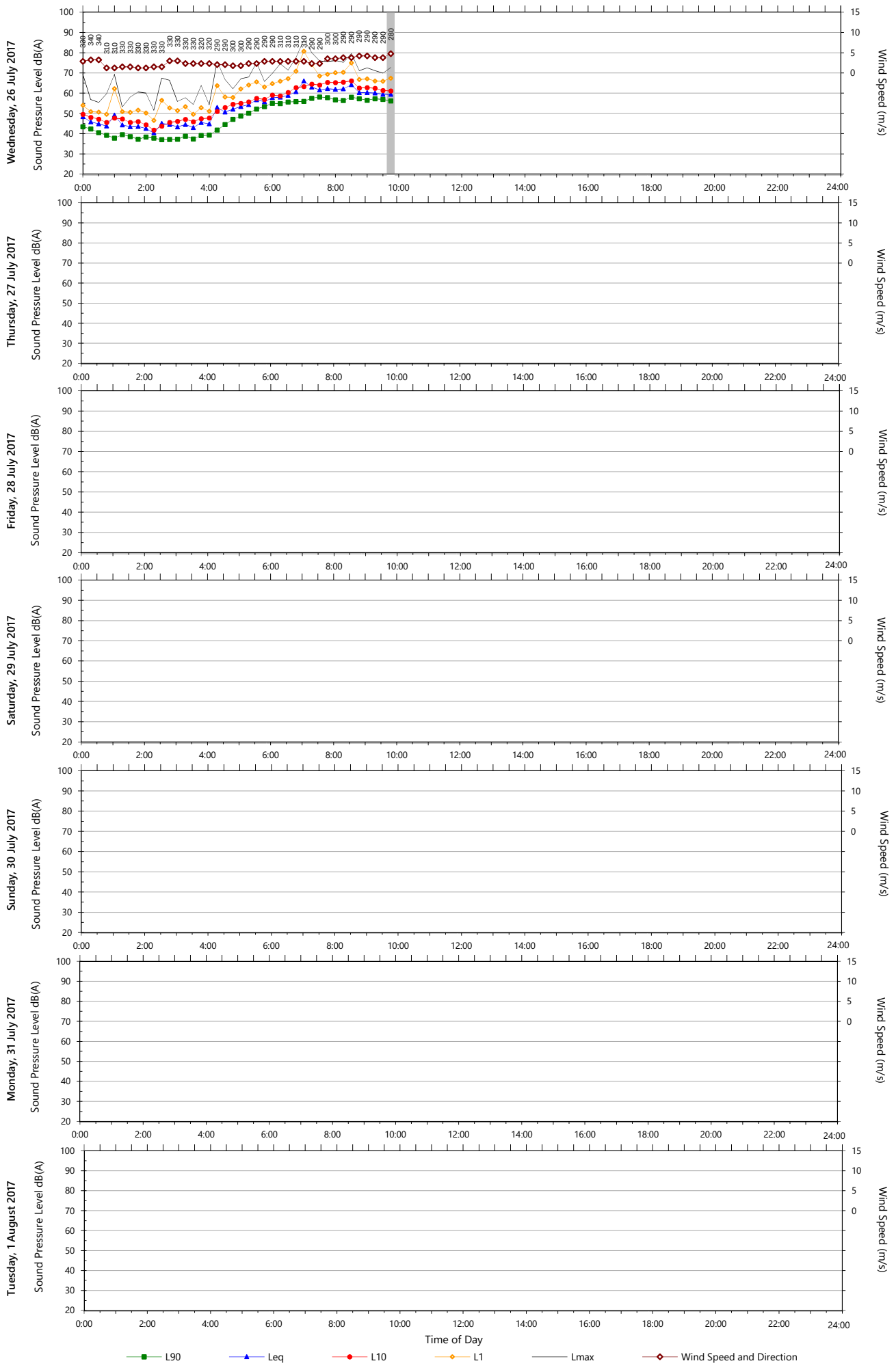
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Wednesday, 19 July 2017
Thursday, 20 July 2017
Friday, 21 July 2017
Saturday, 22 July 2017
Sunday, 23 July 2017
Monday, 24 July 2017
Tuesday, 25 July 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Wednesday, 26 July 2017
Thursday, 27 July 2017
Friday, 28 July 2017
Saturday, 29 July 2017
Sunday, 30 July 2017
Monday, 31 July 2017
Tuesday, 1 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L16
Address: 18/22-24 Donnelly Road, Crows Nest
Description: Noise monitor located in the rear yard and positioned in the free-field. Noise environment dominated by traffic on the Warringah Freeway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	58	56	38	62	61	58

Notes:

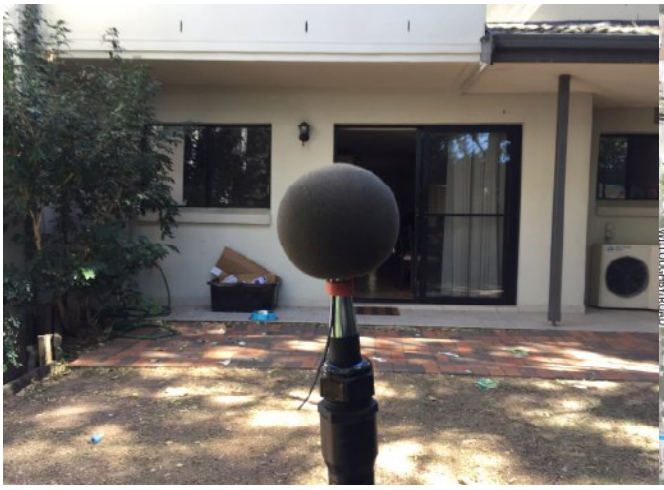
1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	65	60	

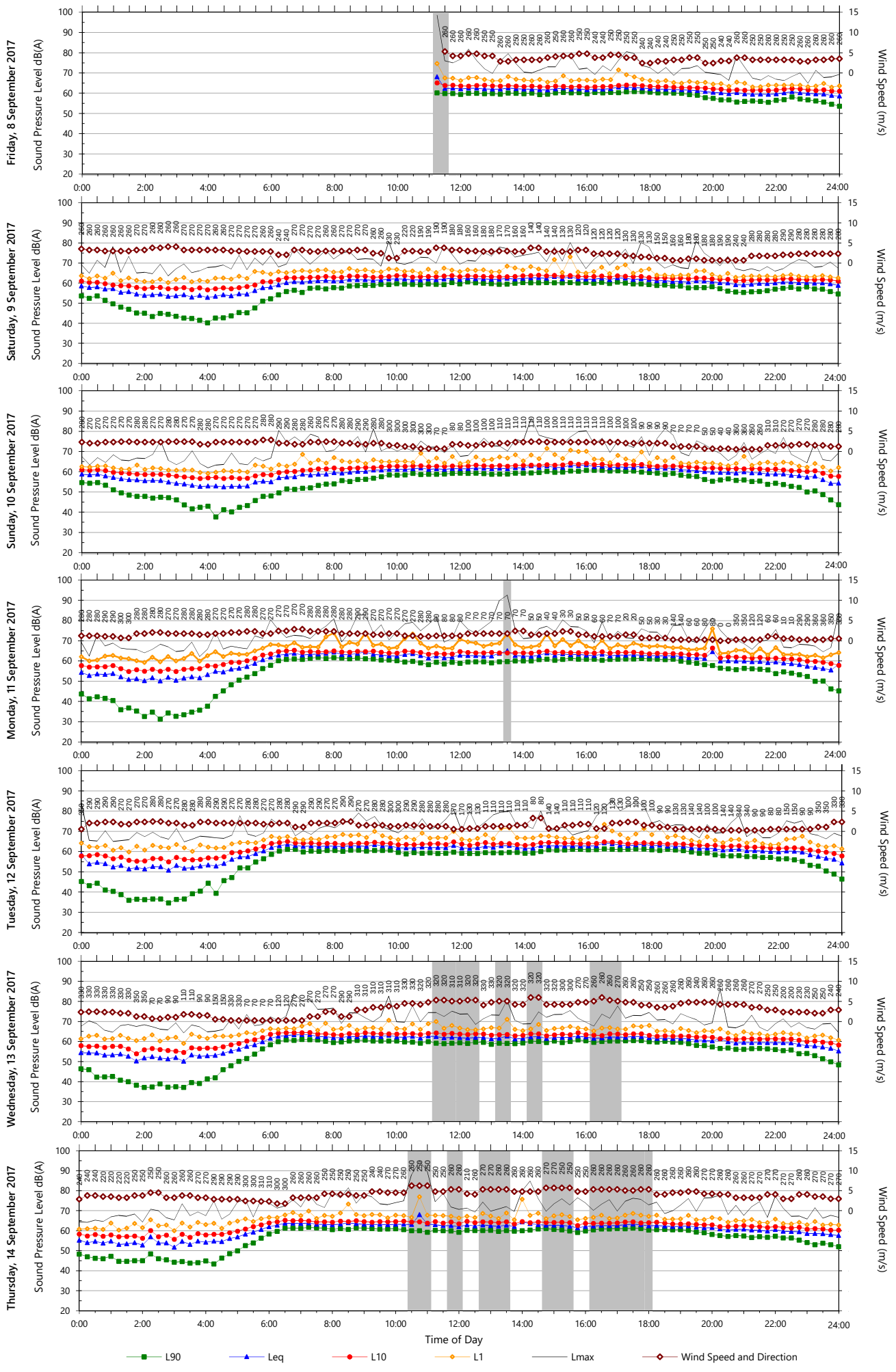
Notes:

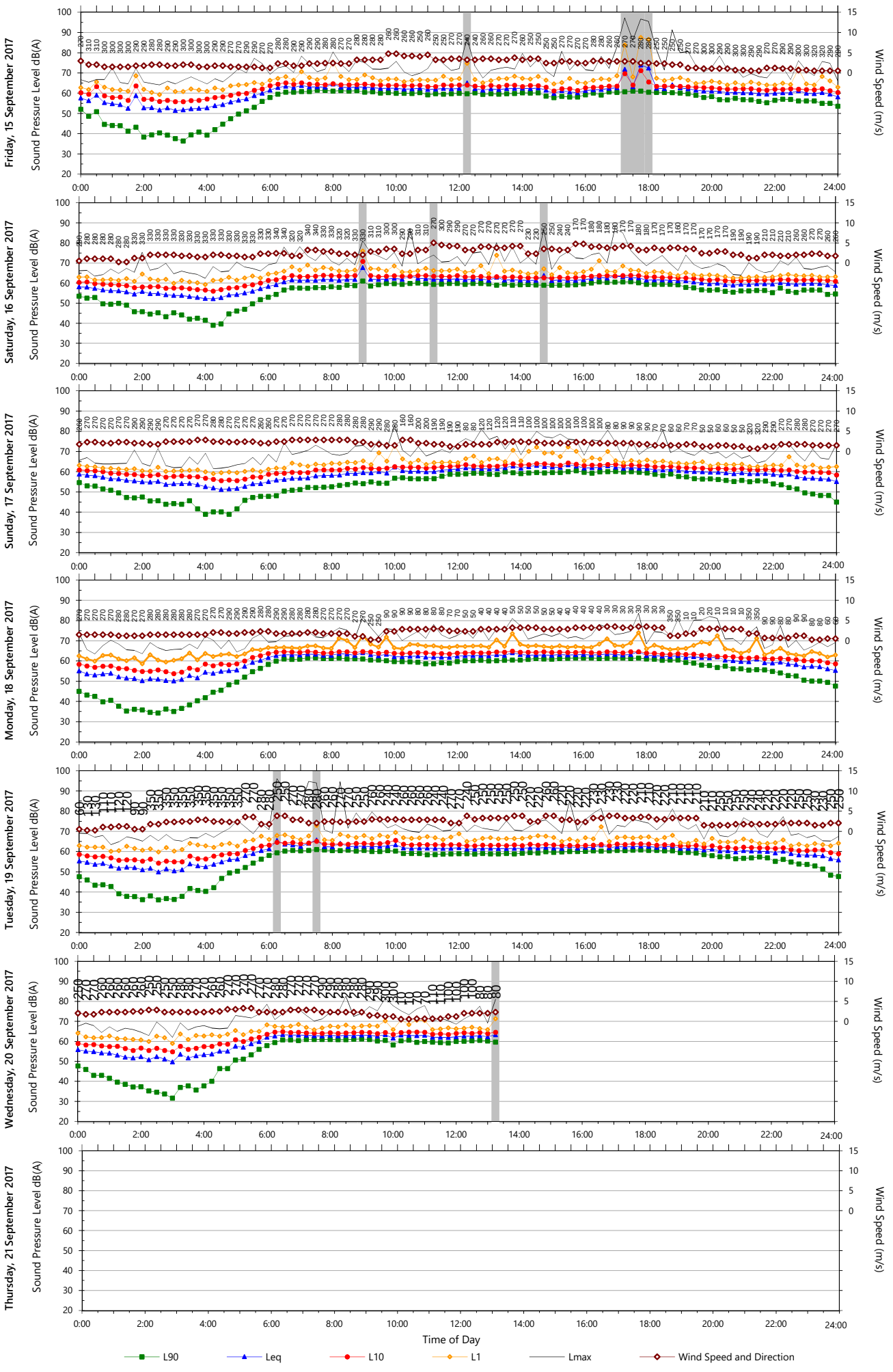
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Friday, 8 September 2017
Saturday, 9 September 2017
Sunday, 10 September 2017
Monday, 11 September 2017
Tuesday, 12 September 2017
Wednesday, 13 September 2017
Thursday, 14 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 15 September 2017
Saturday, 16 September 2017
Sunday, 17 September 2017
Monday, 18 September 2017
Tuesday, 19 September 2017
Wednesday, 20 September 2017
Thursday, 21 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L17
Address: 79 Brook Street, Naremburn
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on Brook Street.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	56	49	37	71	69	65

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	73	67	

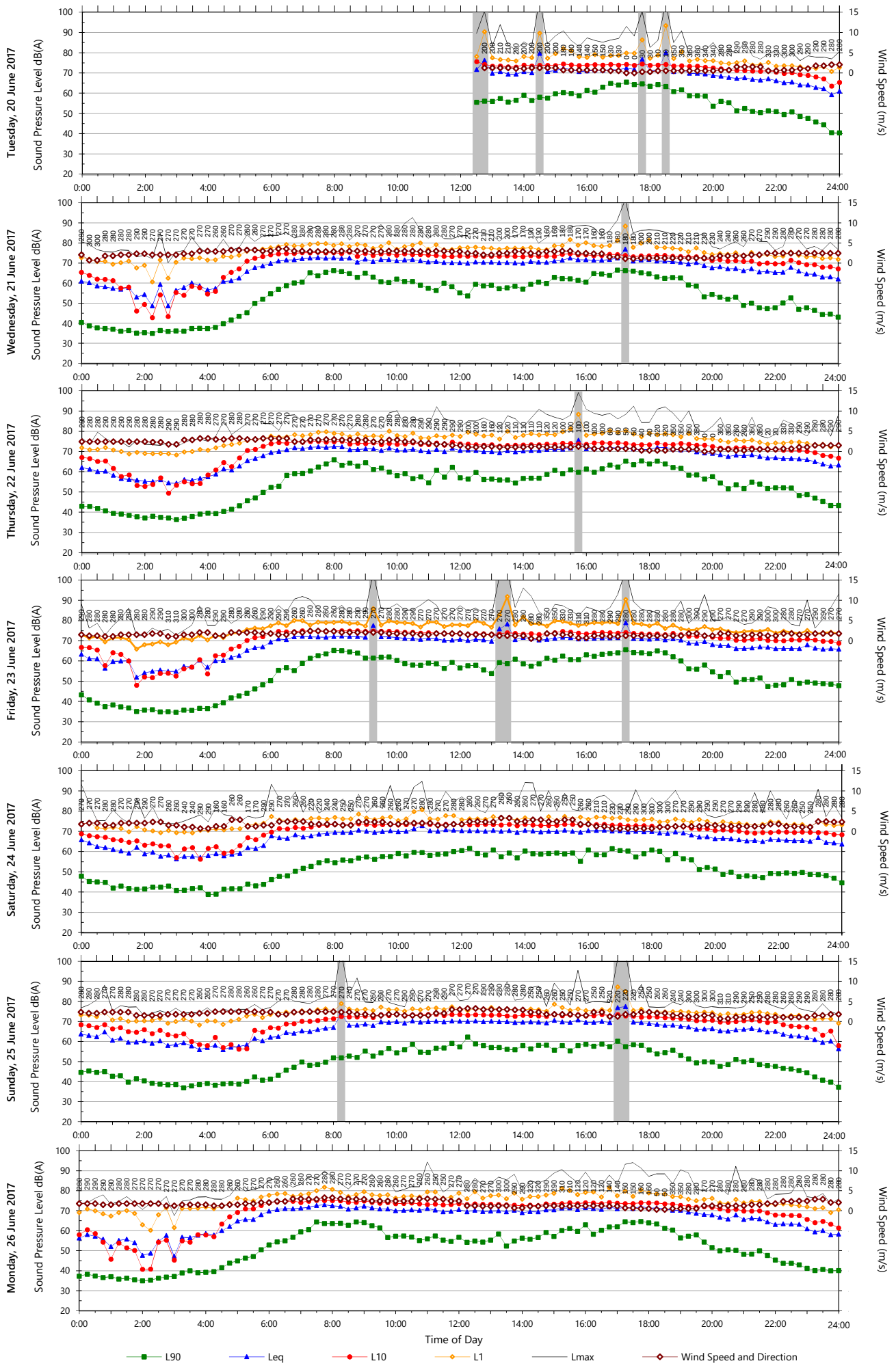
Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

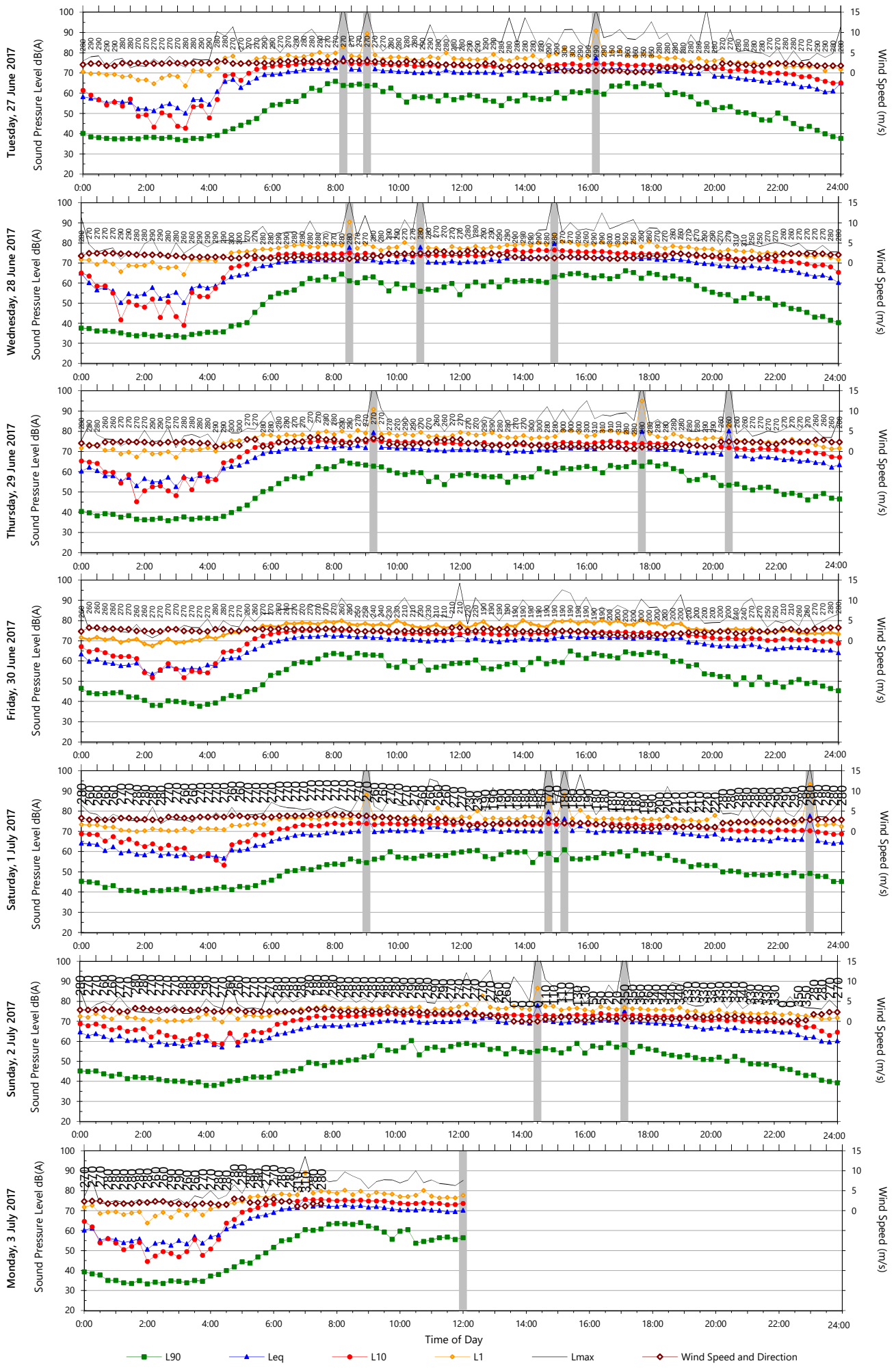
Logger Location	Aerial Photograph






Tuesday, 20 June 2017
Wednesday, 21 June 2017
Thursday, 22 June 2017
Friday, 23 June 2017
Saturday, 24 June 2017
Sunday, 25 June 2017
Monday, 26 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results **Location: 79 Brook Street, Naremburn**



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Monitoring ID: Location L18
Address: 20/2 Parkes Road, Artarmon
Description: Noise monitor located on the second-floor balcony in the free-field. Noise environment dominated by traffic on the Warringah Freeway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	67	63	46	72	70	67

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	74	69	

Notes:

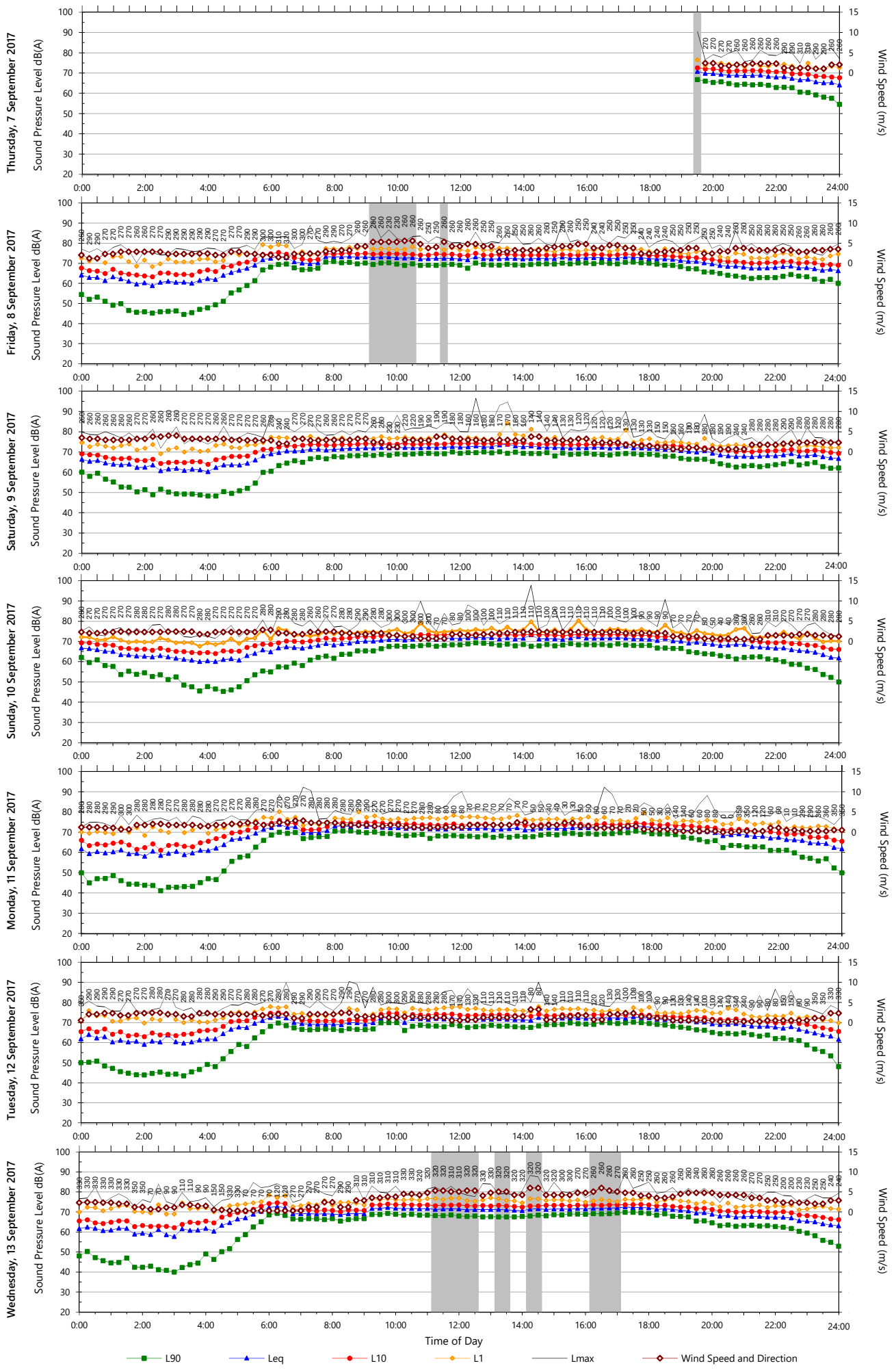
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph

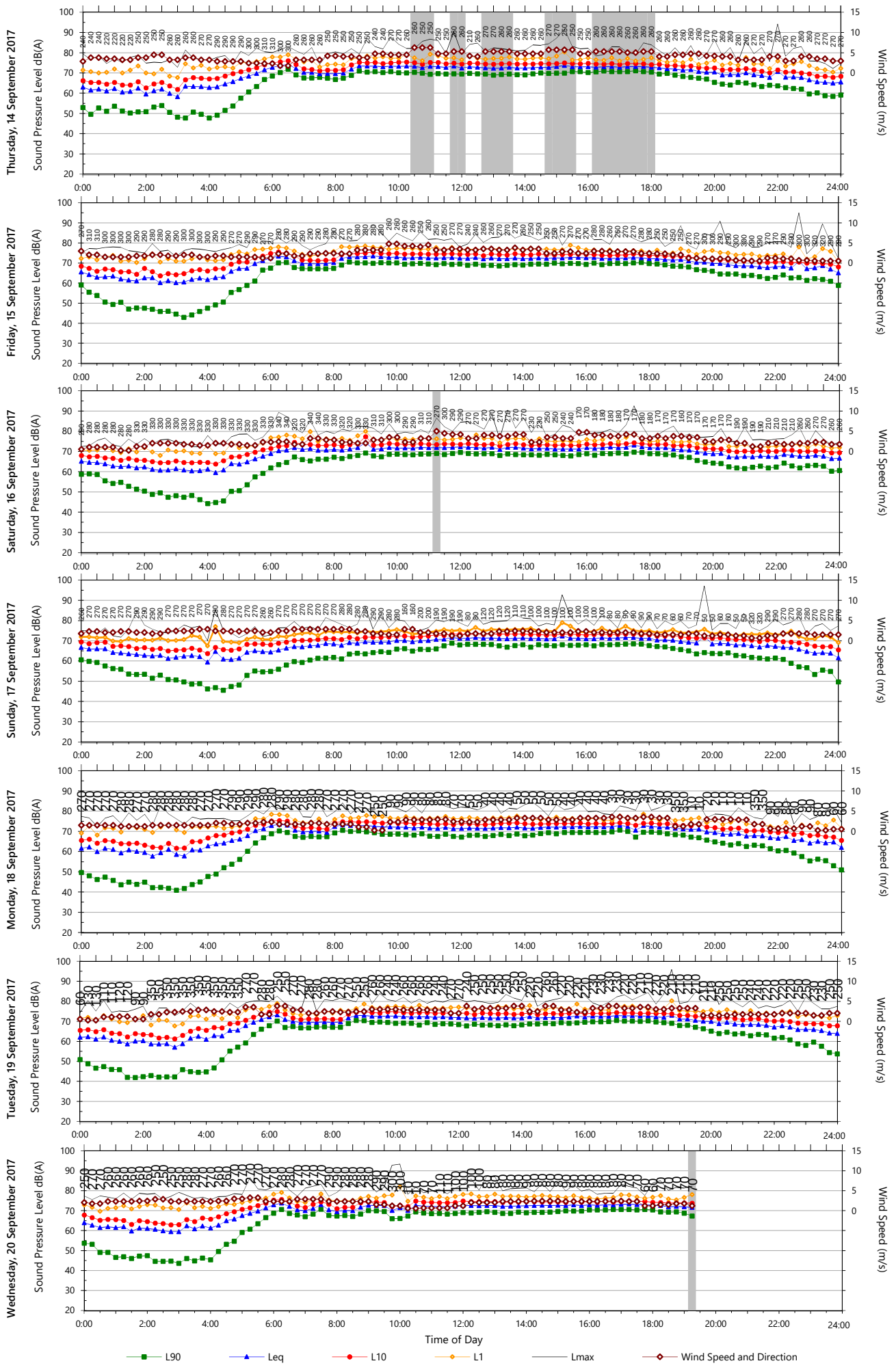




Unattended Monitoring Results **Location: Unit 20, 2 Parkes Road, Artarmon (2F Balcony)**



Unattended Monitoring Results **Location: Unit 20, 2 Parkes Road, Artarmon (2F Balcony)**



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Monitoring ID: Location L19
Address: 3/2 Cleland Road, Artarmon
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on the Warringah Freeway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	55	53	40	59	58	55

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	61	57	

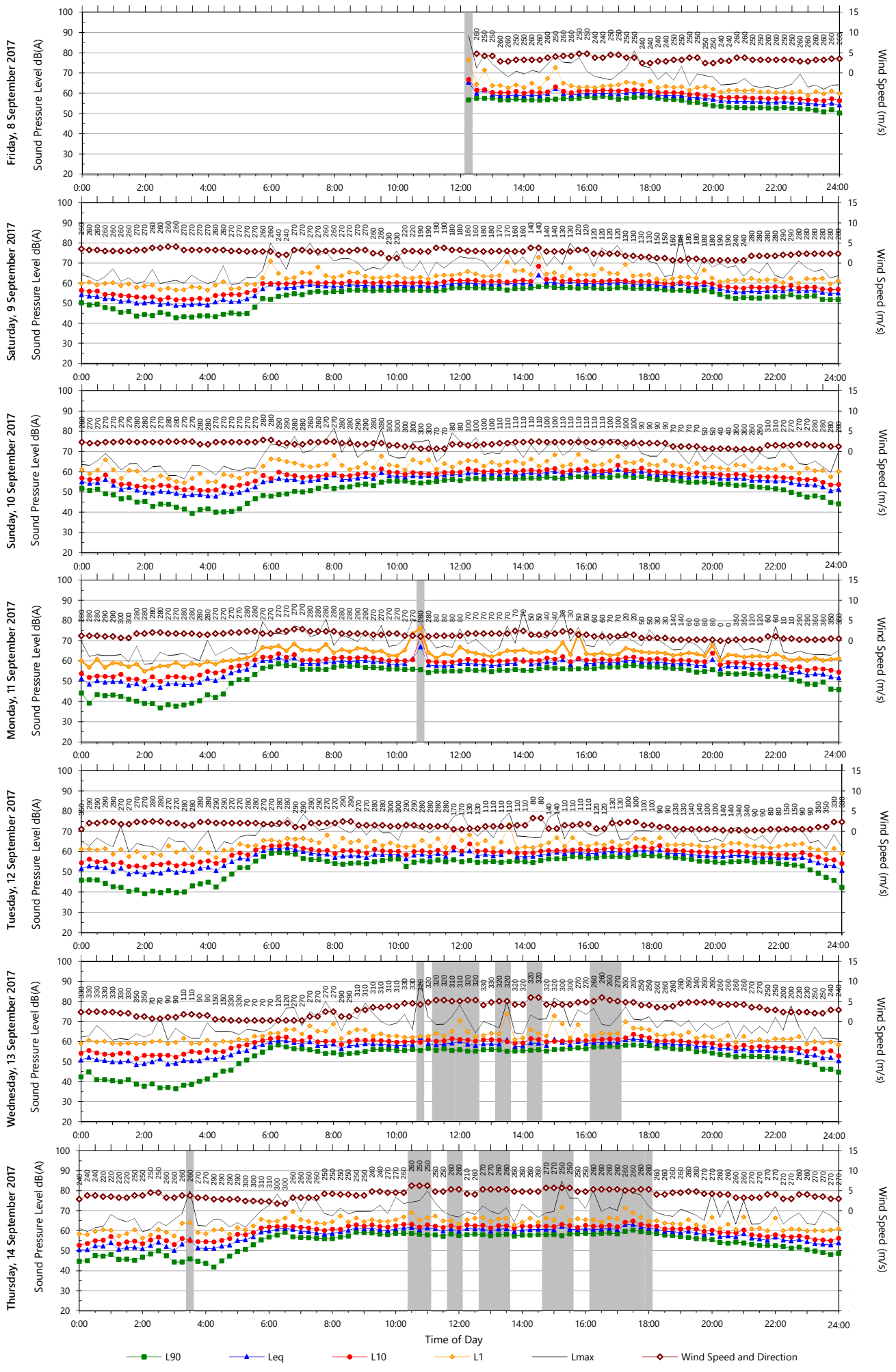
Notes:

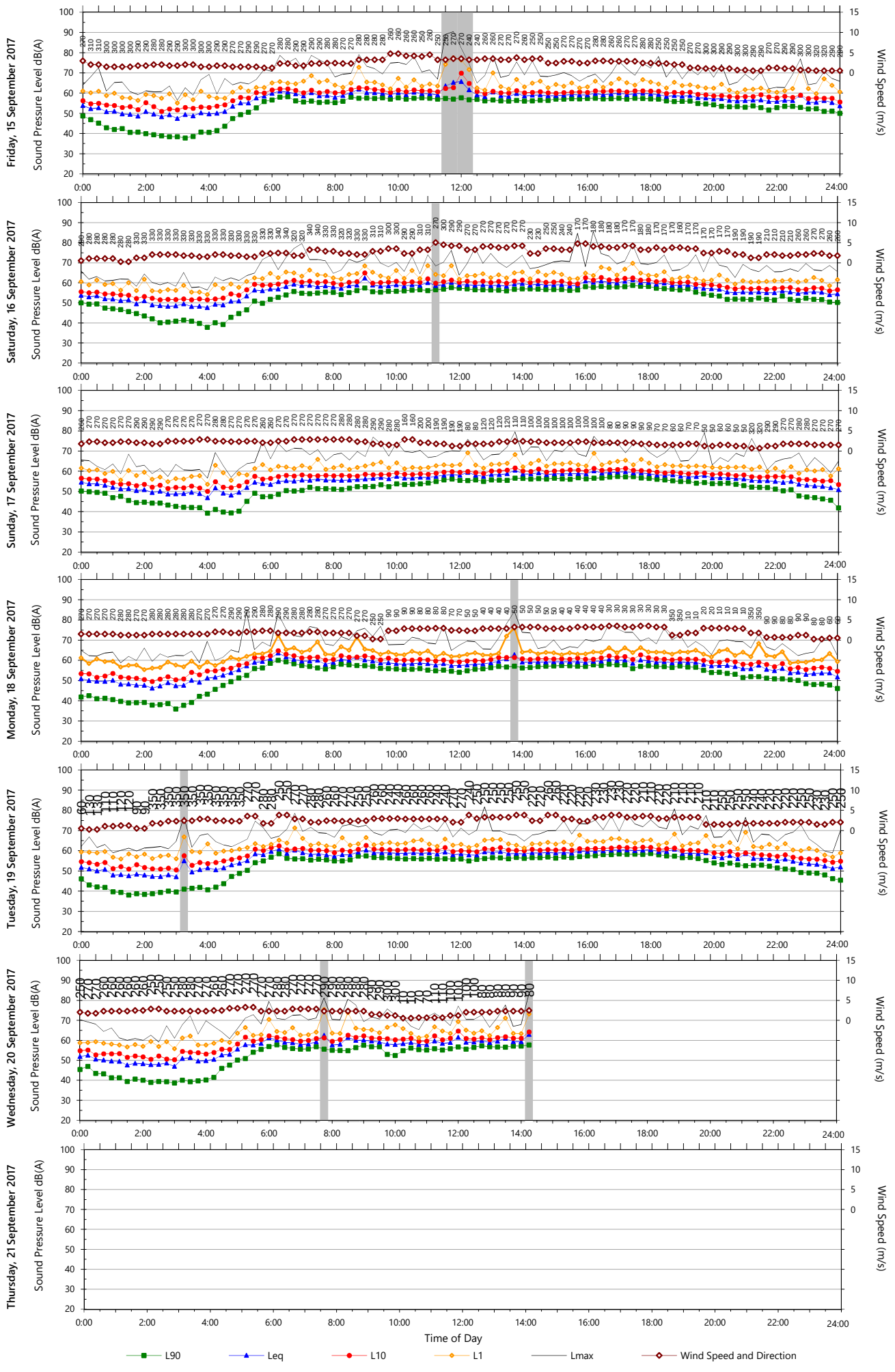
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Friday, 8 September 2017
Saturday, 9 September 2017
Sunday, 10 September 2017
Monday, 11 September 2017
Tuesday, 12 September 2017
Wednesday, 13 September 2017
Thursday, 14 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 15 September 2017
Saturday, 16 September 2017
Sunday, 17 September 2017
Monday, 18 September 2017
Tuesday, 19 September 2017
Wednesday, 20 September 2017
Thursday, 21 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L20
Address: 1 Chelmsford Avenue, Naremburn
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on the Warringah Freeway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	59	55	40	63	61	58

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	65	61	

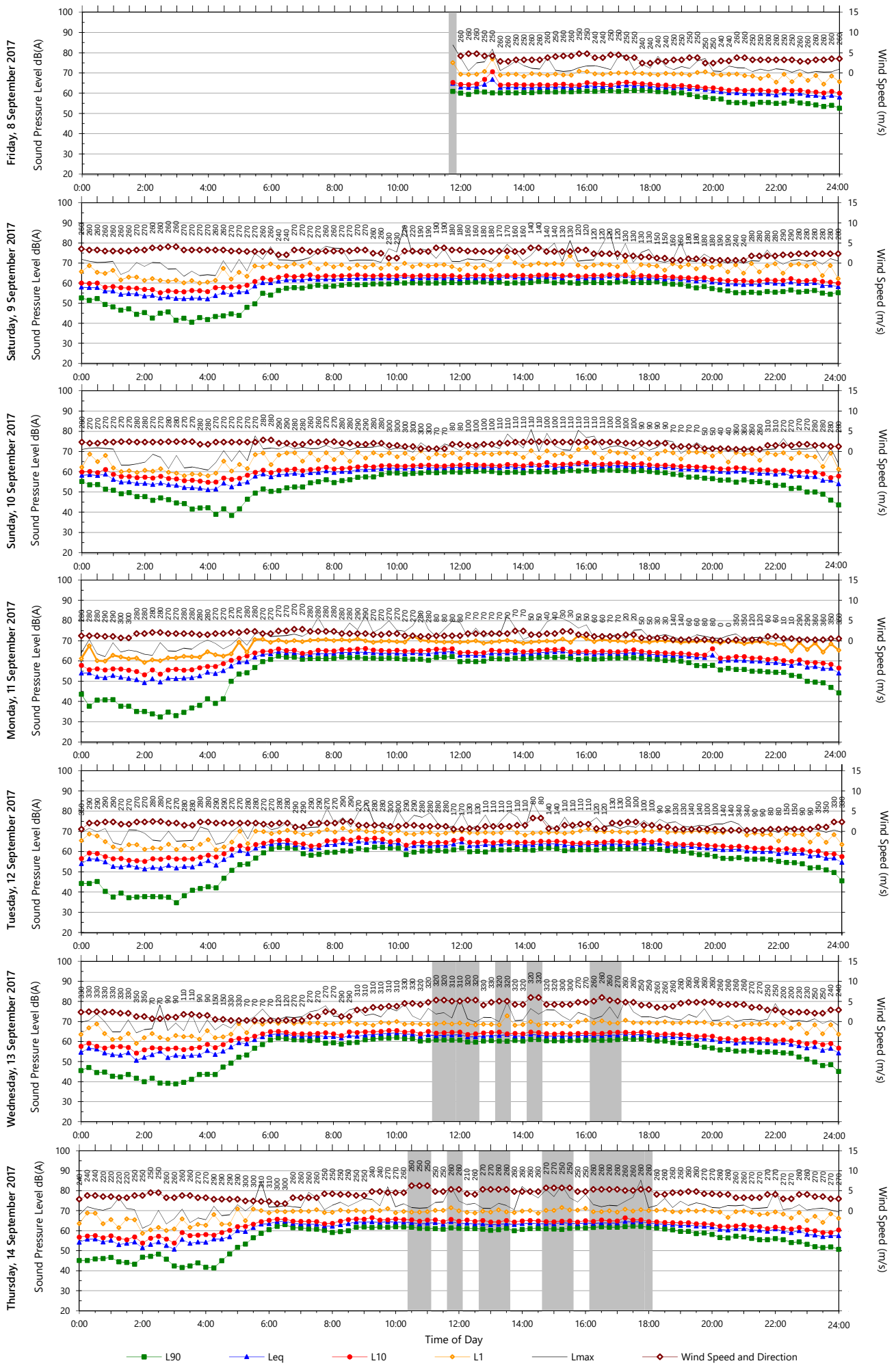
Notes:

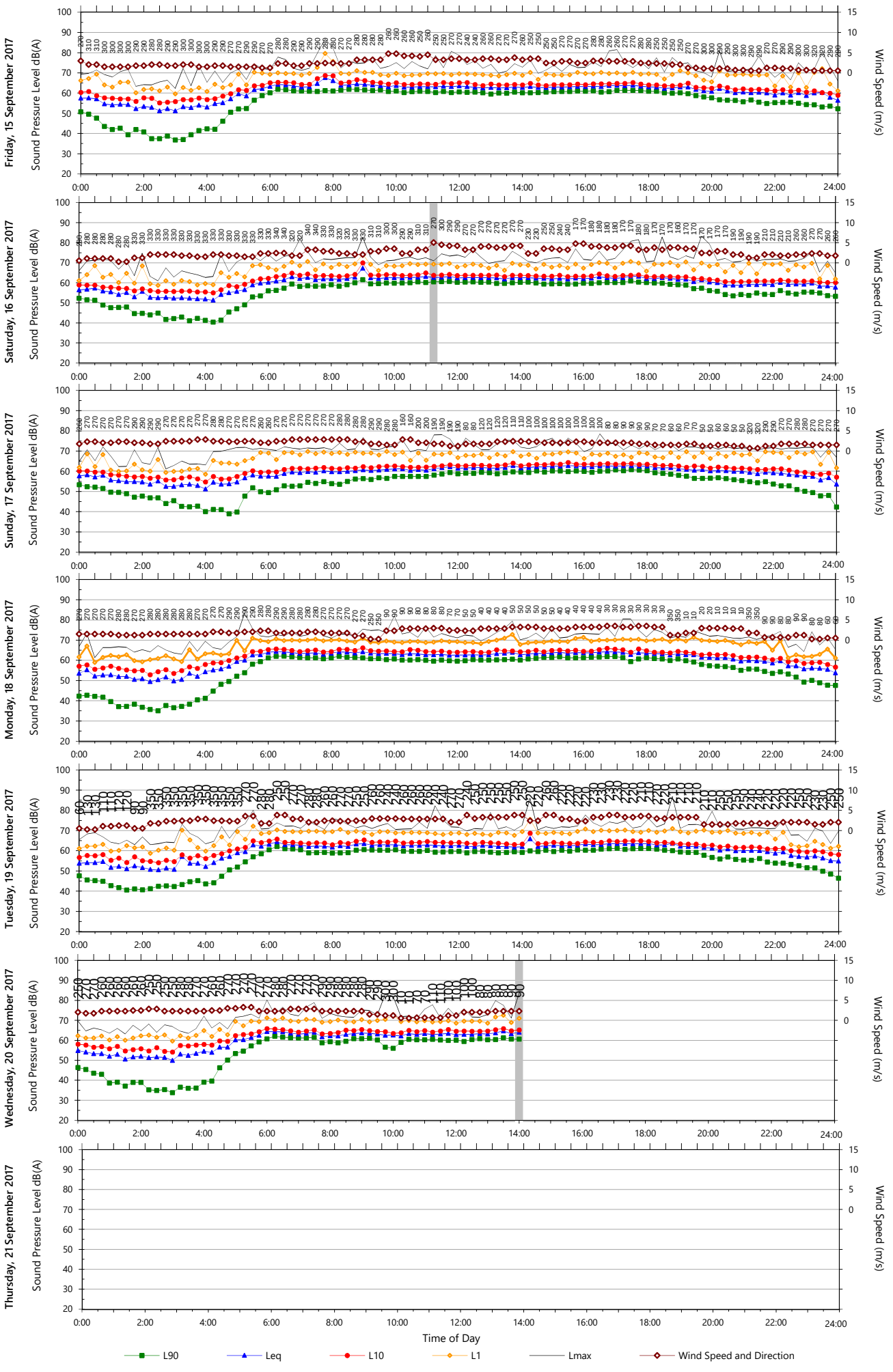
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Friday, 8 September 2017
Saturday, 9 September 2017
Sunday, 10 September 2017
Monday, 11 September 2017
Tuesday, 12 September 2017
Wednesday, 13 September 2017
Thursday, 14 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 15 September 2017
Saturday, 16 September 2017
Sunday, 17 September 2017
Monday, 18 September 2017
Tuesday, 19 September 2017
Wednesday, 20 September 2017
Thursday, 21 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L21
Address: 2 Burra Road, Artarmon
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	44	44	37	53	50	46

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

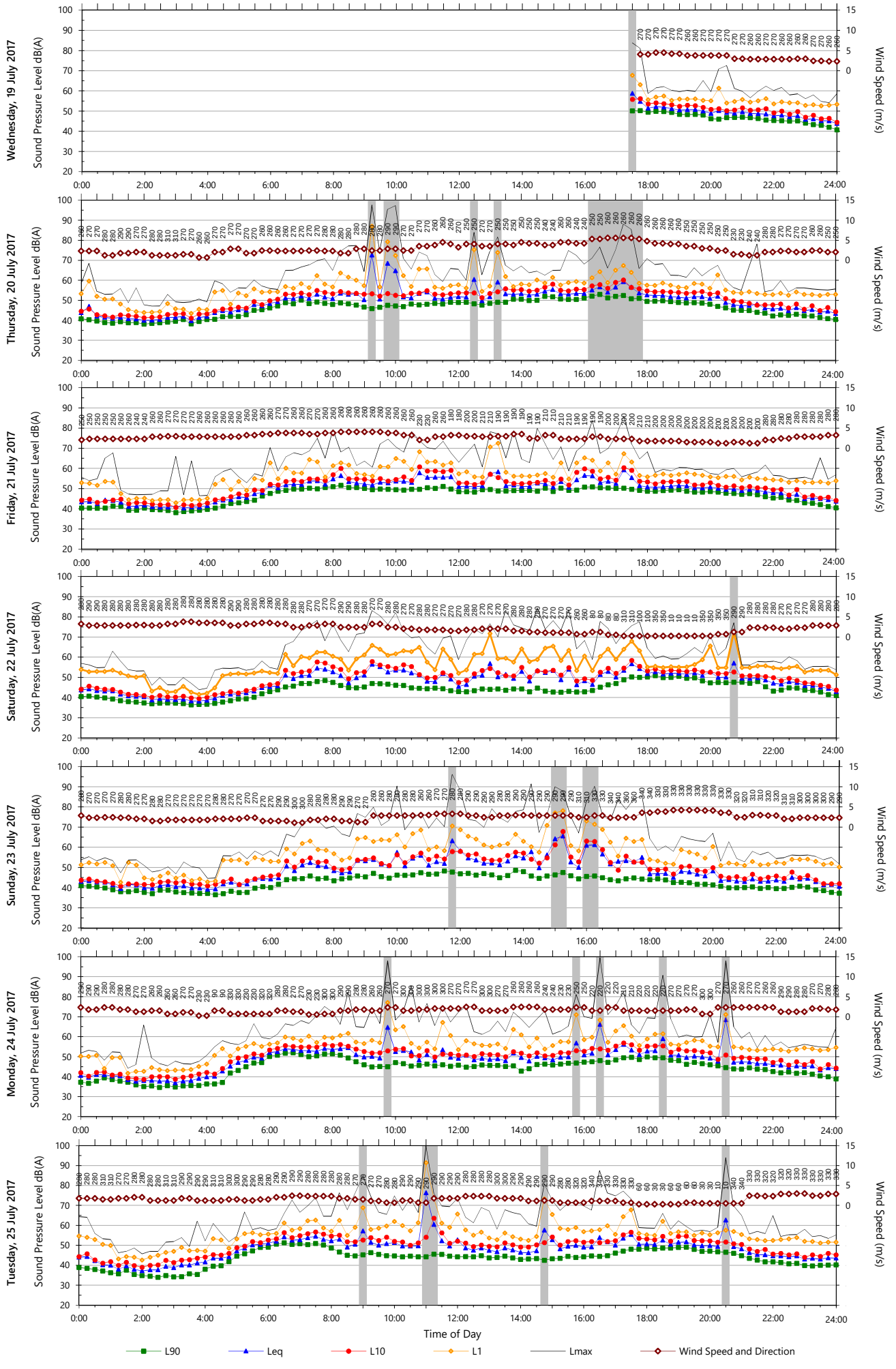
Logger Location	Aerial Photograph





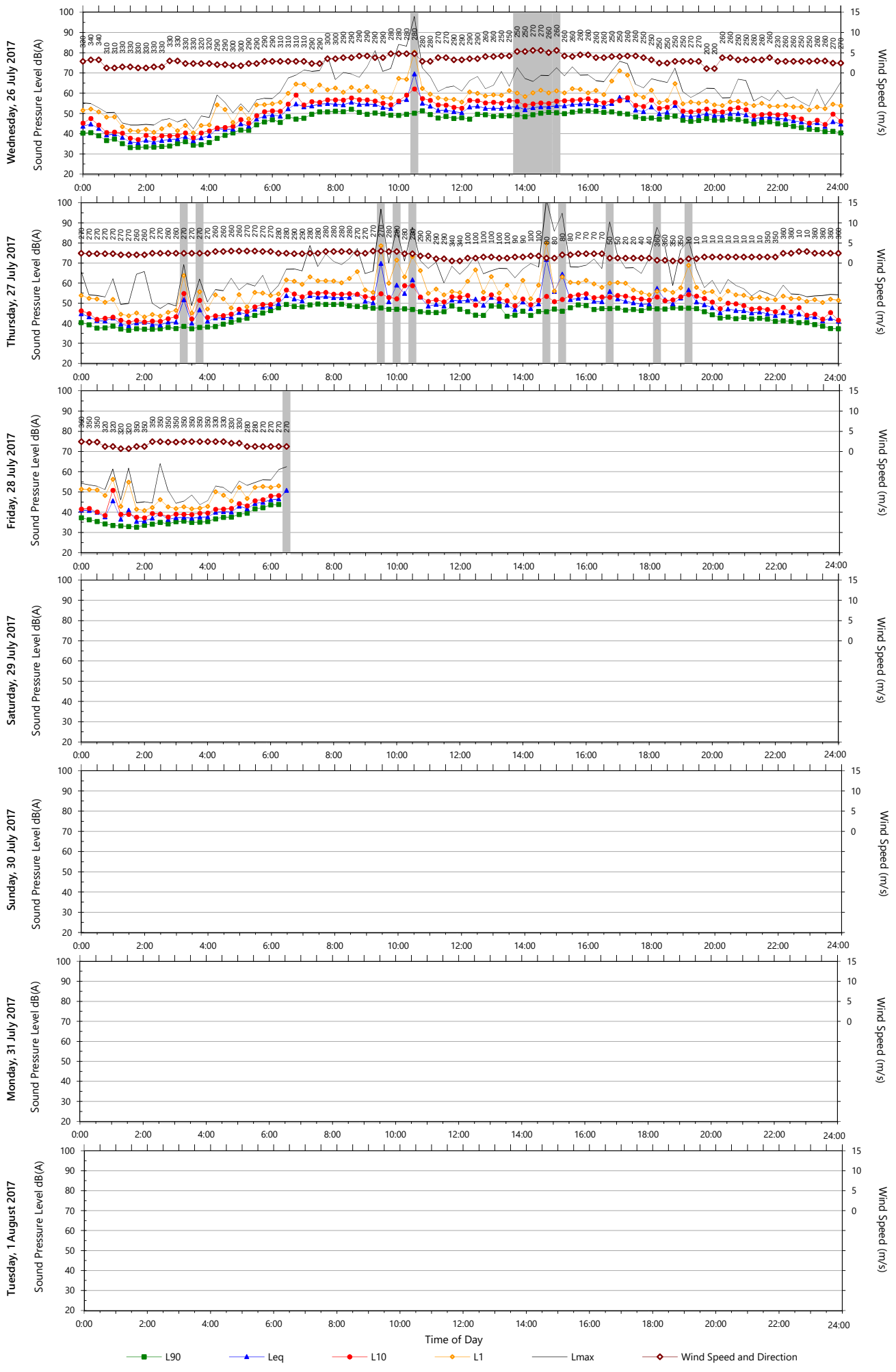
Unattended Monitoring Results

Location: 2 Burra Road, Artarmon



Unattended Monitoring Results

Location: 2 Burra Road, Artarmon



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Monitoring ID: Location L22
Address: 16 Walter Street, Willoughby
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on the Warringah Freeway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	50	48	38	55	52	49

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

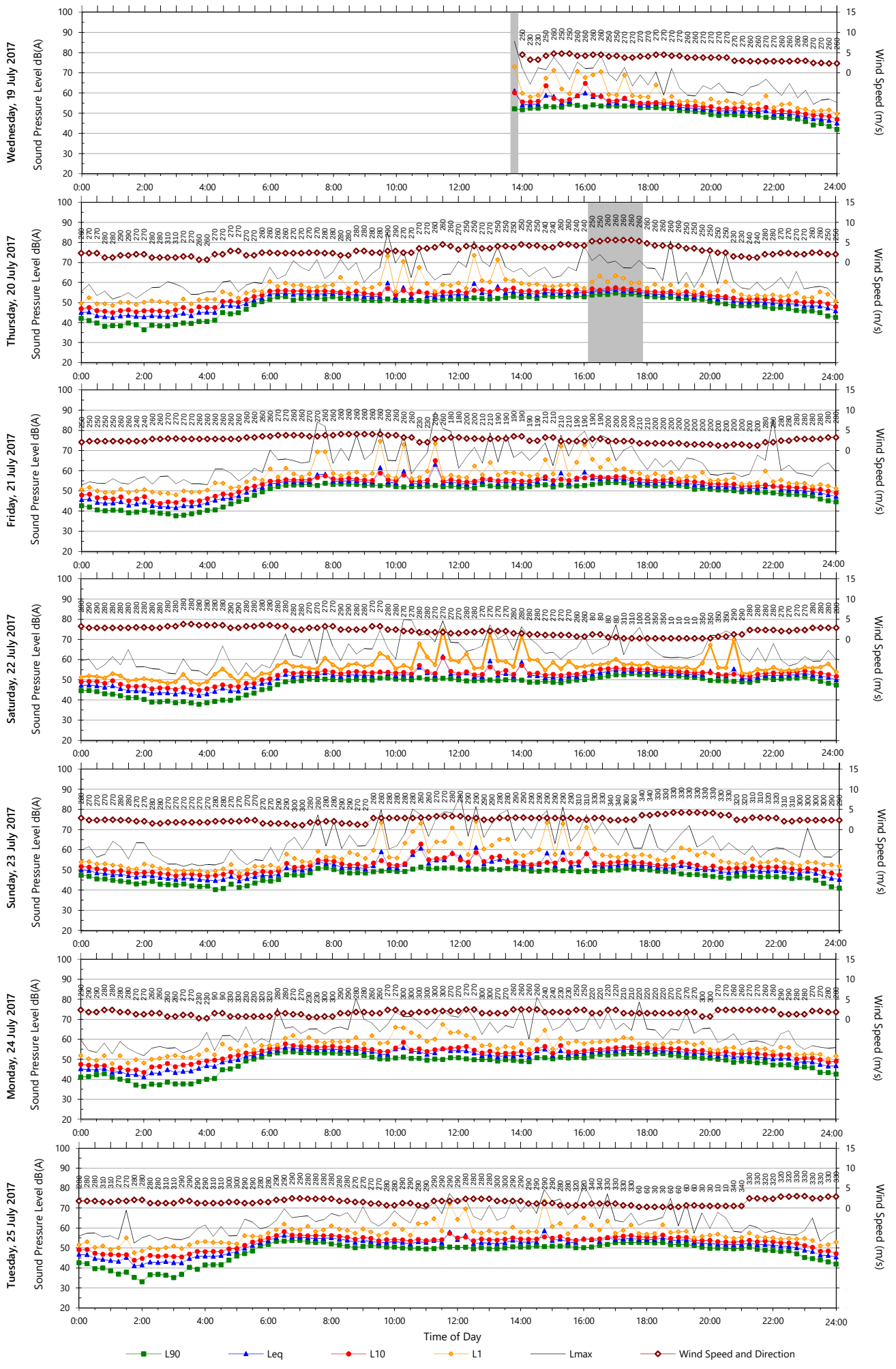
Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph

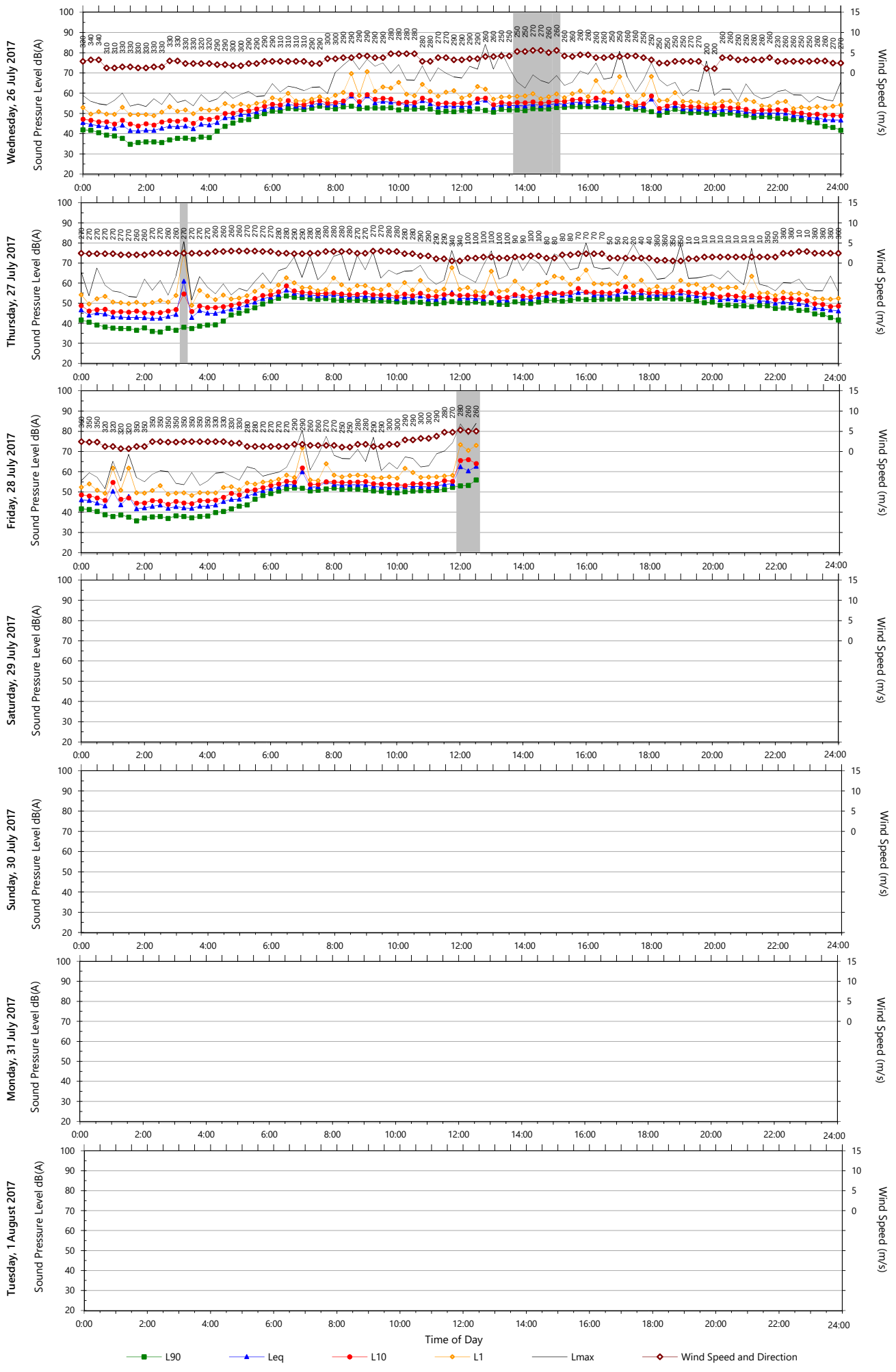





Wednesday, 19 July 2017
Thursday, 20 July 2017
Friday, 21 July 2017
Saturday, 22 July 2017
Sunday, 23 July 2017
Monday, 24 July 2017
Tuesday, 25 July 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results

Location: 16 Walter Street, Willoughby



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Monitoring ID: Location L23
Address: 27 Garland Street, Naremburn
Description: Noise monitor located on the rear balcony and positioned in the free-field. Noise environment dominated by traffic on the Warringah Freeway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	45	44	34	53	52	48

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

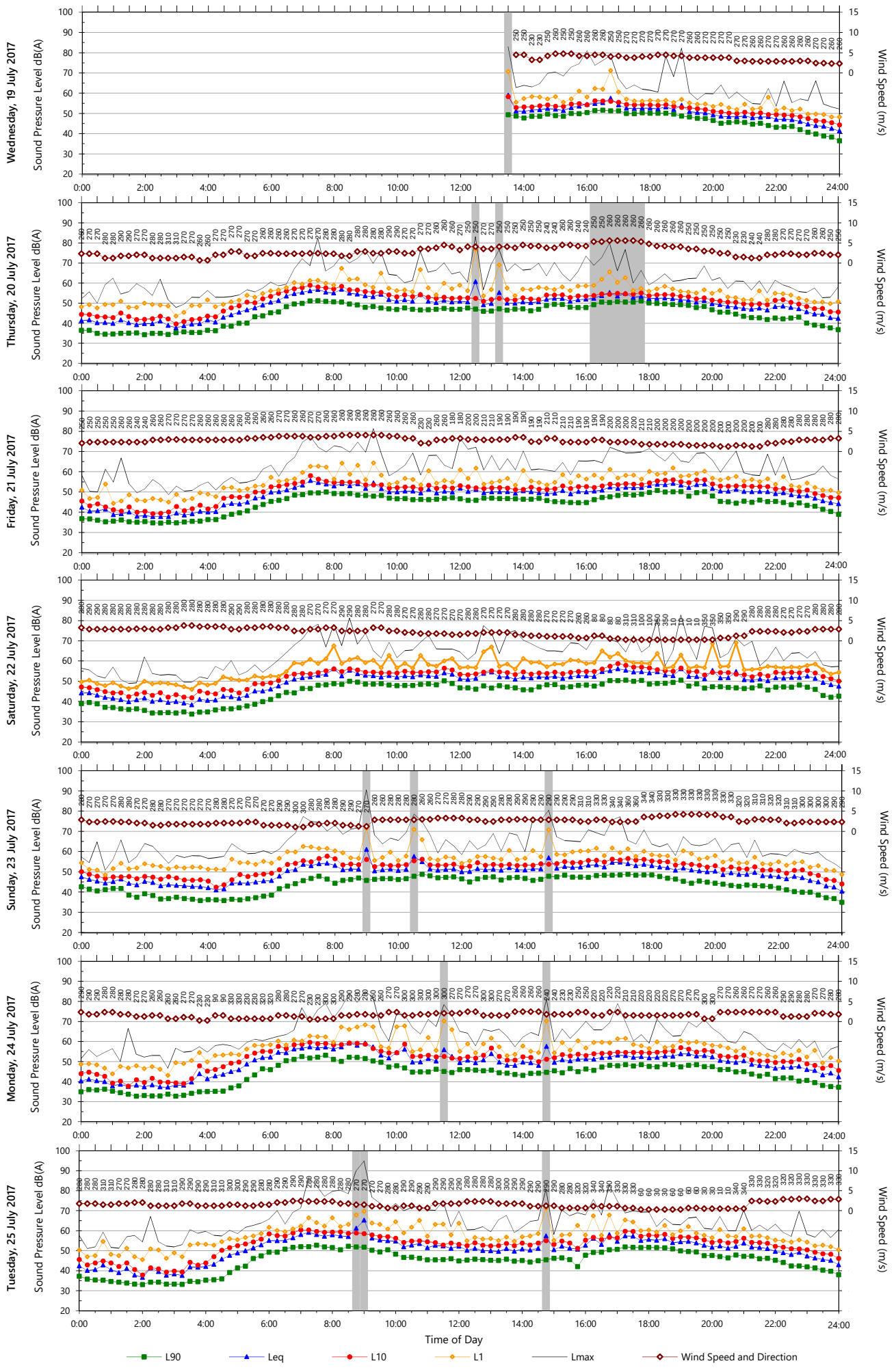
Notes:

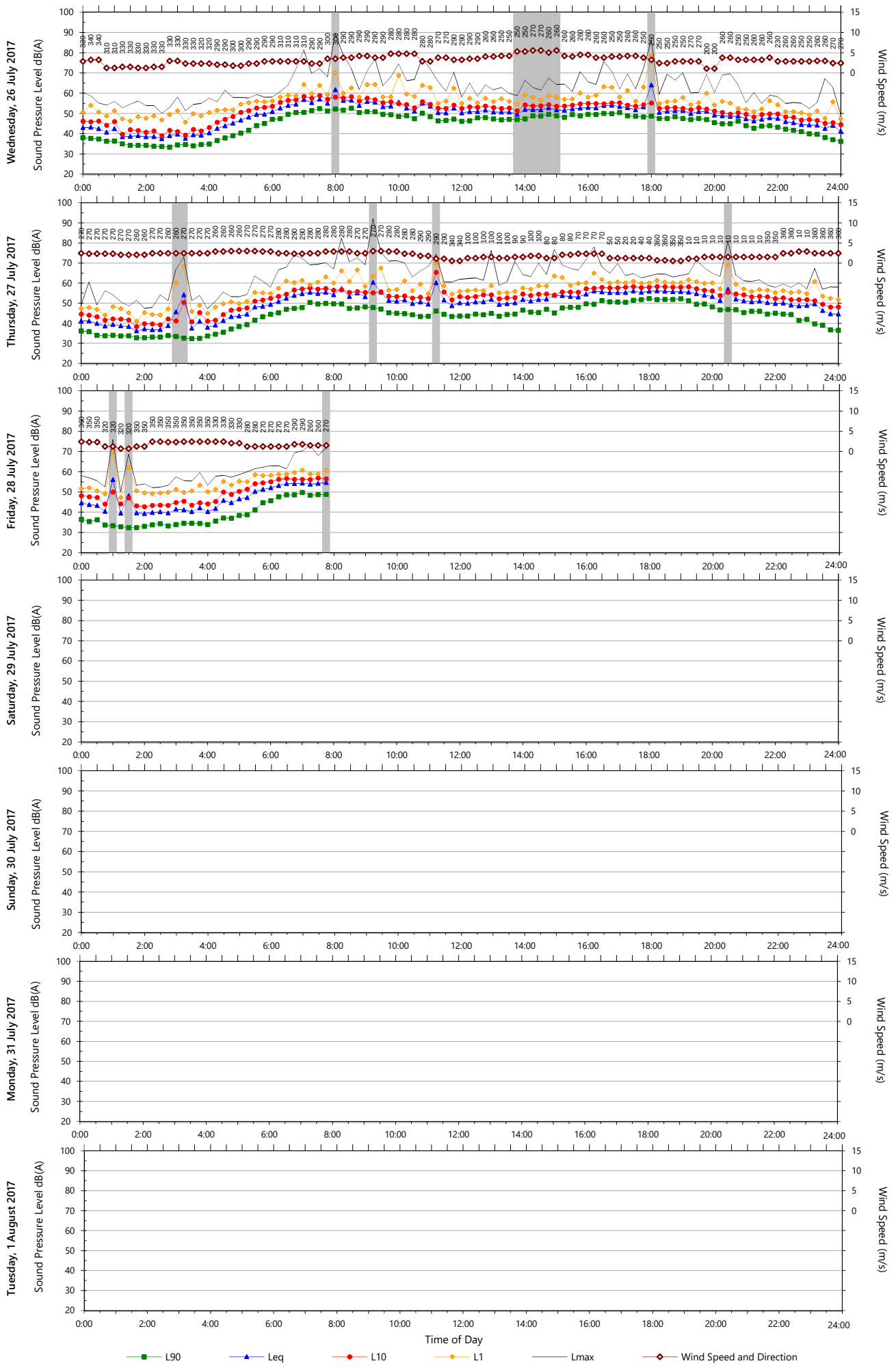
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Wednesday, 19 July 2017
Thursday, 20 July 2017
Friday, 21 July 2017
Saturday, 22 July 2017
Sunday, 23 July 2017
Monday, 24 July 2017
Tuesday, 25 July 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Wednesday, 26 July 2017
Thursday, 27 July 2017
Friday, 28 July 2017
Saturday, 29 July 2017
Sunday, 30 July 2017
Monday, 31 July 2017
Tuesday, 1 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L24
Address: 2 Pyalla Street, Northbridge
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	52	48	37	60	56	57

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

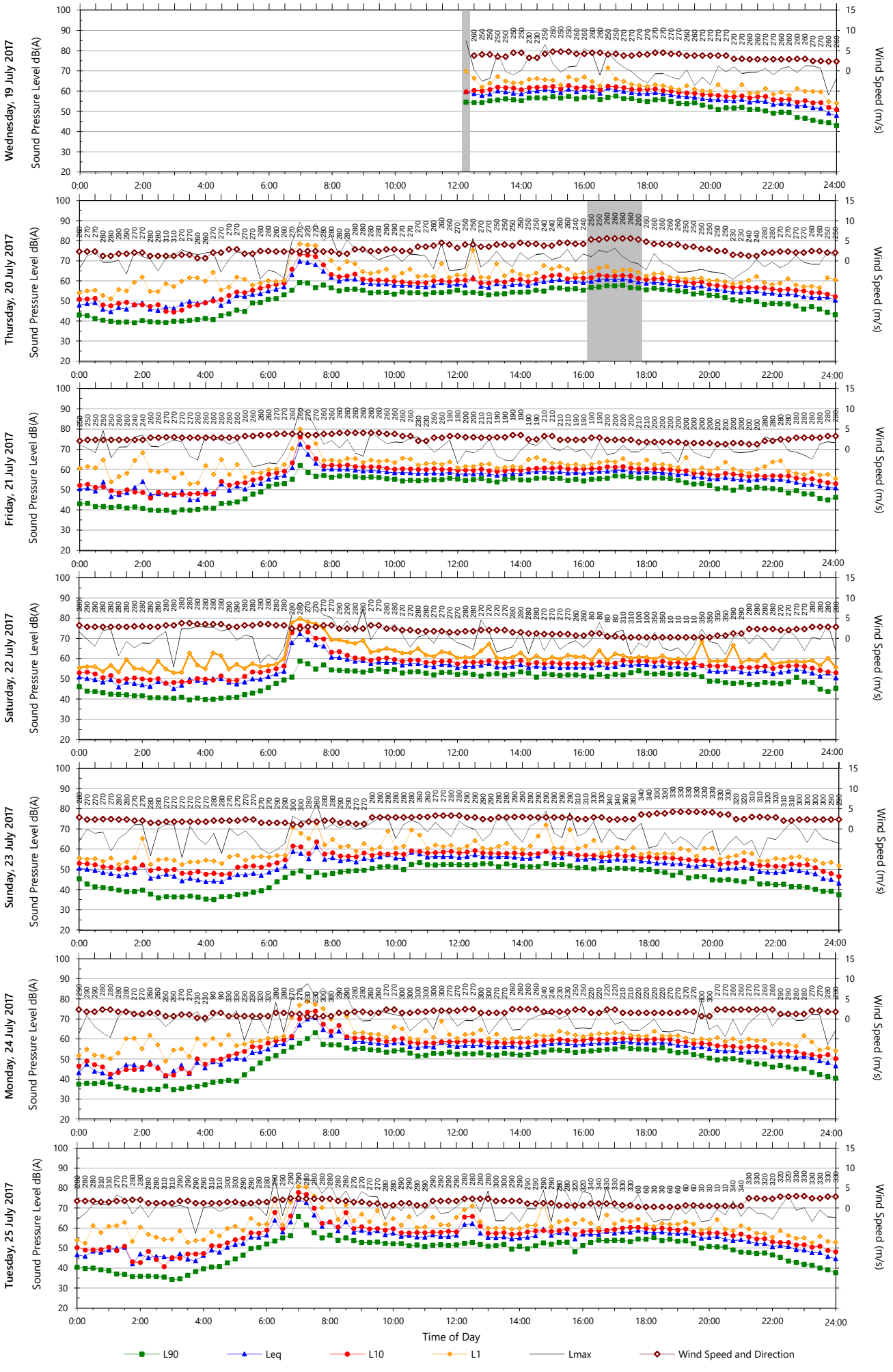
Logger Location	Aerial Photograph

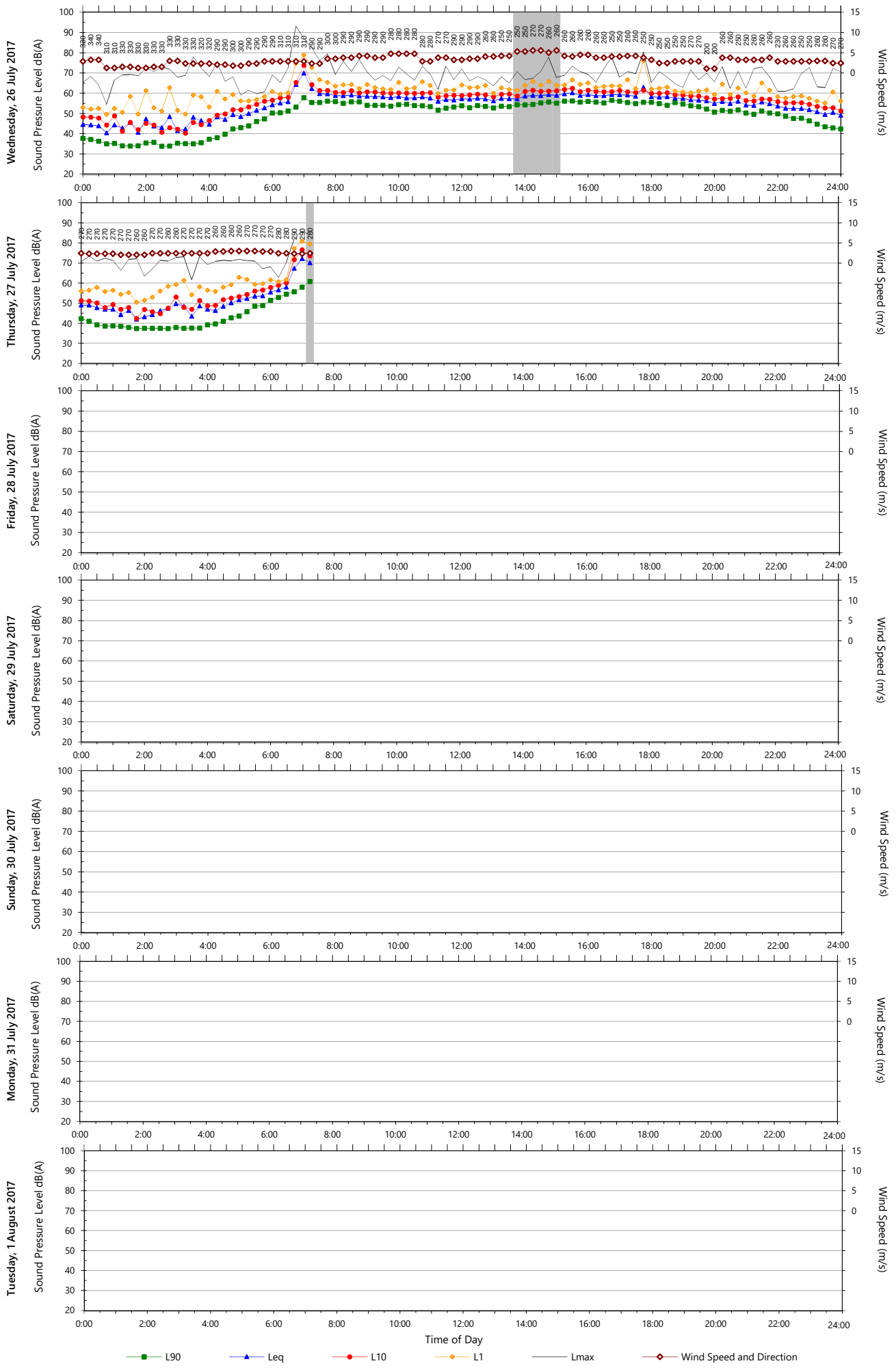




Unattended Monitoring Results

Location: 2 Pyalla Street, Northbridge




Wednesday, 26 July 2017
Thursday, 27 July 2017
Friday, 28 July 2017
Saturday, 29 July 2017
Sunday, 30 July 2017
Monday, 31 July 2017
Tuesday, 1 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L25
Address: 375 Sailors Bay Road, Northbridge
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on Sailors Bay Road.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	43	40	36	66	63	58

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

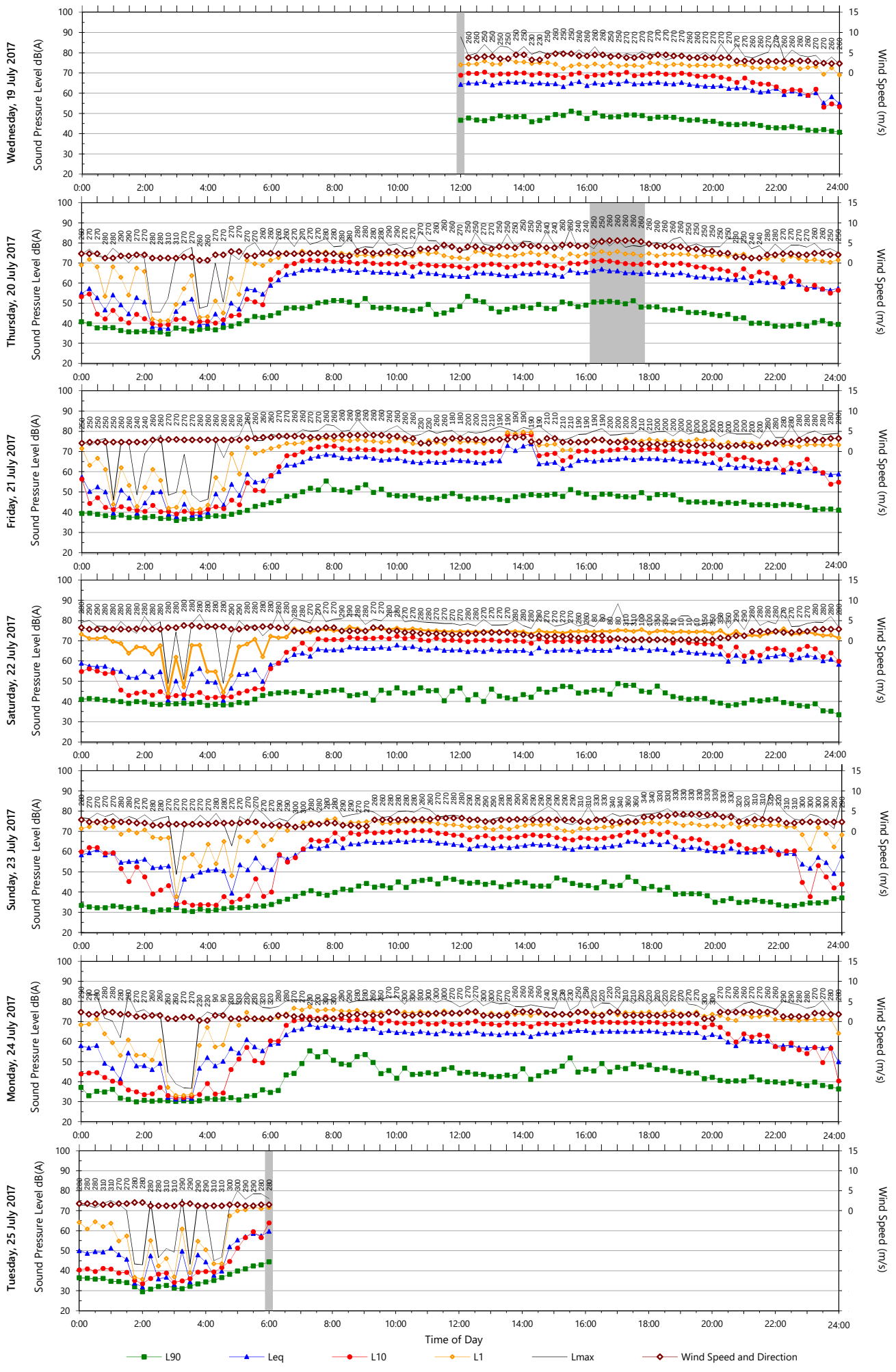
Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Wednesday, 19 July 2017
Thursday, 20 July 2017
Friday, 21 July 2017
Saturday, 22 July 2017
Sunday, 23 July 2017
Monday, 24 July 2017
Tuesday, 25 July 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Structural Dynamics

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Monitoring ID: Location L26
Address: 8 Wollombi Road, Northbridge
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	**37**	**37**	**33**	**52**	**44**	**46**

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

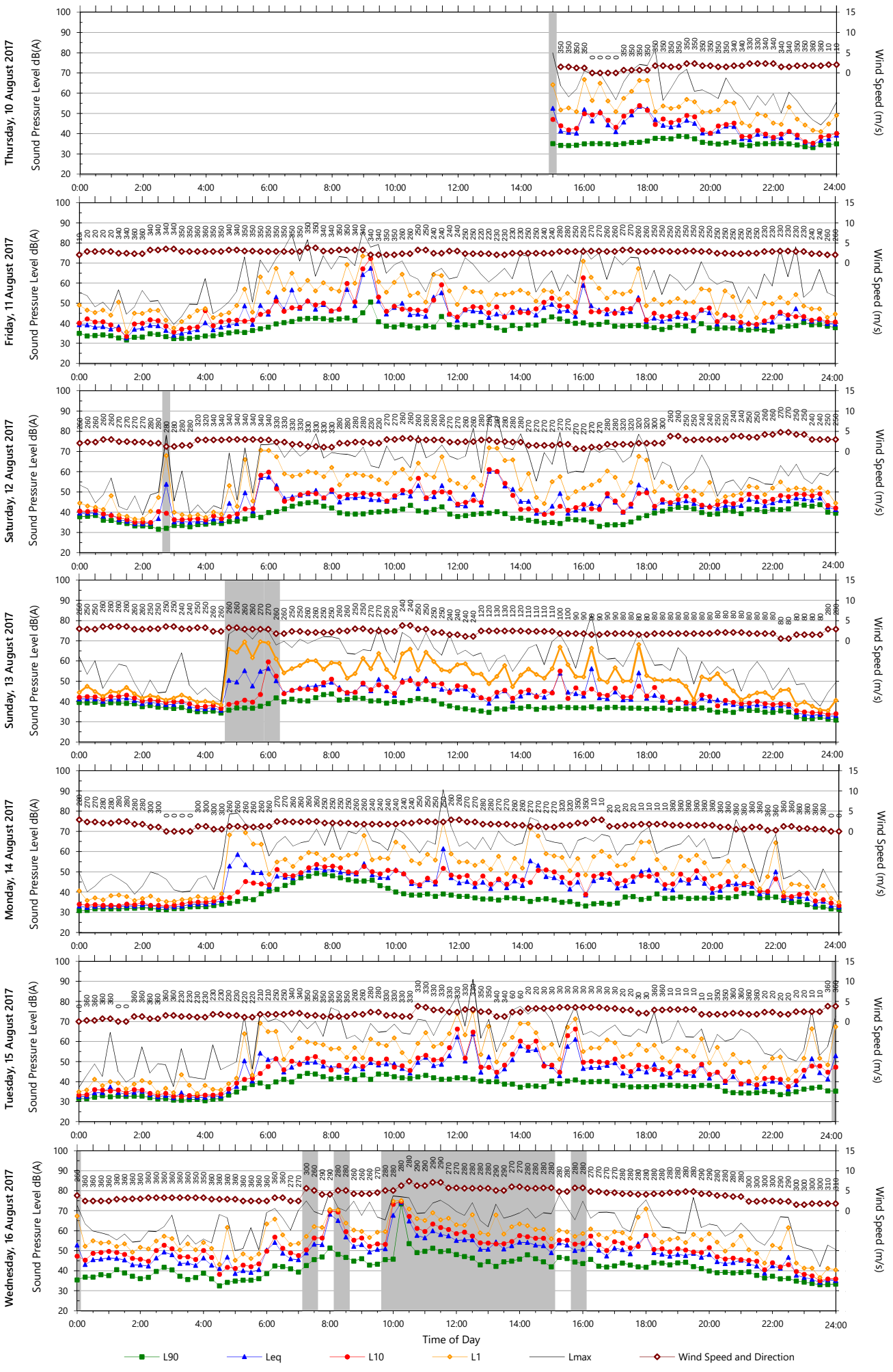
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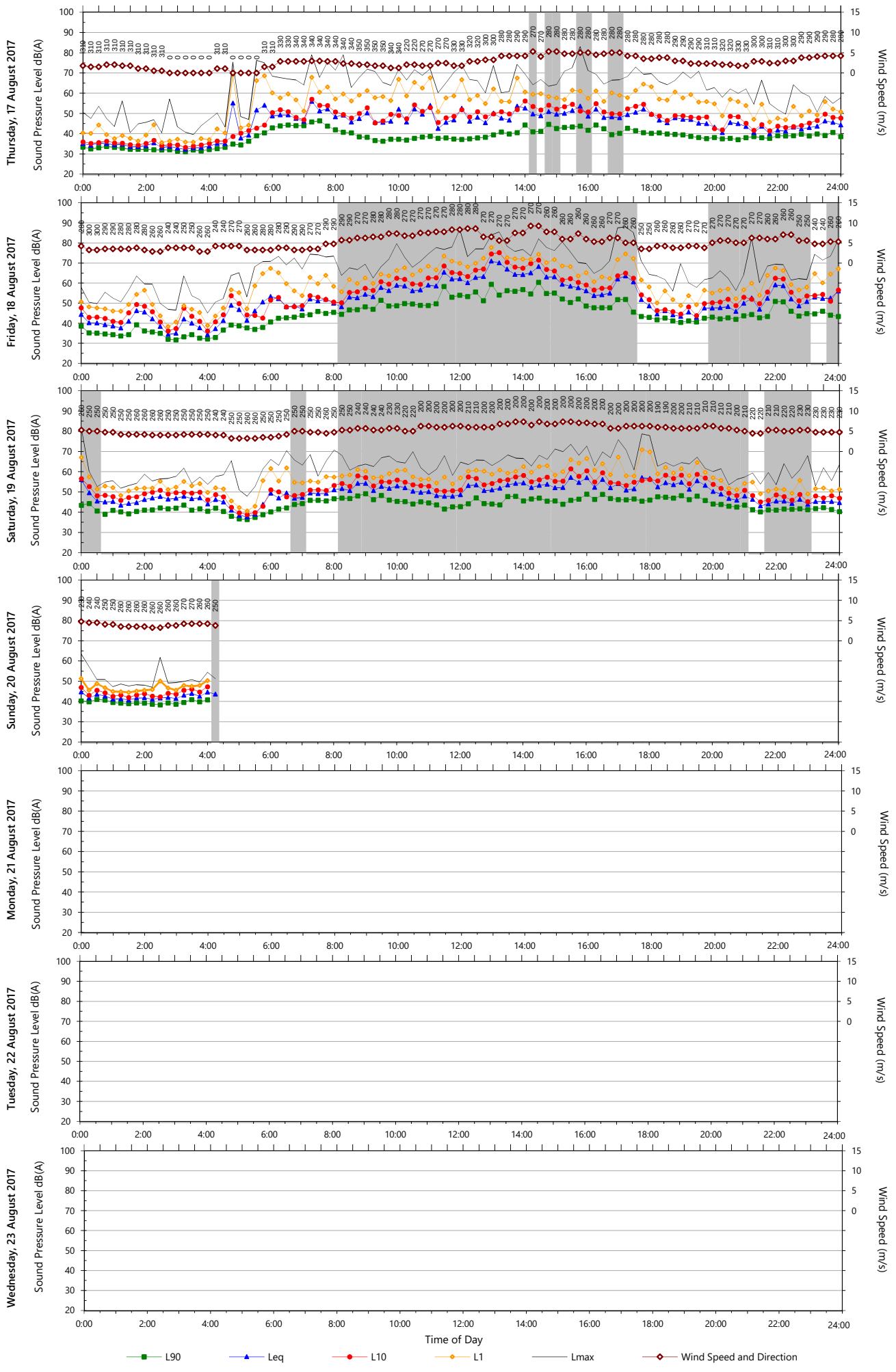
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Thursday, 10 August 2017
Friday, 11 August 2017
Saturday, 12 August 2017
Sunday, 13 August 2017
Monday, 14 August 2017
Tuesday, 15 August 2017
Wednesday, 16 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Thursday, 17 August 2017
Friday, 18 August 2017
Saturday, 19 August 2017
Sunday, 20 August 2017
Monday, 21 August 2017
Tuesday, 22 August 2017
Wednesday, 23 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Structural Dynamics

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Monitoring ID: Location L27
Address: 1 Tycannah Road, Northbridge
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	**37**	**34**	**28**	**52**	**43**	**43**

Notes:

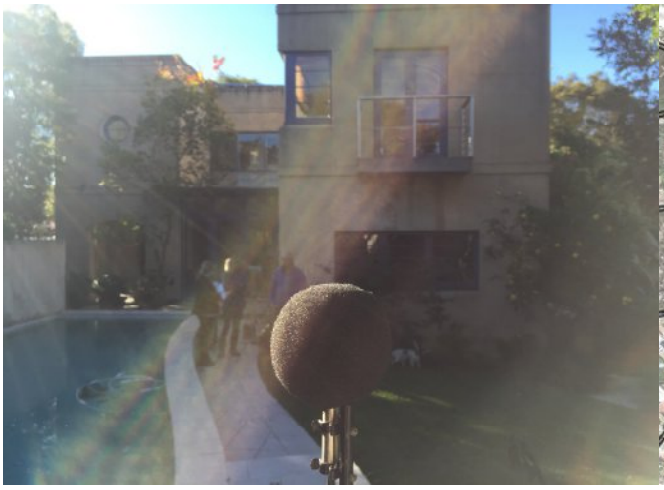
1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

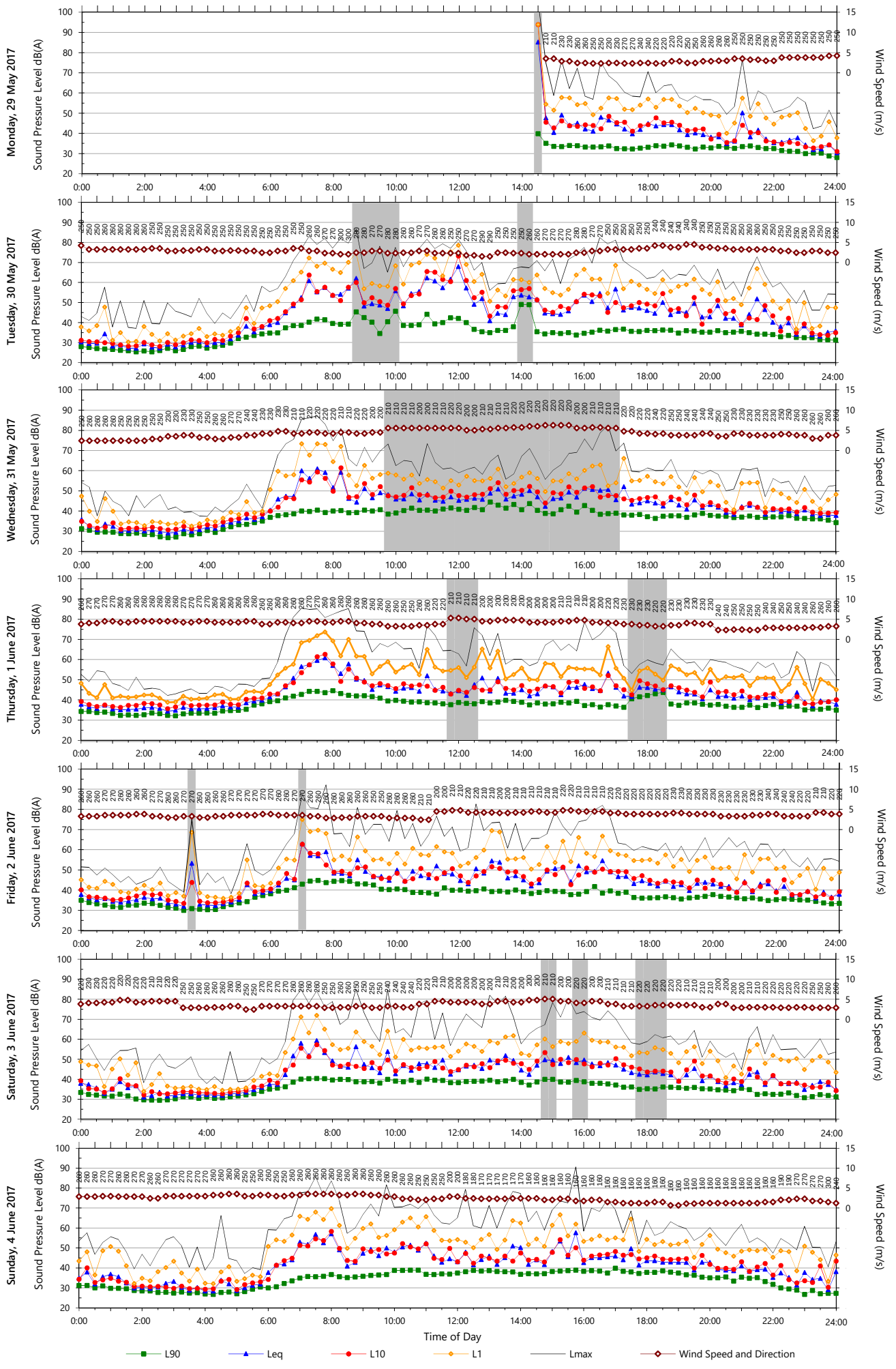
Notes:

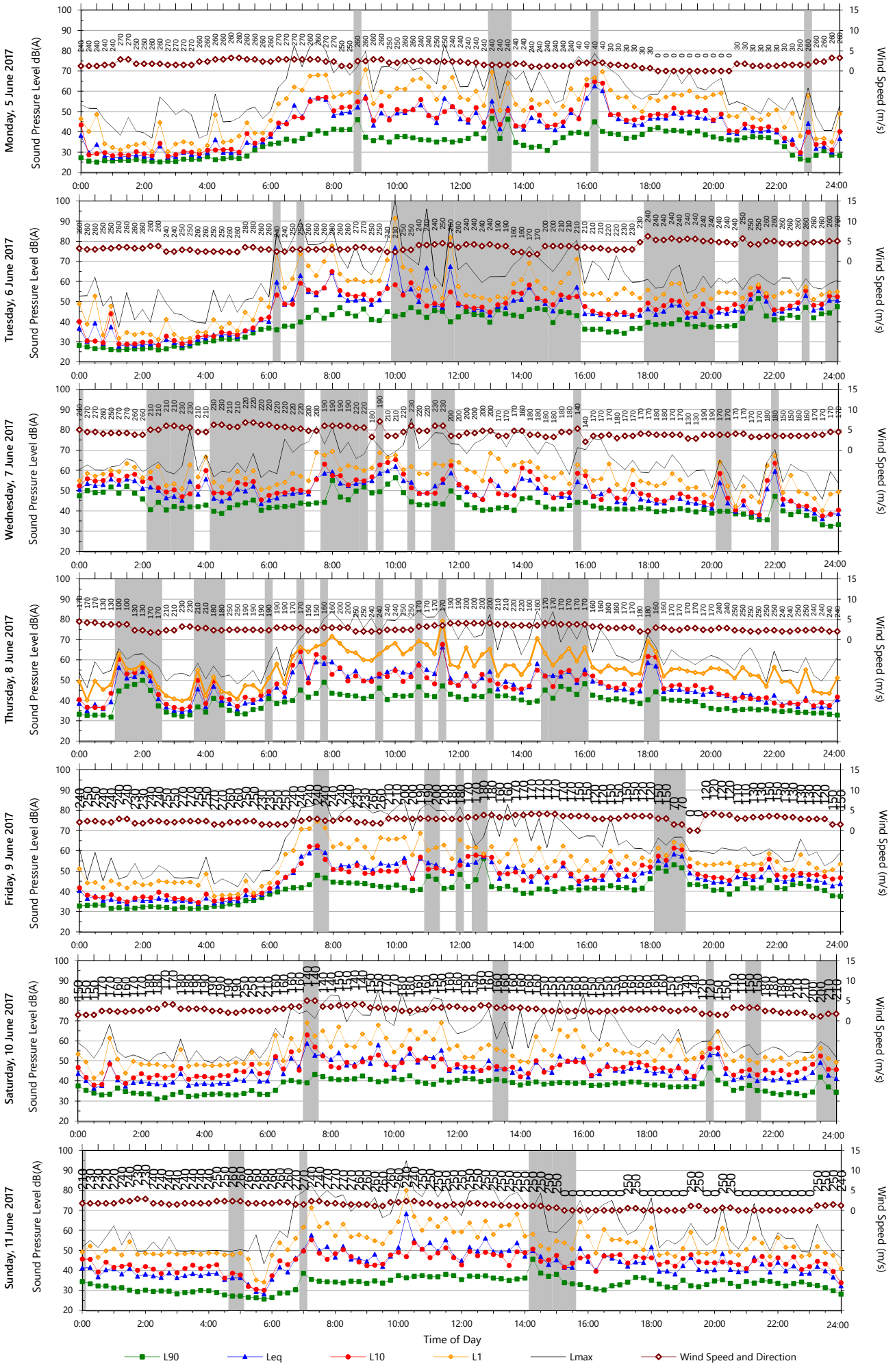
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

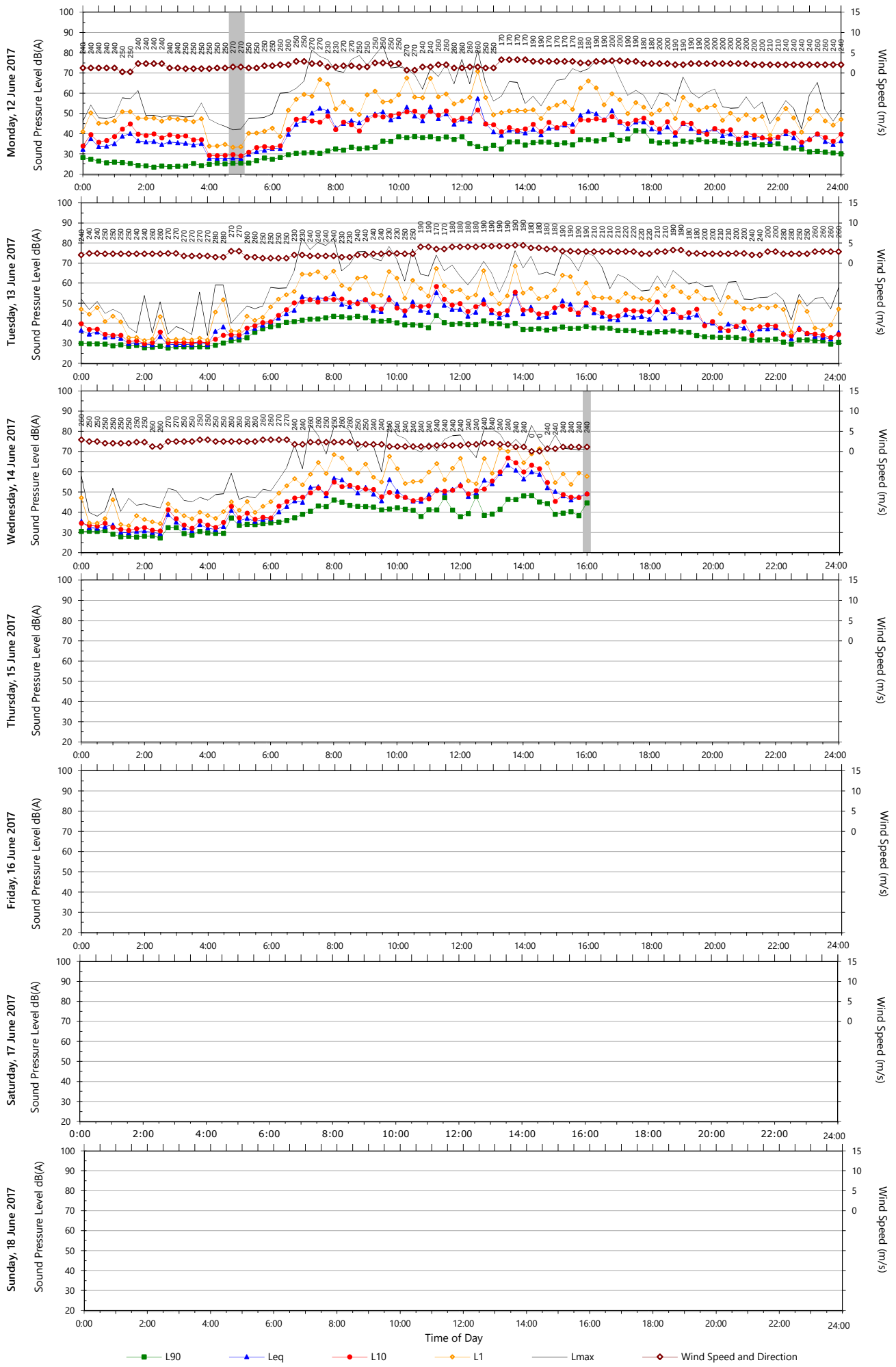
Logger Location	Aerial Photograph






Monday, 29 May 2017
Tuesday, 30 May 2017
Wednesday, 31 May 2017
Thursday, 1 June 2017
Friday, 2 June 2017
Saturday, 3 June 2017
Sunday, 4 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Monday, 5 June 2017
Tuesday, 6 June 2017
Wednesday, 7 June 2017
Thursday, 8 June 2017
Friday, 9 June 2017
Saturday, 10 June 2017
Sunday, 11 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Monday, 12 June 2017
Tuesday, 13 June 2017
Wednesday, 14 June 2017
Thursday, 15 June 2017
Friday, 16 June 2017
Saturday, 17 June 2017
Sunday, 18 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L28
Address: 8 Cheyne Walk, Castlecrag
Description: Noise monitor located in the rear yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	36	32	27	50	42	38

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

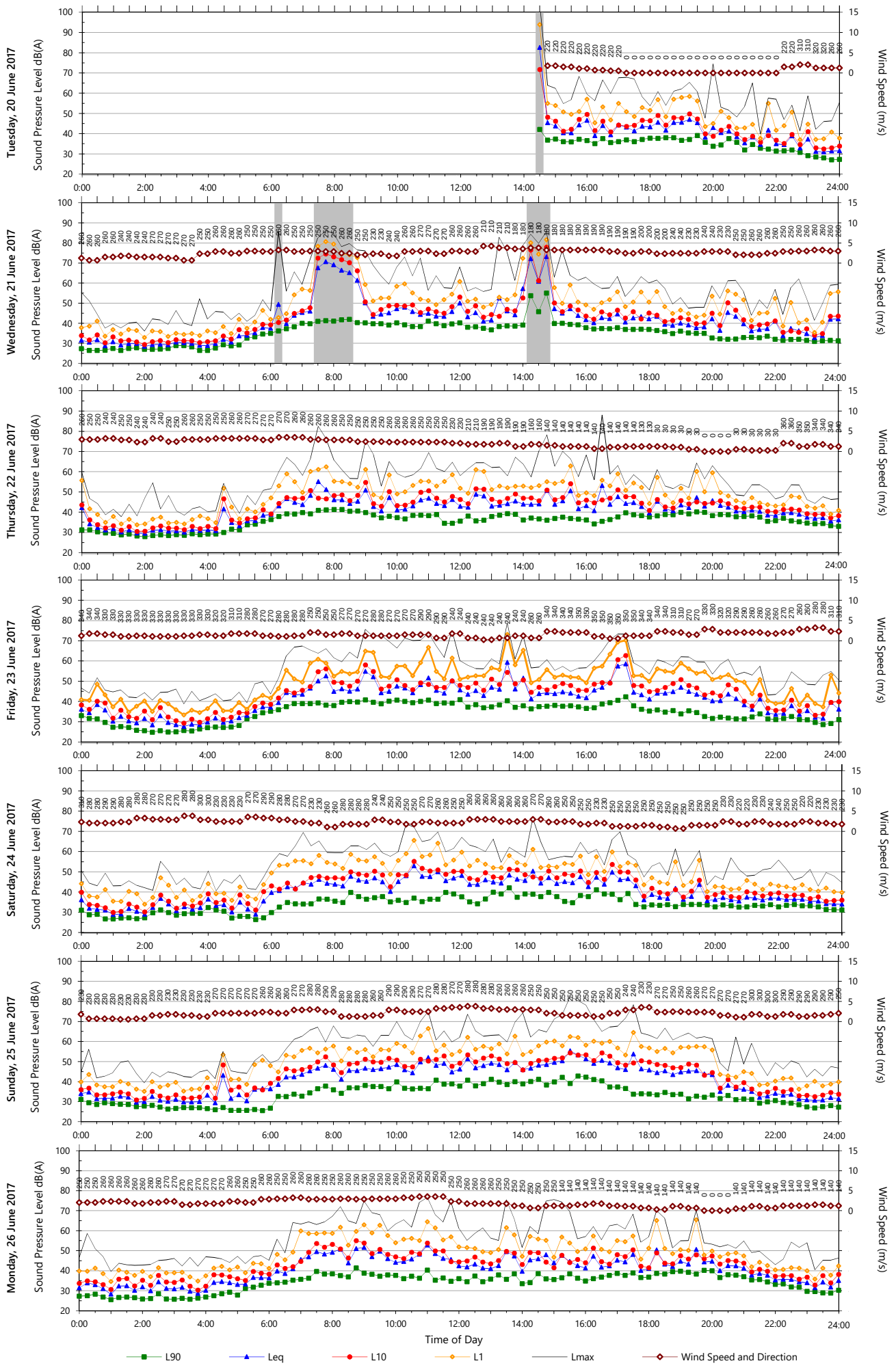
Logger Location	Aerial Photograph





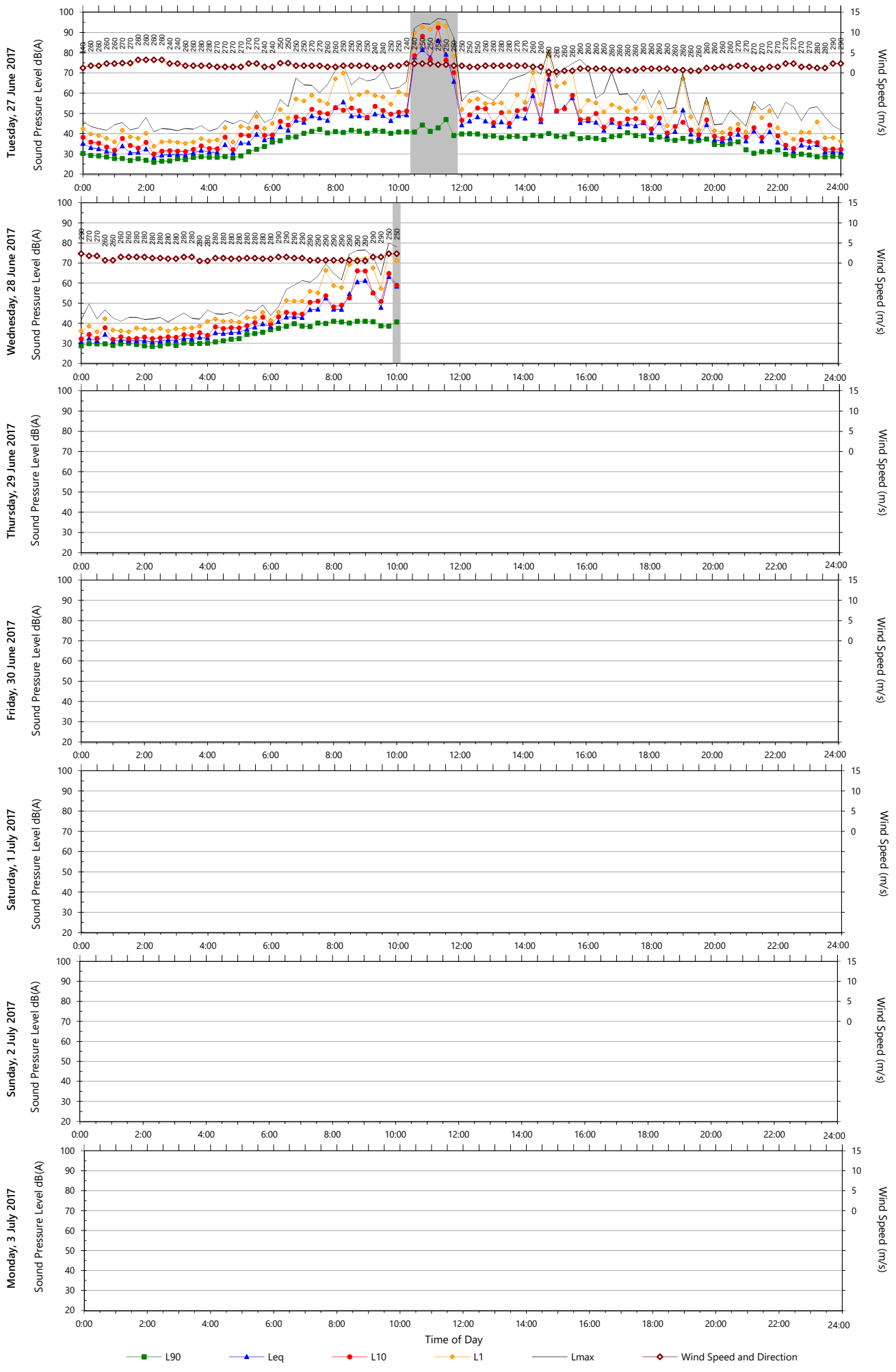
Unattended Monitoring Results

Location: 8 Cheyne Walk, Castlecrag



Unattended Monitoring Results

Location: 8 Cheyne Walk, Castlecrag



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Monitoring ID: Location L29
Address: 1 Delecta Avenue, Mosman
Description: Noise monitor located in the rear yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	45	43	36	52	50	46

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

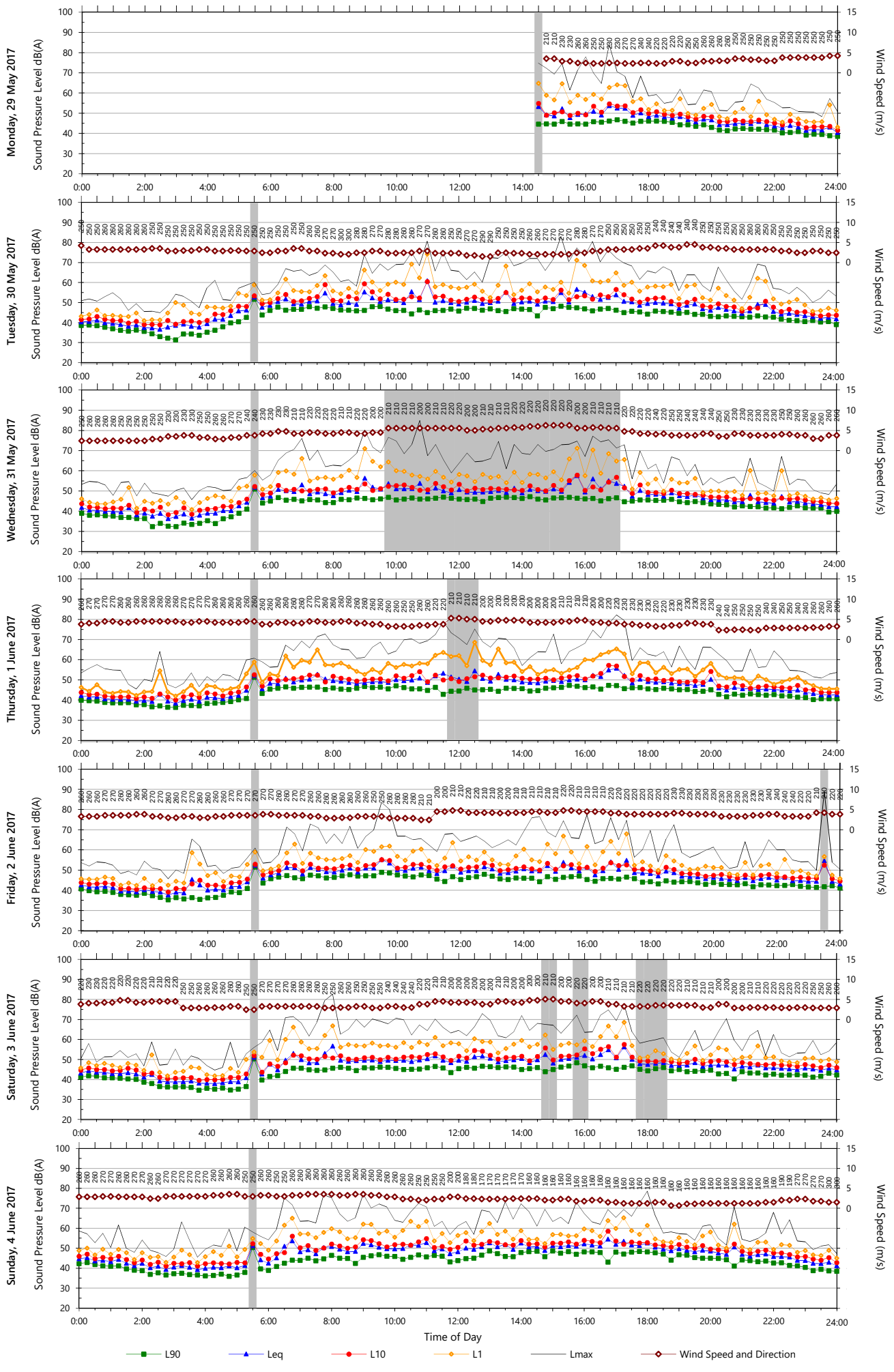
Notes:

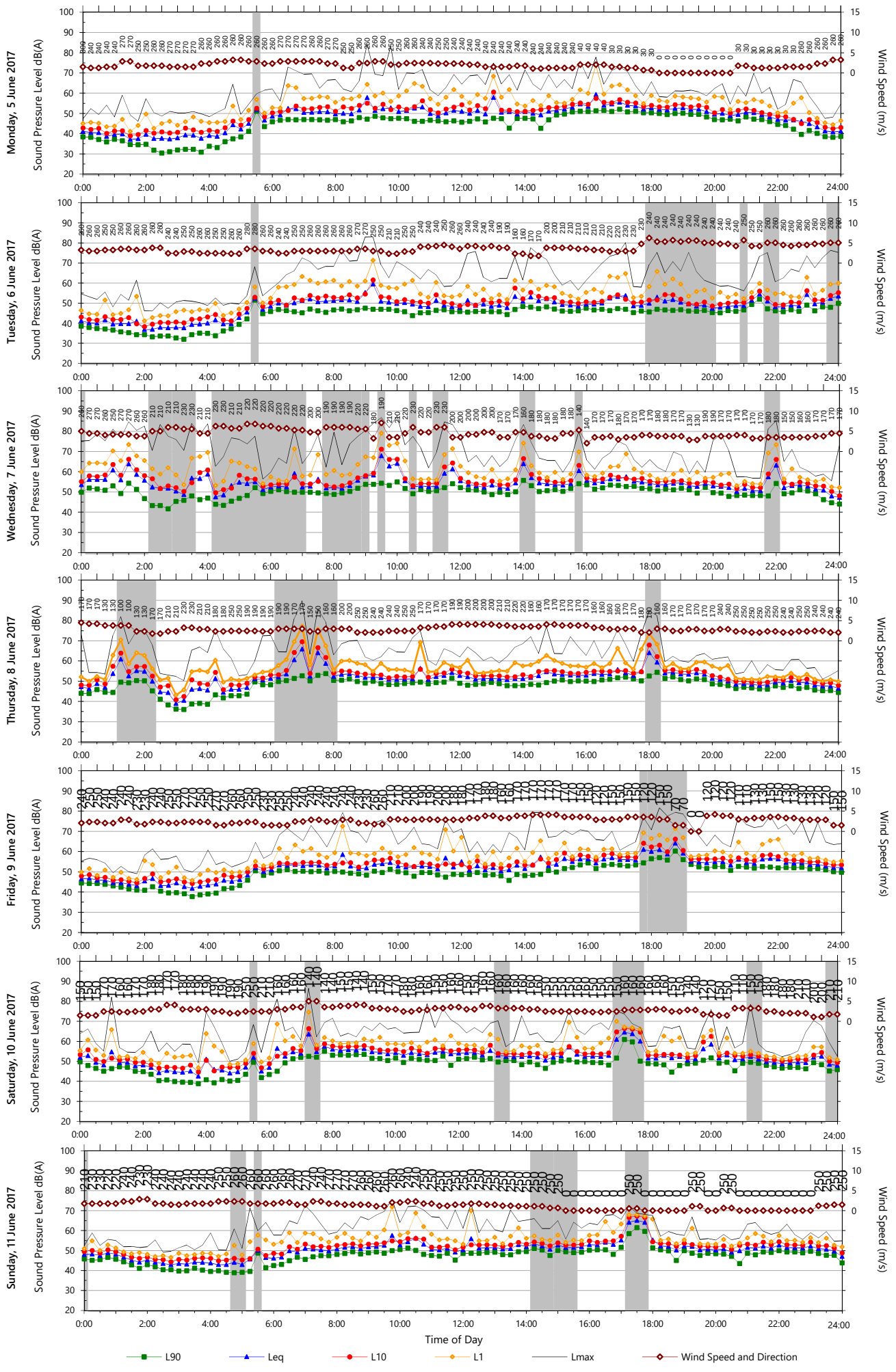
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph



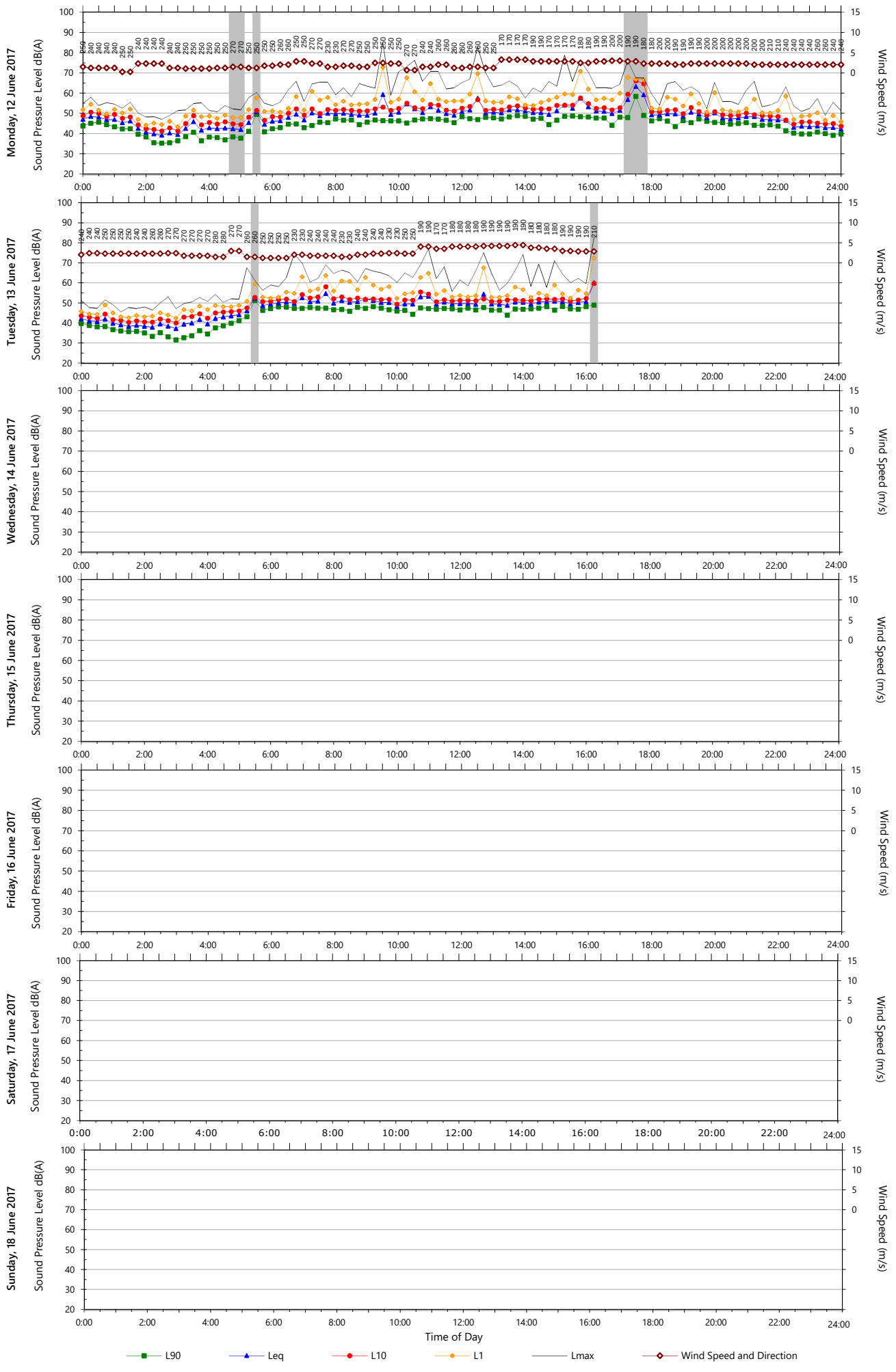



Monday, 29 May 2017
Tuesday, 30 May 2017
Wednesday, 31 May 2017
Thursday, 1 June 2017
Friday, 2 June 2017
Saturday, 3 June 2017
Sunday, 4 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Monday, 5 June 2017
Tuesday, 6 June 2017
Wednesday, 7 June 2017
Thursday, 8 June 2017
Friday, 9 June 2017
Saturday, 10 June 2017
Sunday, 11 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results

Location: 1 Delecta Avenue, Mosman



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Monitoring ID: Location L30
Address: 14 Allenby Street, Clontarf
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	40	38	33	52	48	44

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)		
	L_{Aeq} Noise Levels	
	Day[1]	Night[2]
Representative Week[3]	-	-

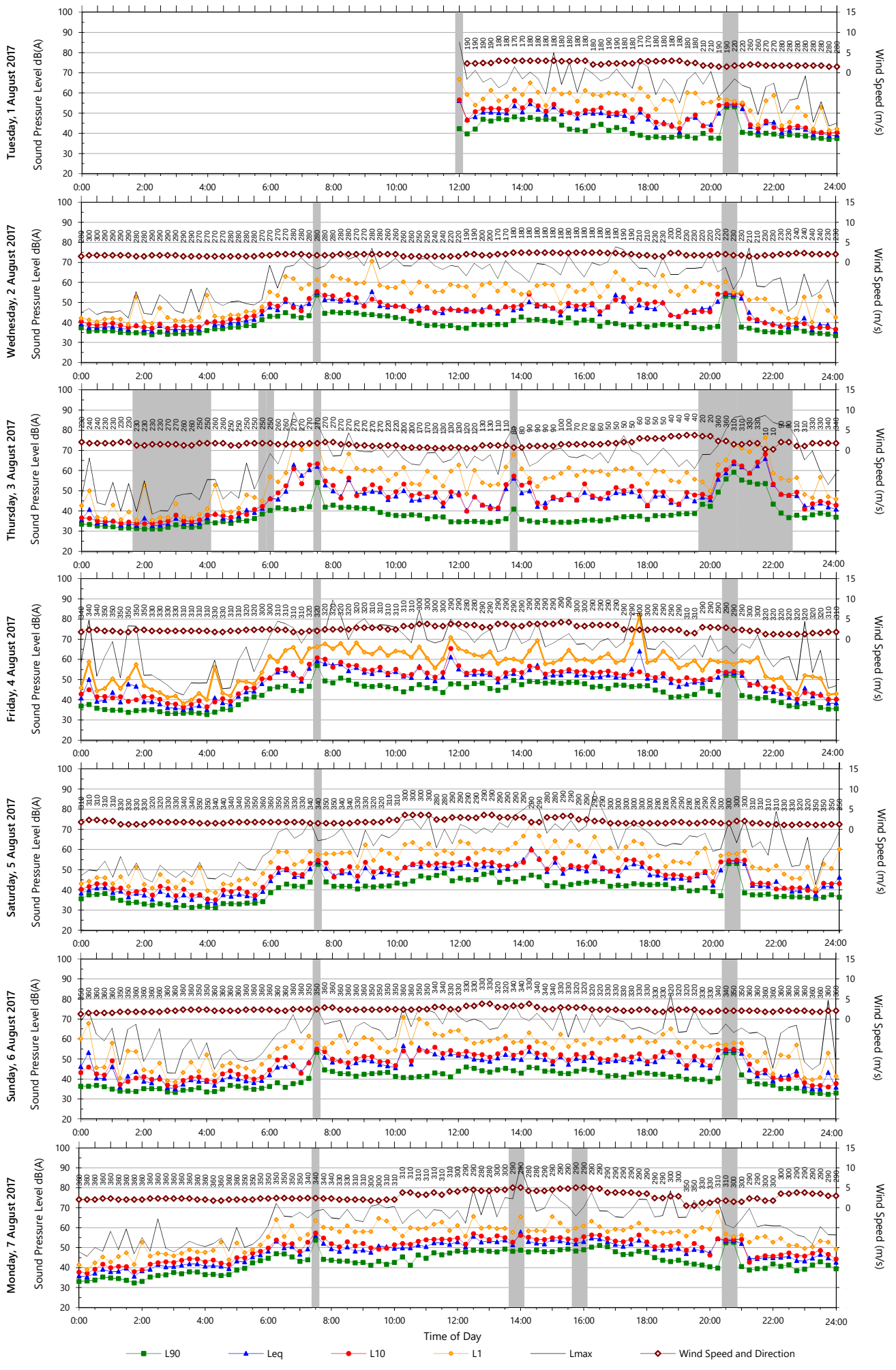
Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

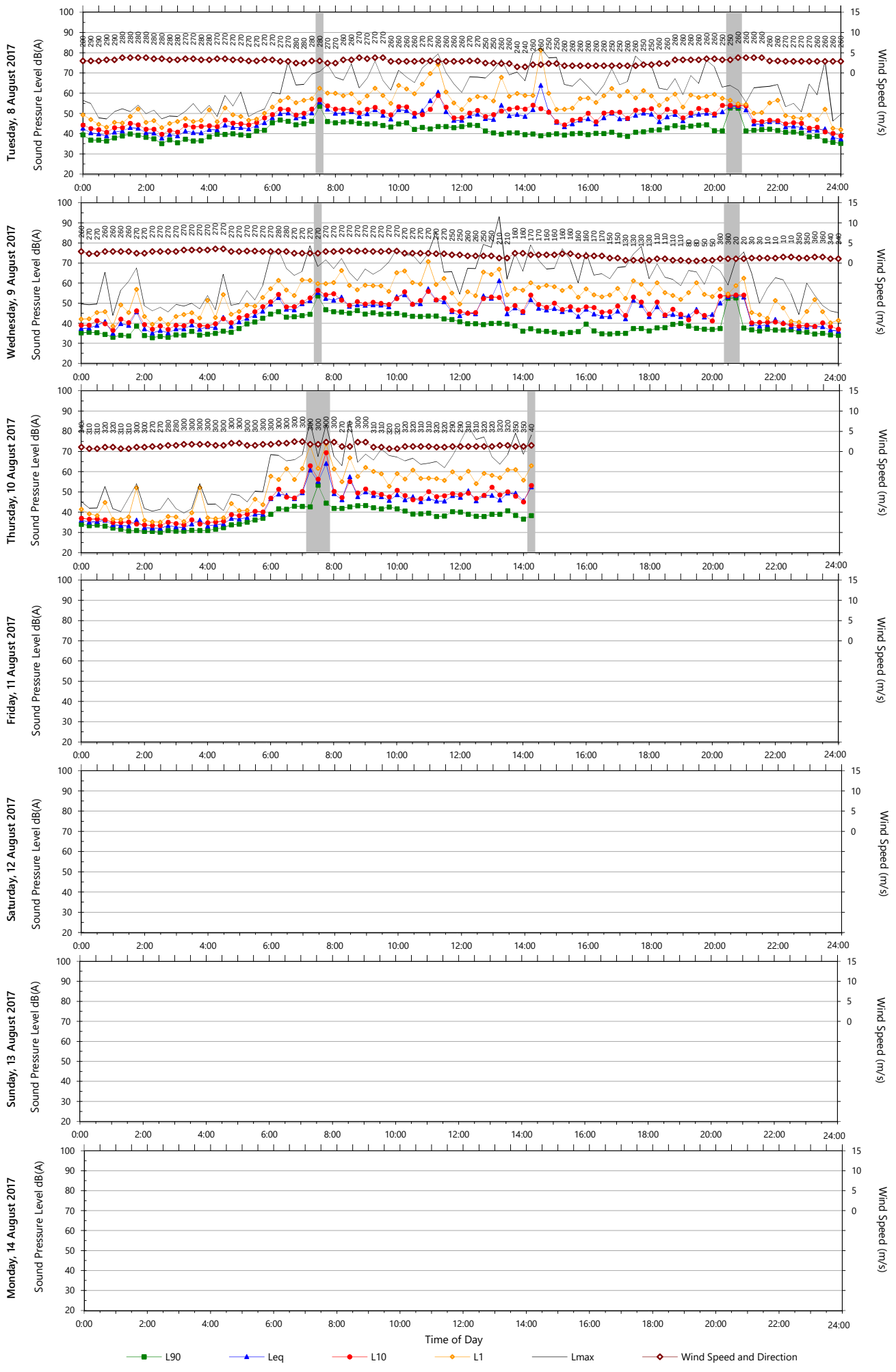
Logger Location	Aerial Photograph






Tuesday, 1 August 2017
Wednesday, 2 August 2017
Thursday, 3 August 2017
Friday, 4 August 2017
Saturday, 5 August 2017
Sunday, 6 August 2017
Monday, 7 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results **Location: 14 Allenby Street, Clontarf**



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Monitoring ID: Location L31
Address: 73 Seaforth Crescent, Seaforth
Description: Noise monitor located in the rear yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	42	38	36	51	46	47

Notes:

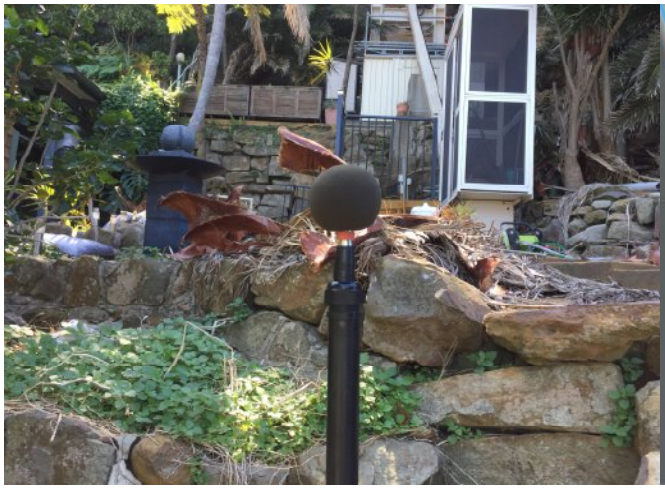
1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

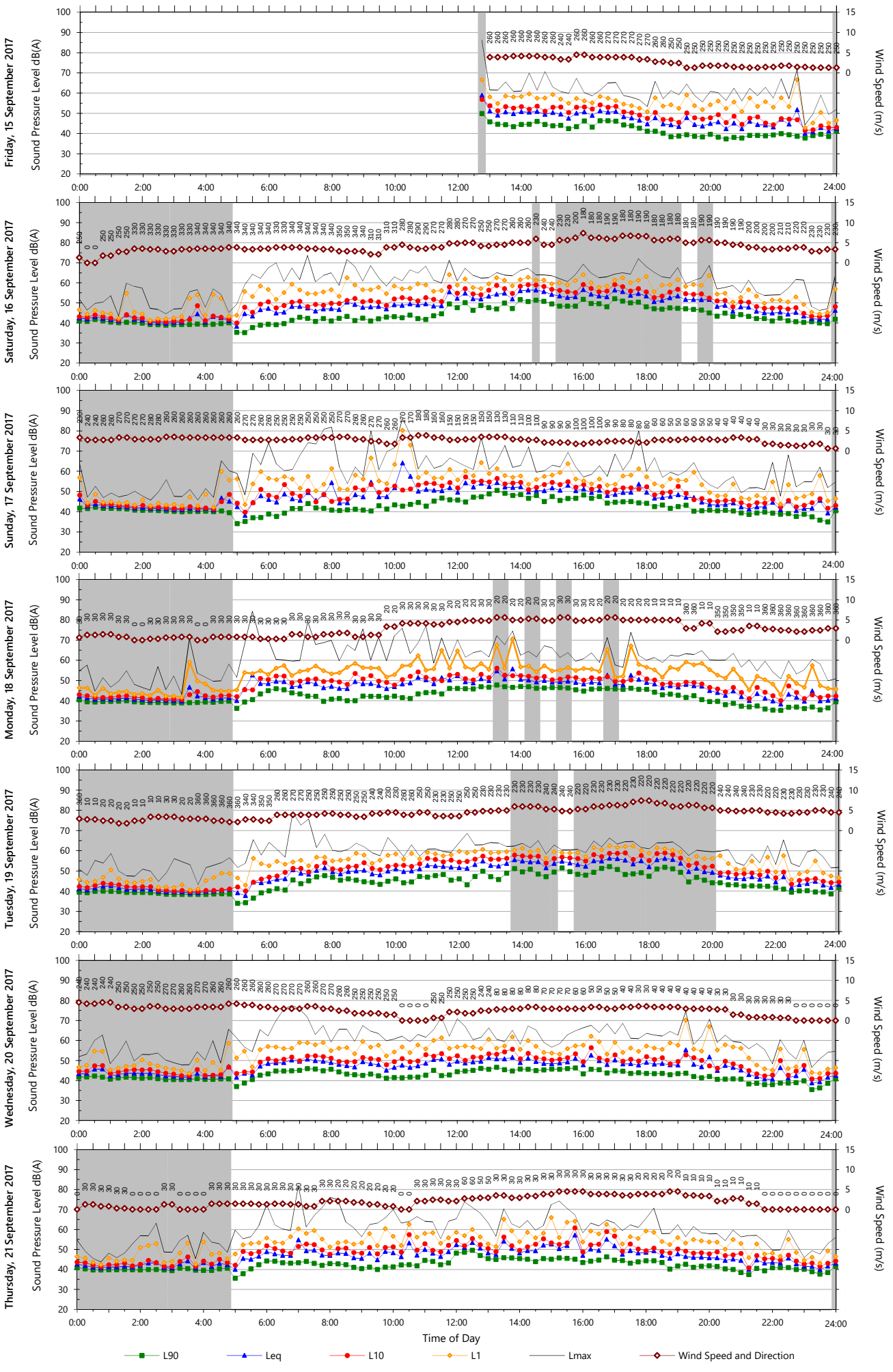
Notes:

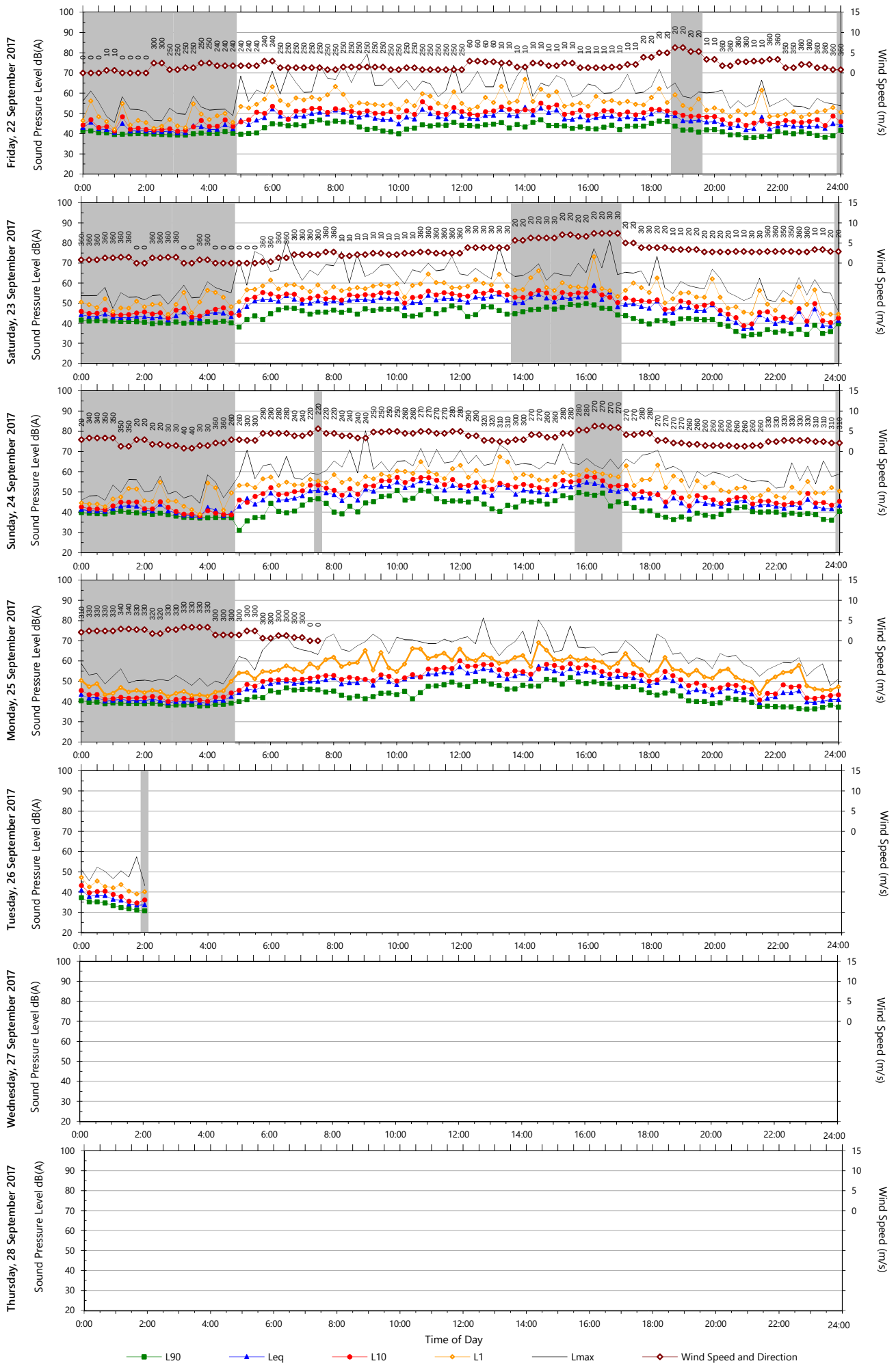
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Friday, 15 September 2017
Saturday, 16 September 2017
Sunday, 17 September 2017
Monday, 18 September 2017
Tuesday, 19 September 2017
Wednesday, 20 September 2017
Thursday, 21 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 22 September 2017
Saturday, 23 September 2017
Sunday, 24 September 2017
Monday, 25 September 2017
Tuesday, 26 September 2017
Wednesday, 27 September 2017
Thursday, 28 September 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L32
Address: 17 Seaforth Crescent, Seaforth
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	50	49	40	55	54	49

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

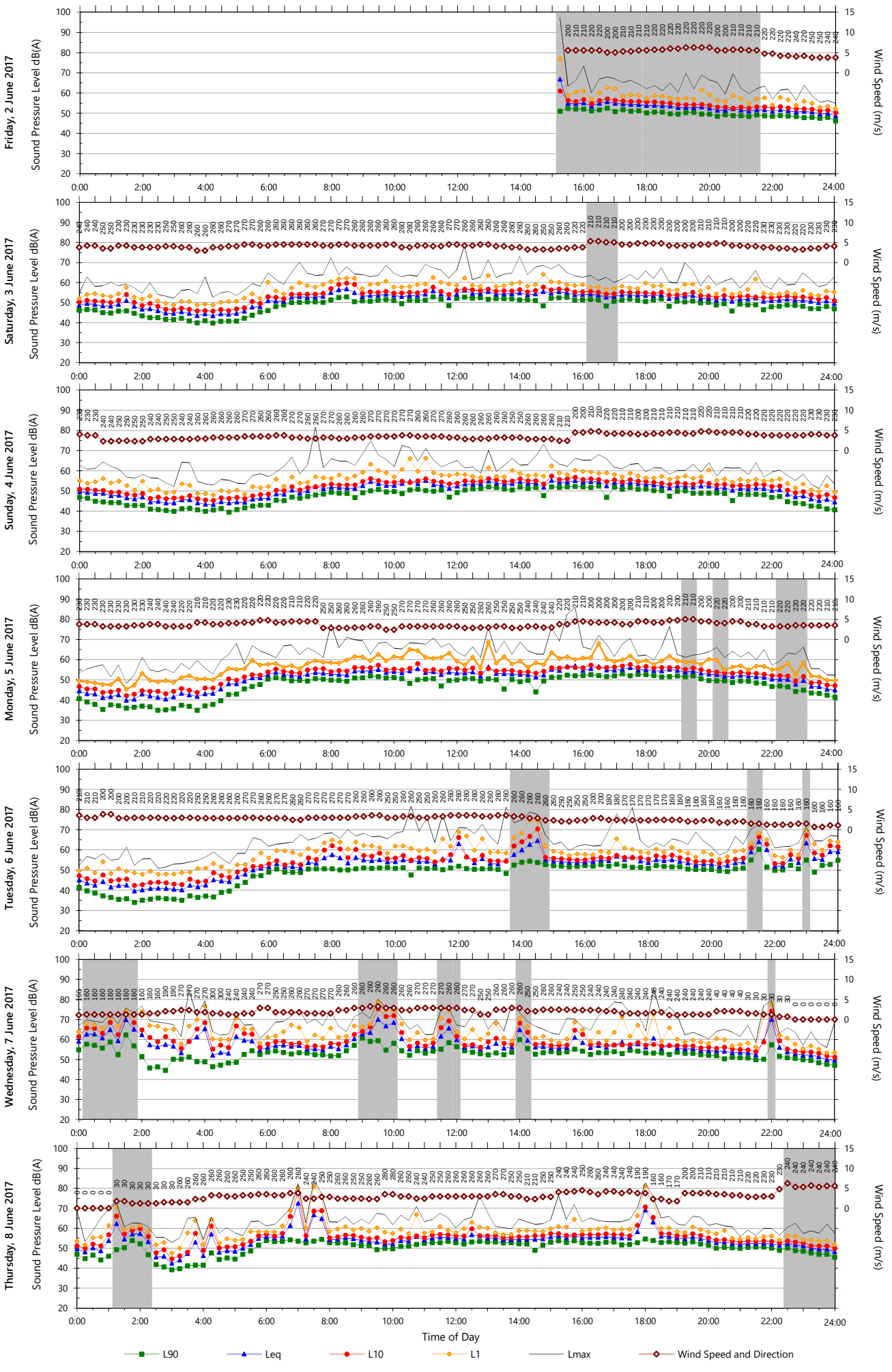
Logger Location	Aerial Photograph

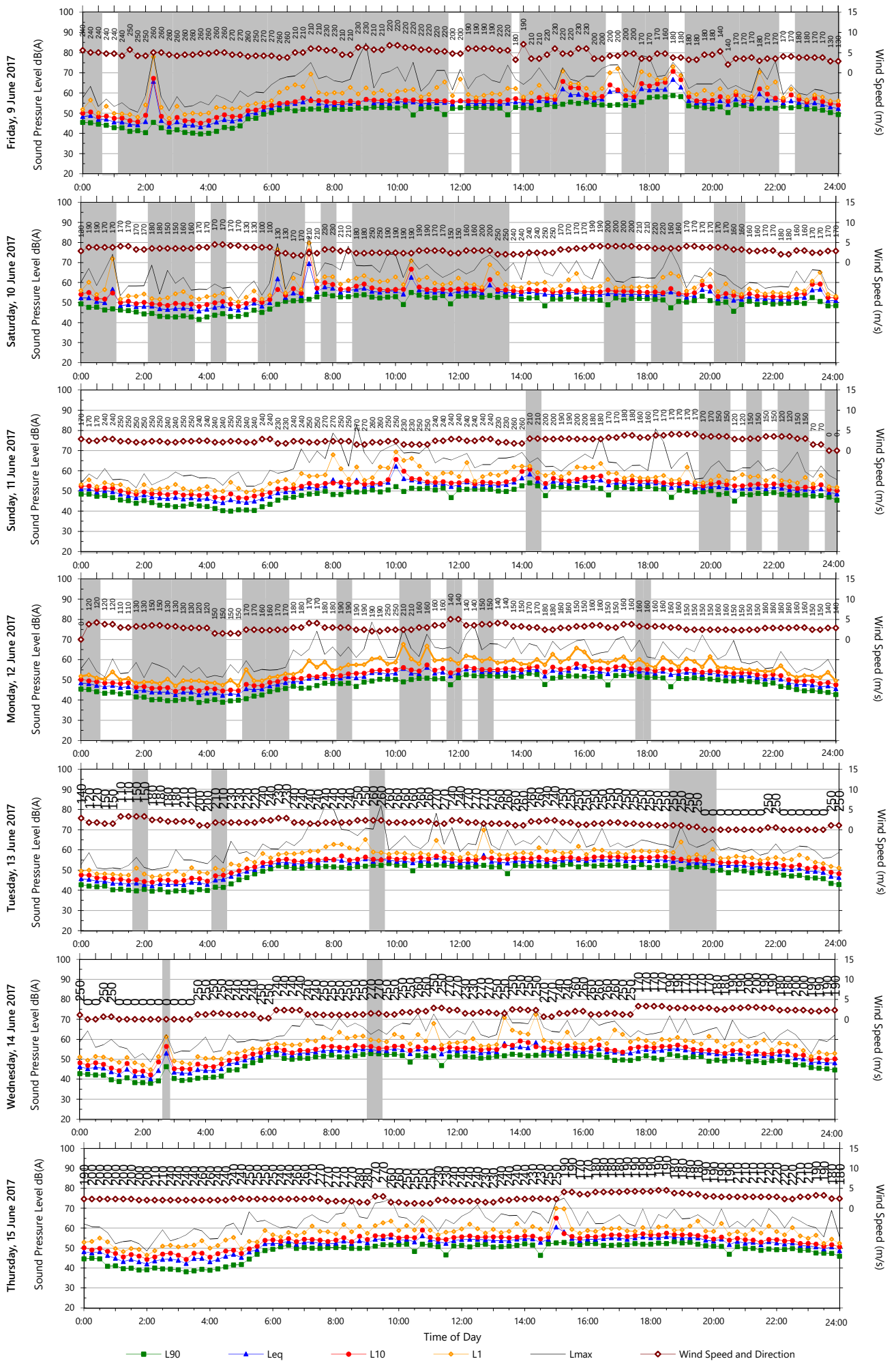


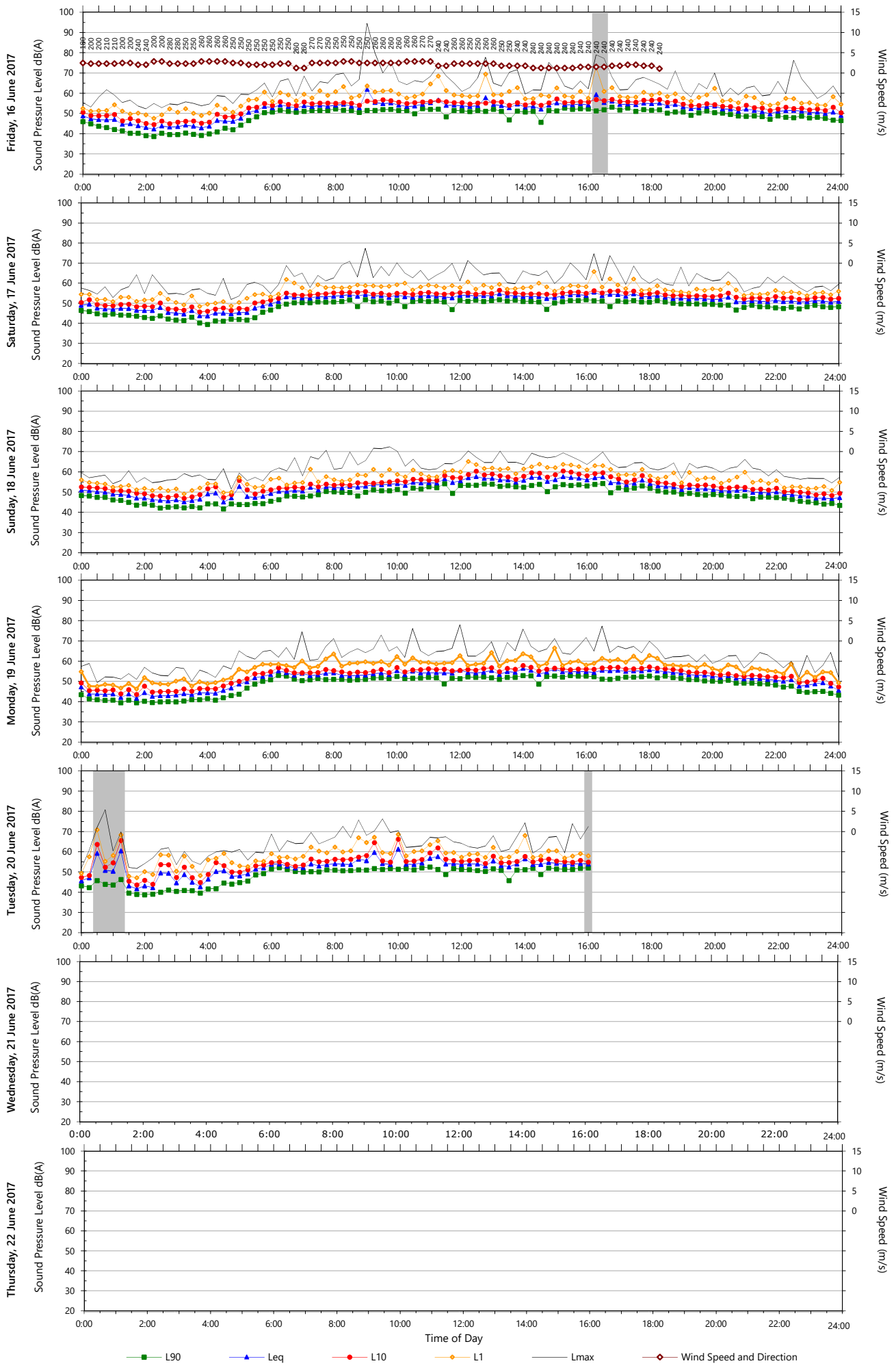


Unattended Monitoring Results

Location: 17 Seaforth Crescent, Seaforth




Friday, 9 June 2017
Saturday, 10 June 2017
Sunday, 11 June 2017
Monday, 12 June 2017
Tuesday, 13 June 2017
Wednesday, 14 June 2017
Thursday, 15 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 16 June 2017
Saturday, 17 June 2017
Sunday, 18 June 2017
Monday, 19 June 2017
Tuesday, 20 June 2017
Wednesday, 21 June 2017
Thursday, 22 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L33
Address: 2 Ross Street, Seaforth
Description: Noise monitor located in the rear yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	**43**	**39**	**30**	**53**	**50**	**43**

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

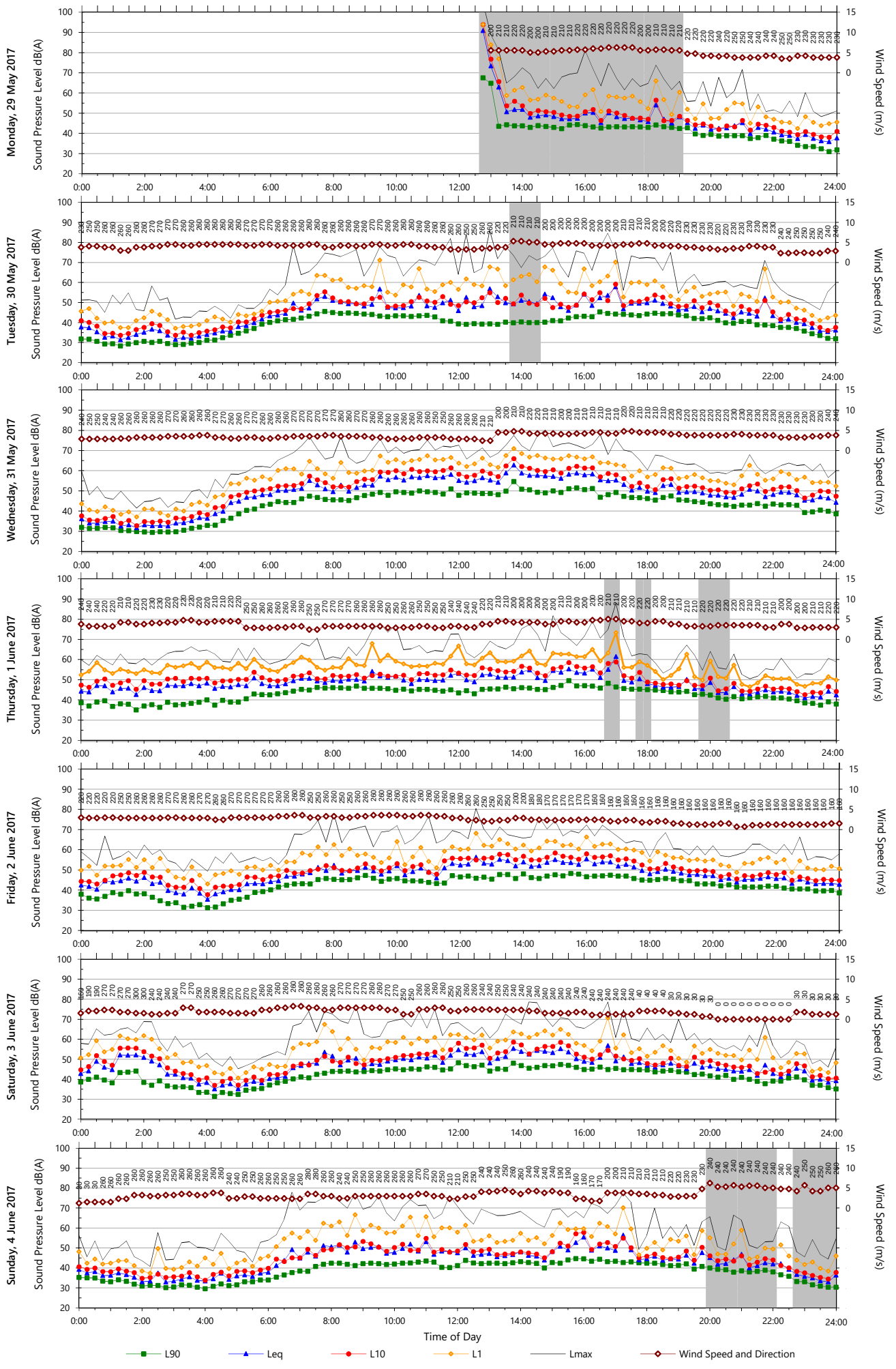
Notes:

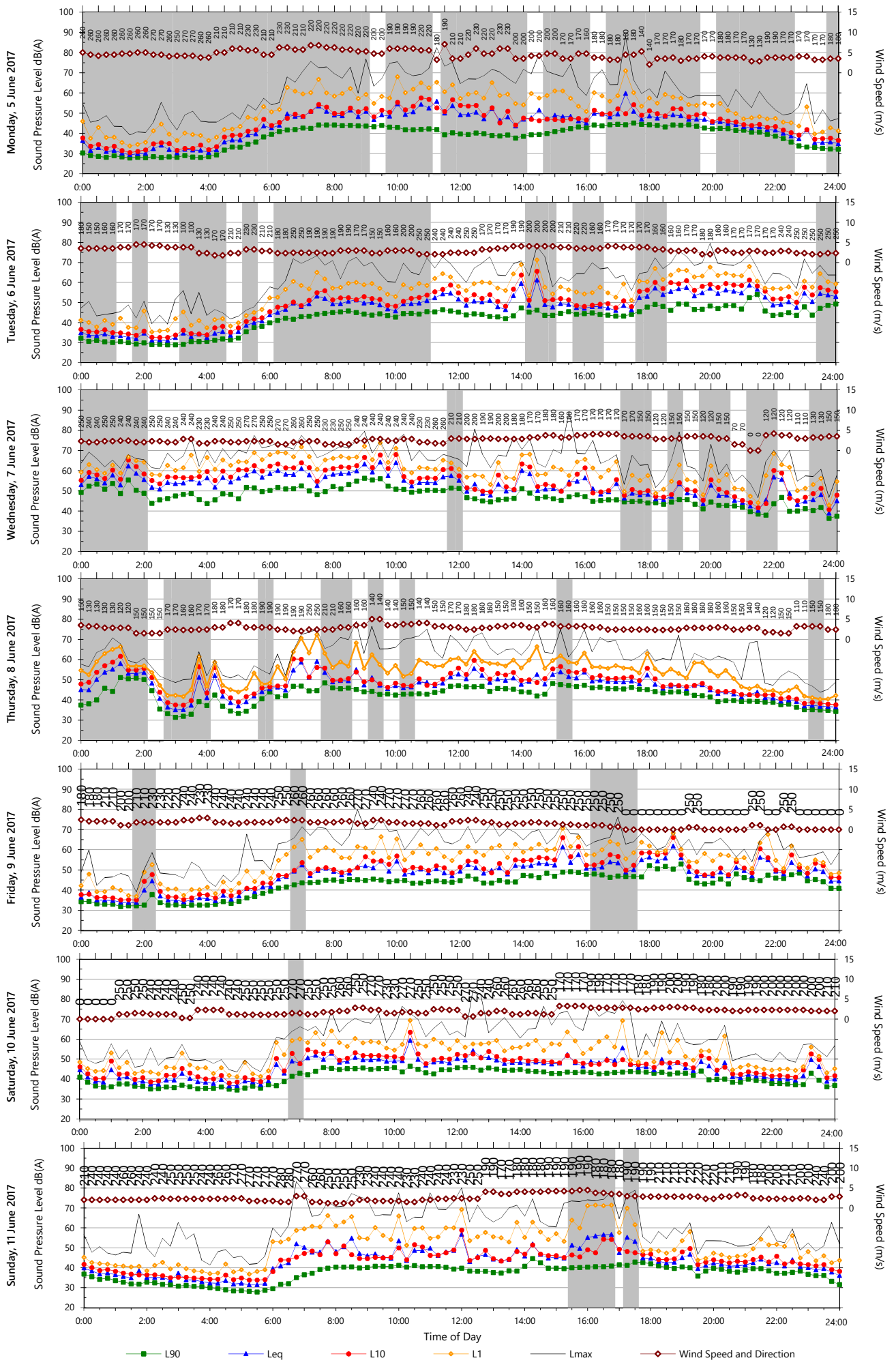
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph



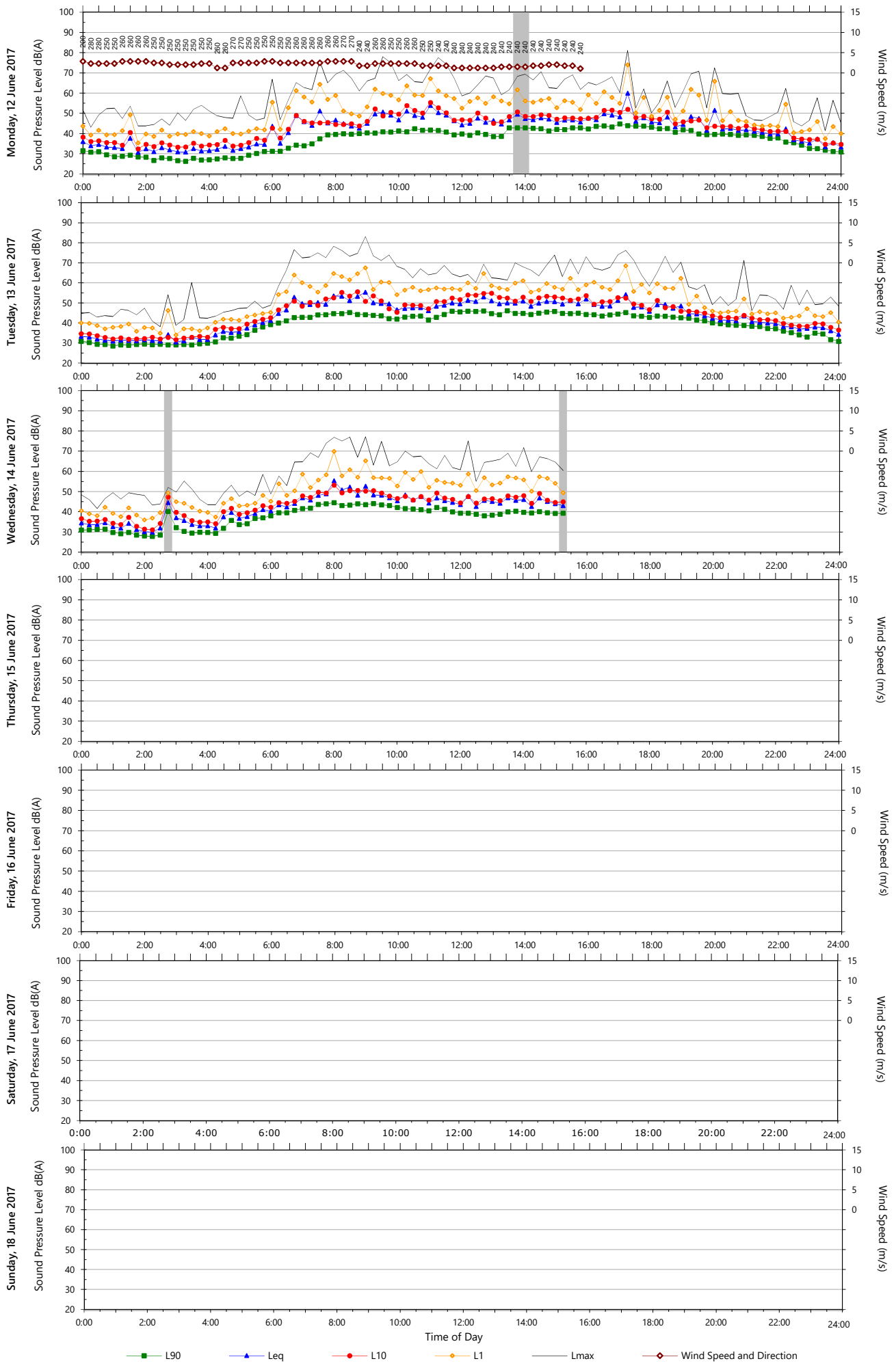



Monday, 29 May 2017
Tuesday, 30 May 2017
Wednesday, 31 May 2017
Thursday, 1 June 2017
Friday, 2 June 2017
Saturday, 3 June 2017
Sunday, 4 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Monday, 5 June 2017
Tuesday, 6 June 2017
Wednesday, 7 June 2017
Thursday, 8 June 2017
Friday, 9 June 2017
Saturday, 10 June 2017
Sunday, 11 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results

Location: 2 Ross Street, Seaforth



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Monitoring ID: Location L34
Address: 1/6 Whittle Avenue, Balgowlah
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on Manly Road.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	58	54	37	65	63	61

Notes:

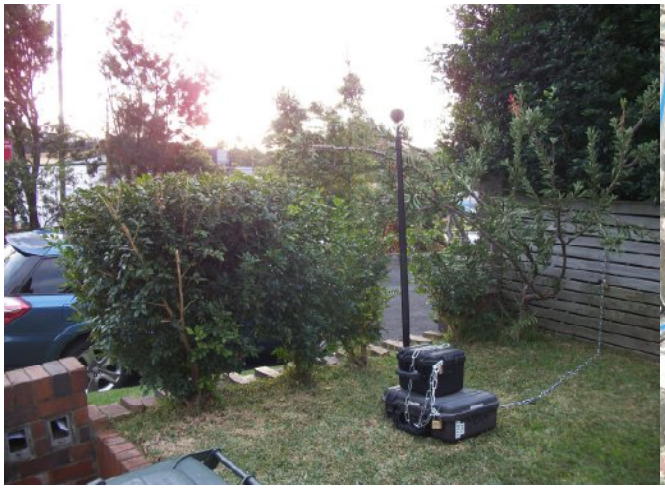
1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	67	64	

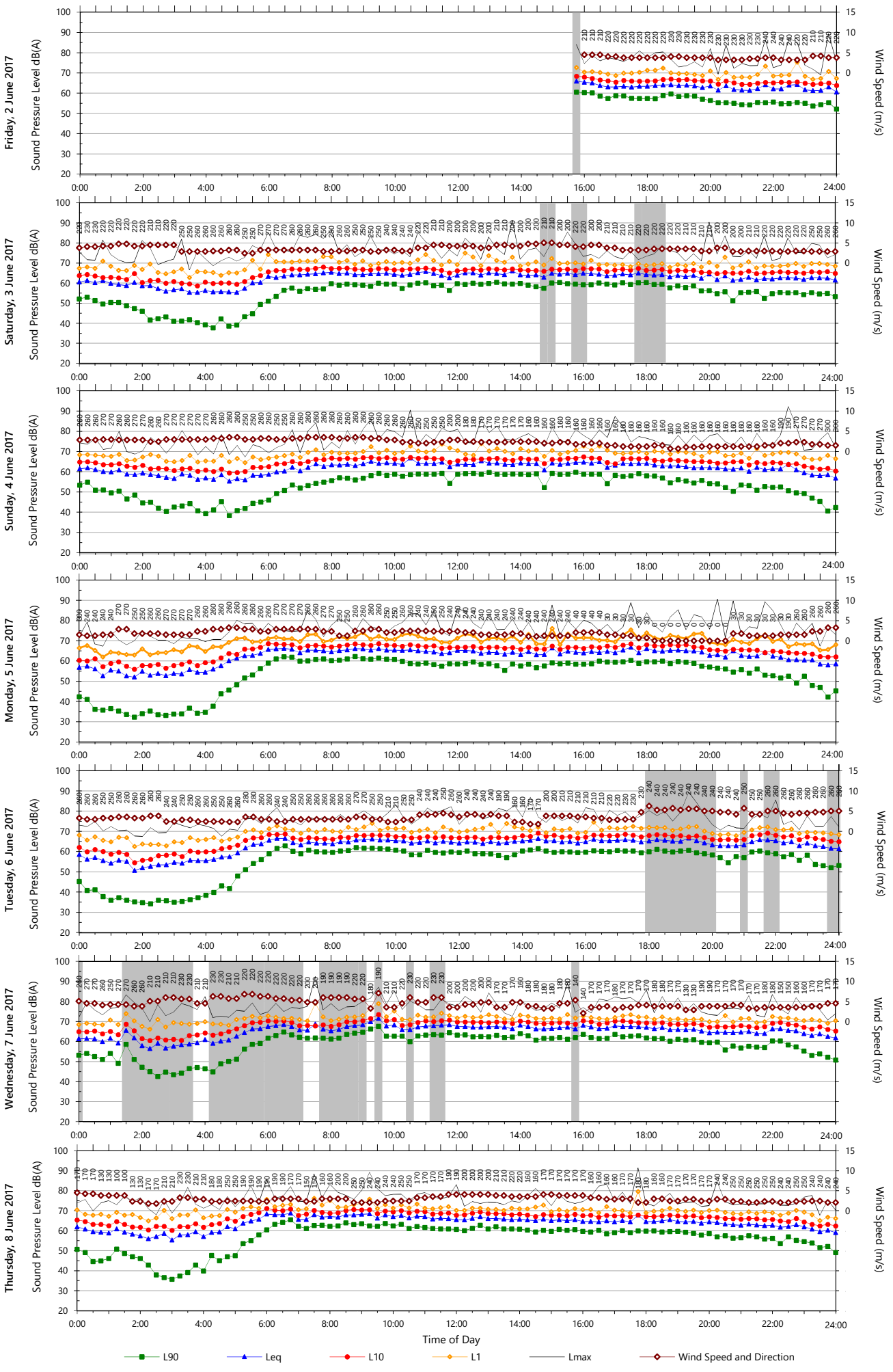
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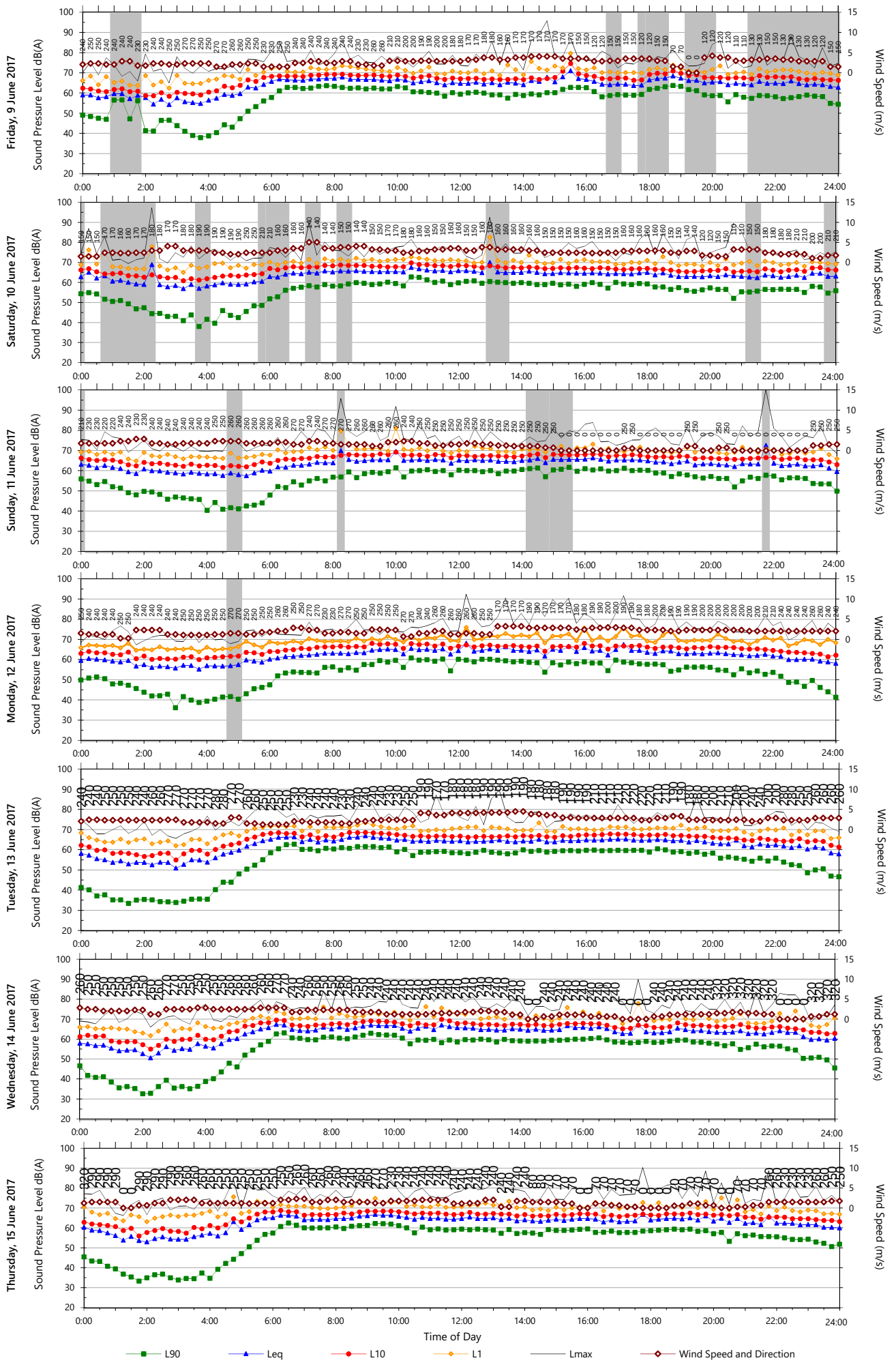
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

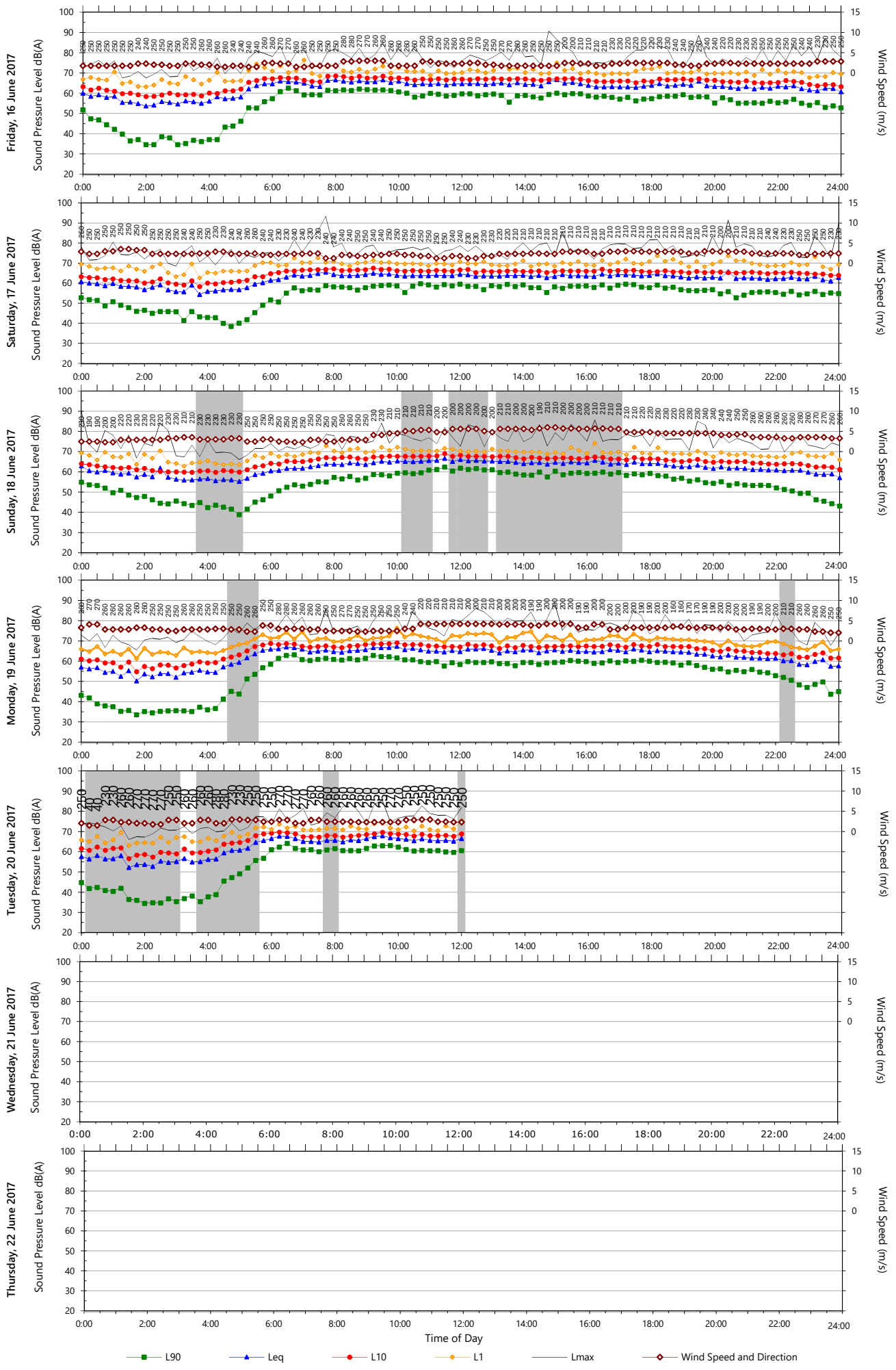
Logger Location	Aerial Photograph






Friday, 2 June 2017
Saturday, 3 June 2017
Sunday, 4 June 2017
Monday, 5 June 2017
Tuesday, 6 June 2017
Wednesday, 7 June 2017
Thursday, 8 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 9 June 2017
Saturday, 10 June 2017
Sunday, 11 June 2017
Monday, 12 June 2017
Tuesday, 13 June 2017
Wednesday, 14 June 2017
Thursday, 15 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Friday, 16 June 2017
Saturday, 17 June 2017
Sunday, 18 June 2017
Monday, 19 June 2017
Tuesday, 20 June 2017
Wednesday, 21 June 2017
Thursday, 22 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L35
Address: 469 Sydney Road, Balgowlah
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on Sydney Road.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	55	50	32	71	70	68

Notes:

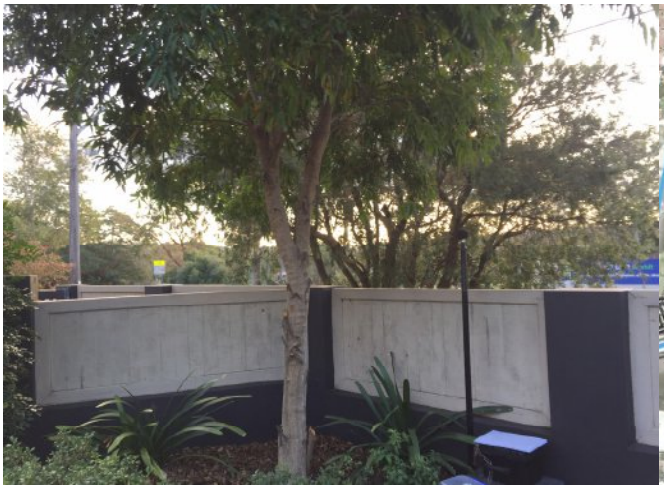
1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	73	71	

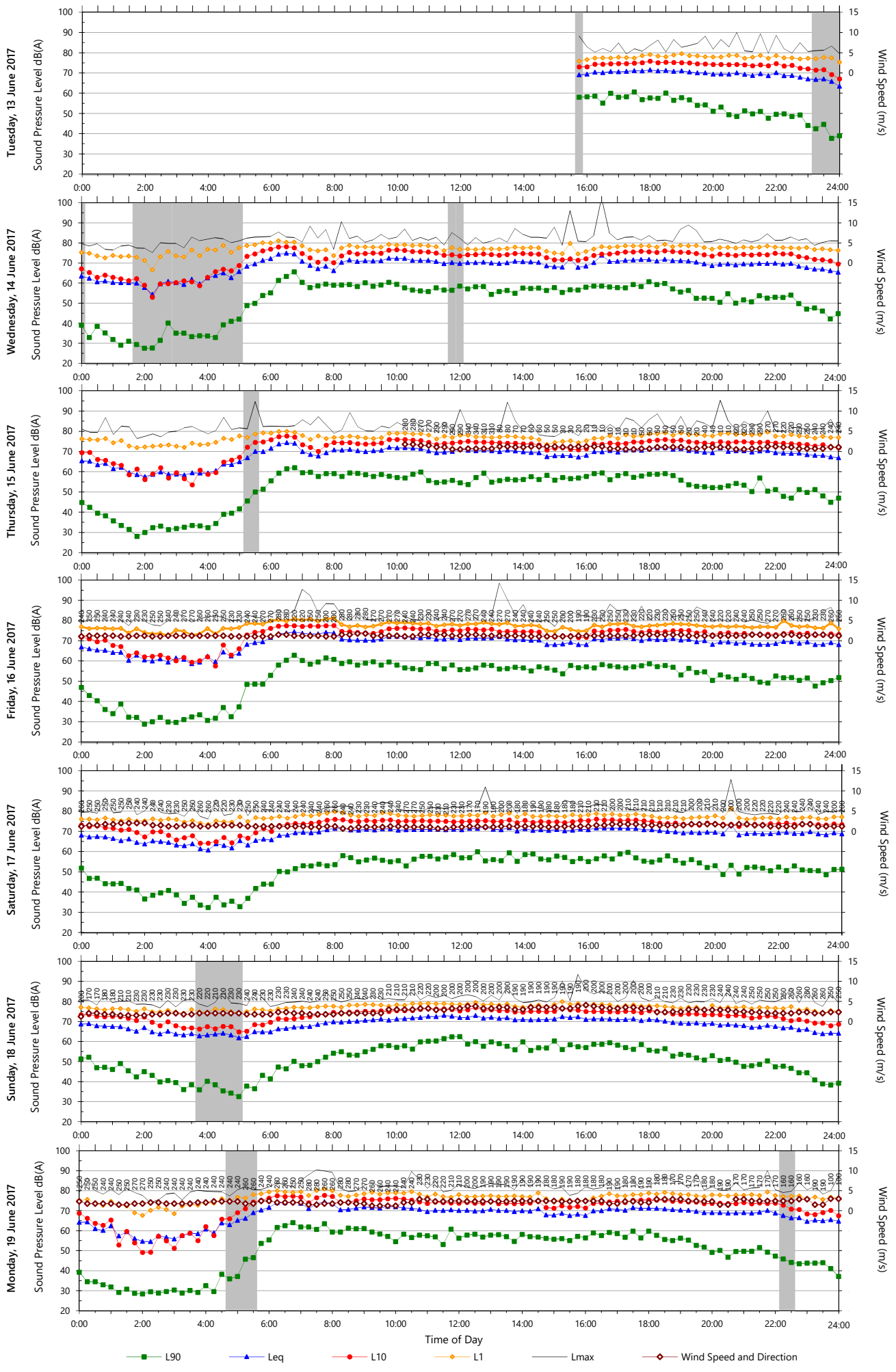
Notes:

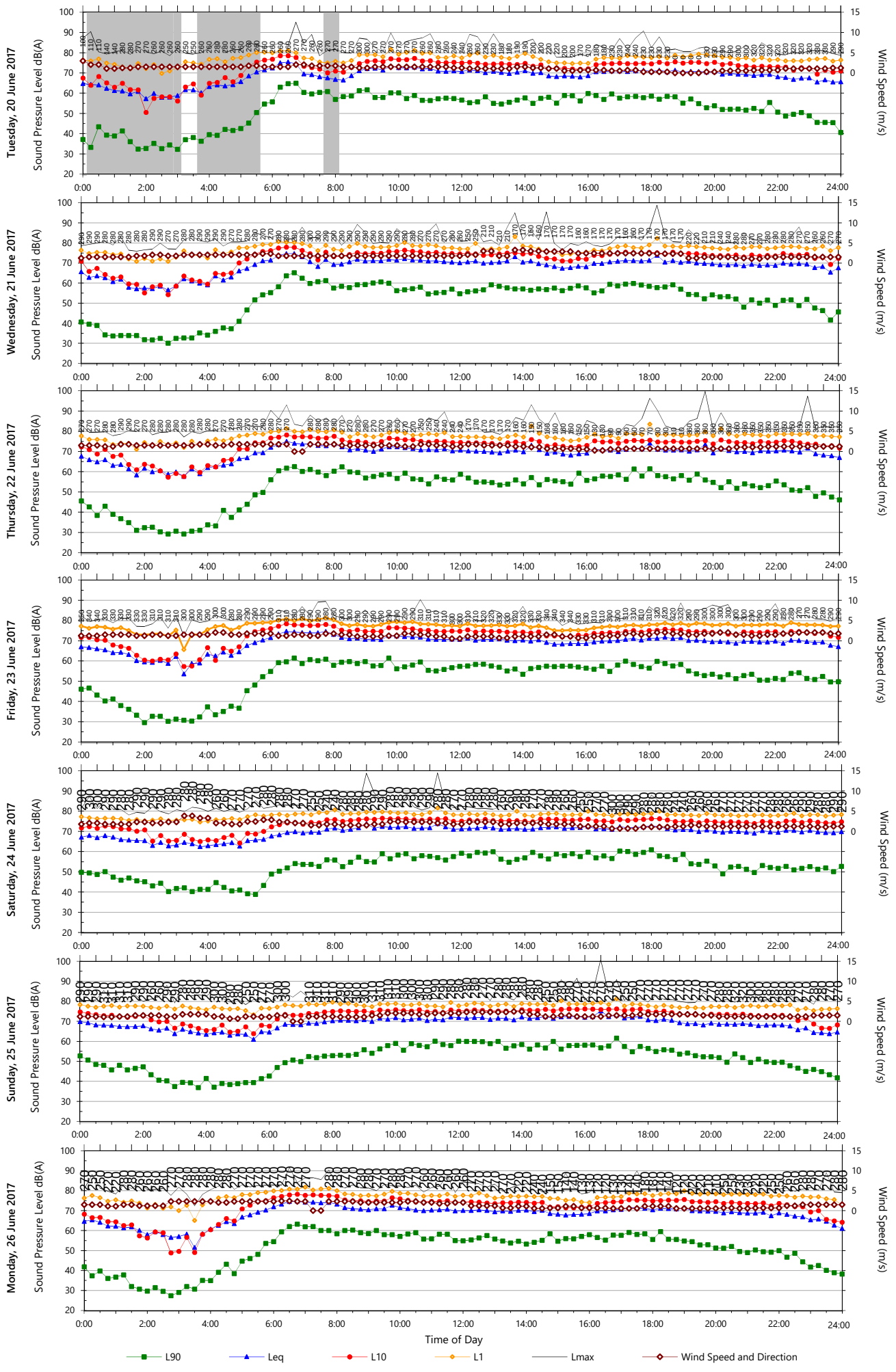
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph



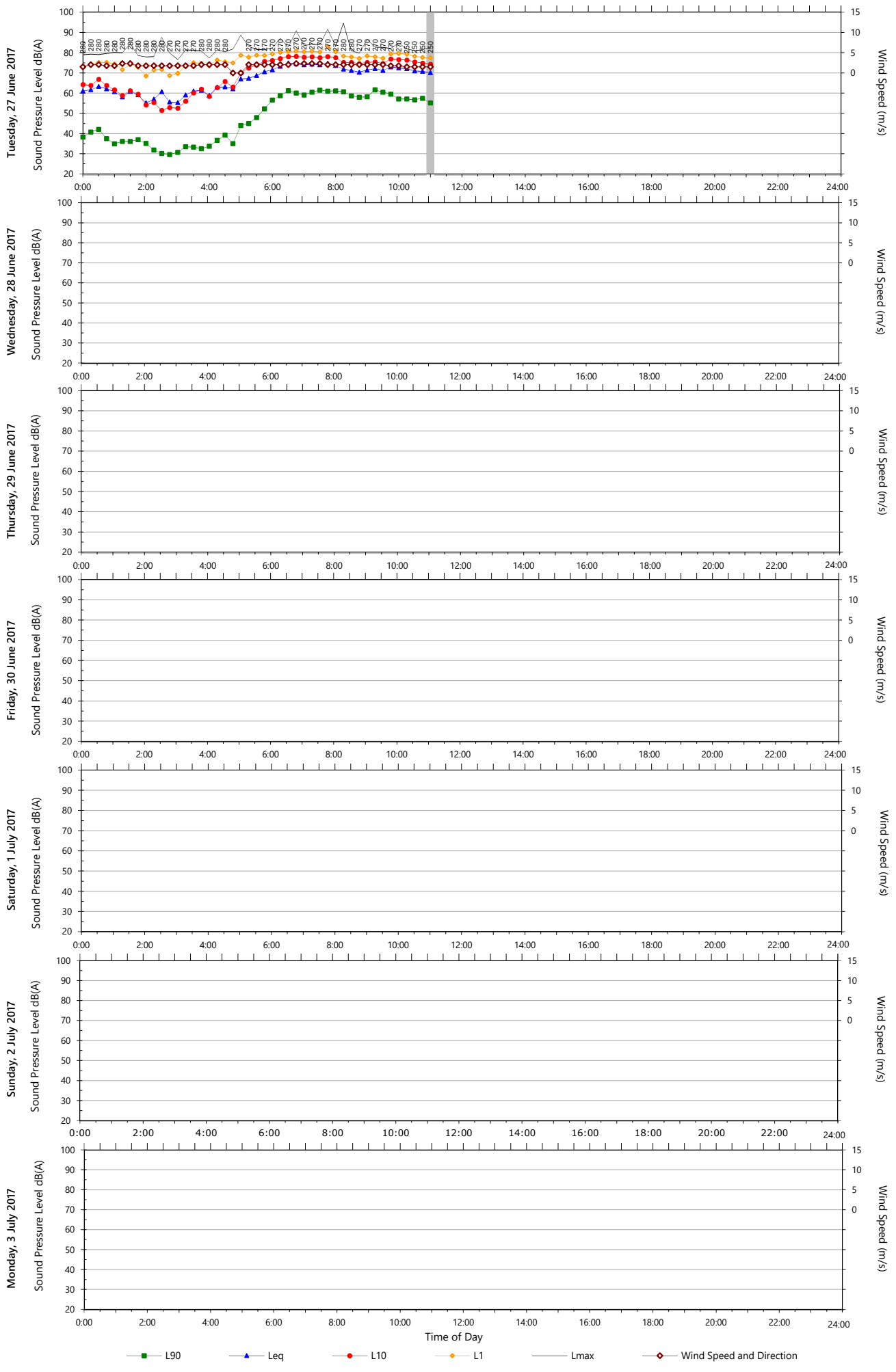



Tuesday, 13 June 2017
Wednesday, 14 June 2017
Thursday, 15 June 2017
Friday, 16 June 2017
Saturday, 17 June 2017
Sunday, 18 June 2017
Monday, 19 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Tuesday, 20 June 2017
Wednesday, 21 June 2017
Thursday, 22 June 2017
Friday, 23 June 2017
Saturday, 24 June 2017
Sunday, 25 June 2017
Monday, 26 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results

Location: 469 Sydney Road, Balgowlah



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Monitoring ID: Location L36
Address: 14 Pickworth Avenue, Balgowlah
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on Sydney Road.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	47	45	35	53	51	49

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	55	52	

Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

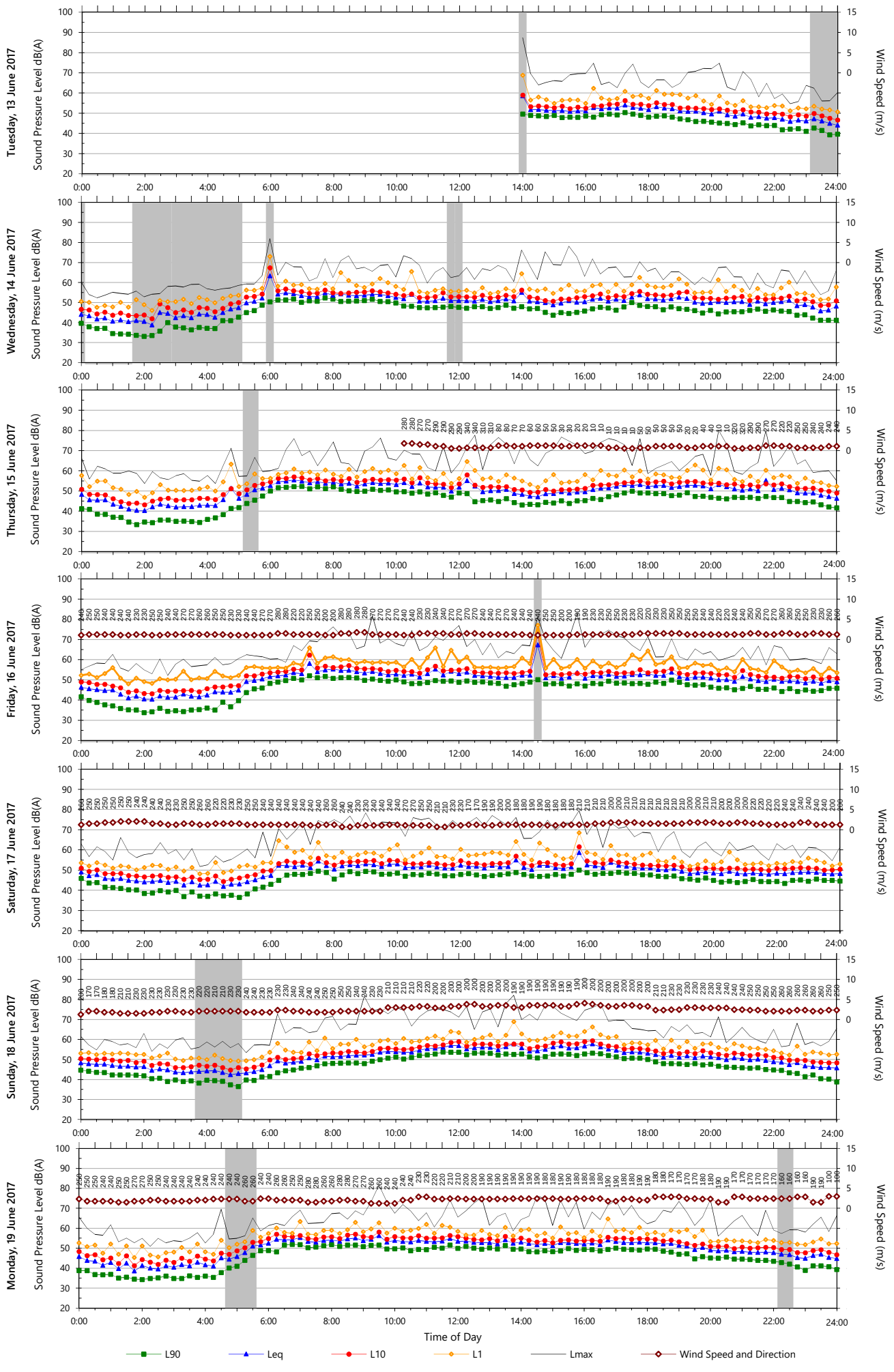
Logger Location	Aerial Photograph

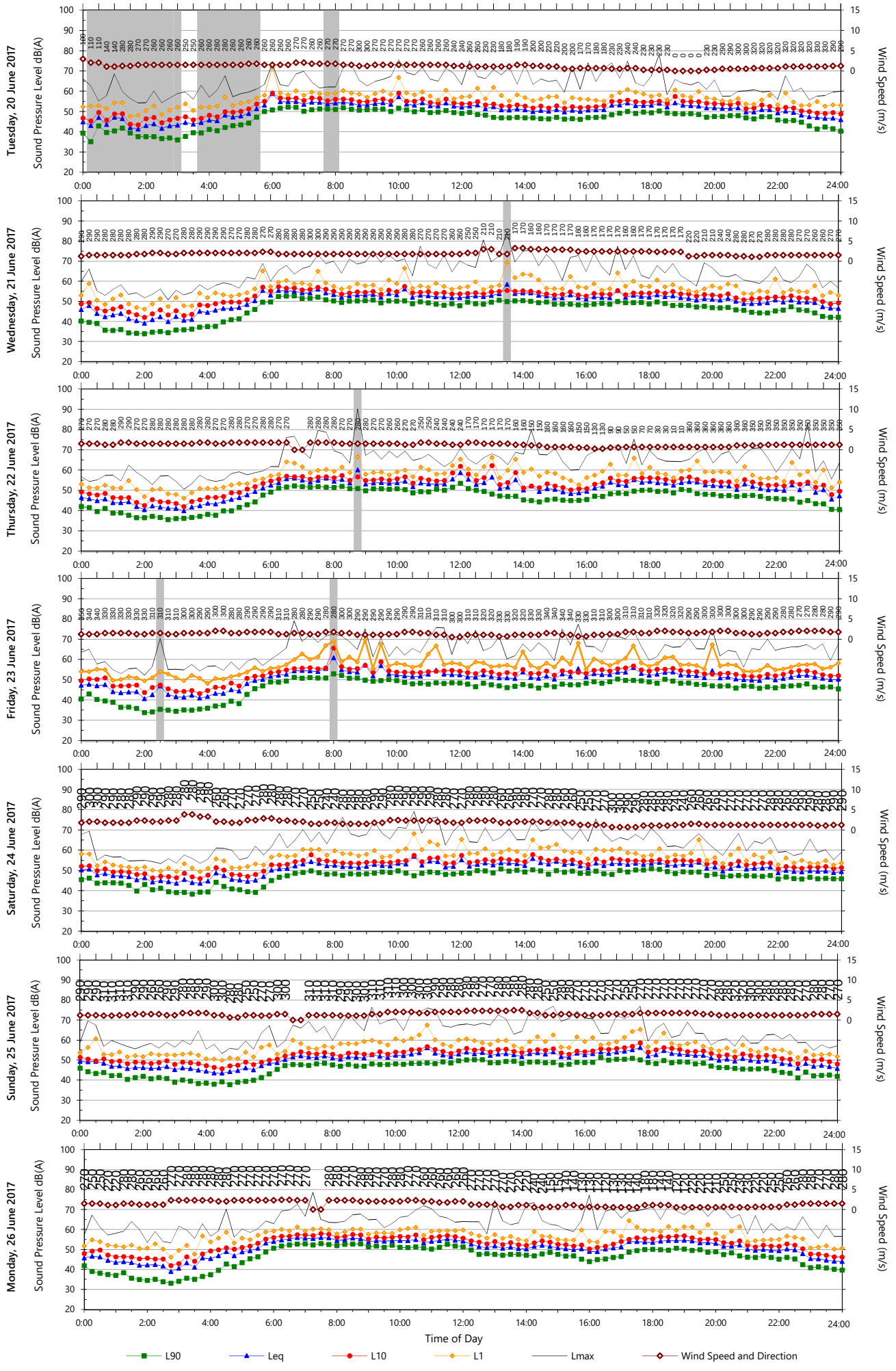


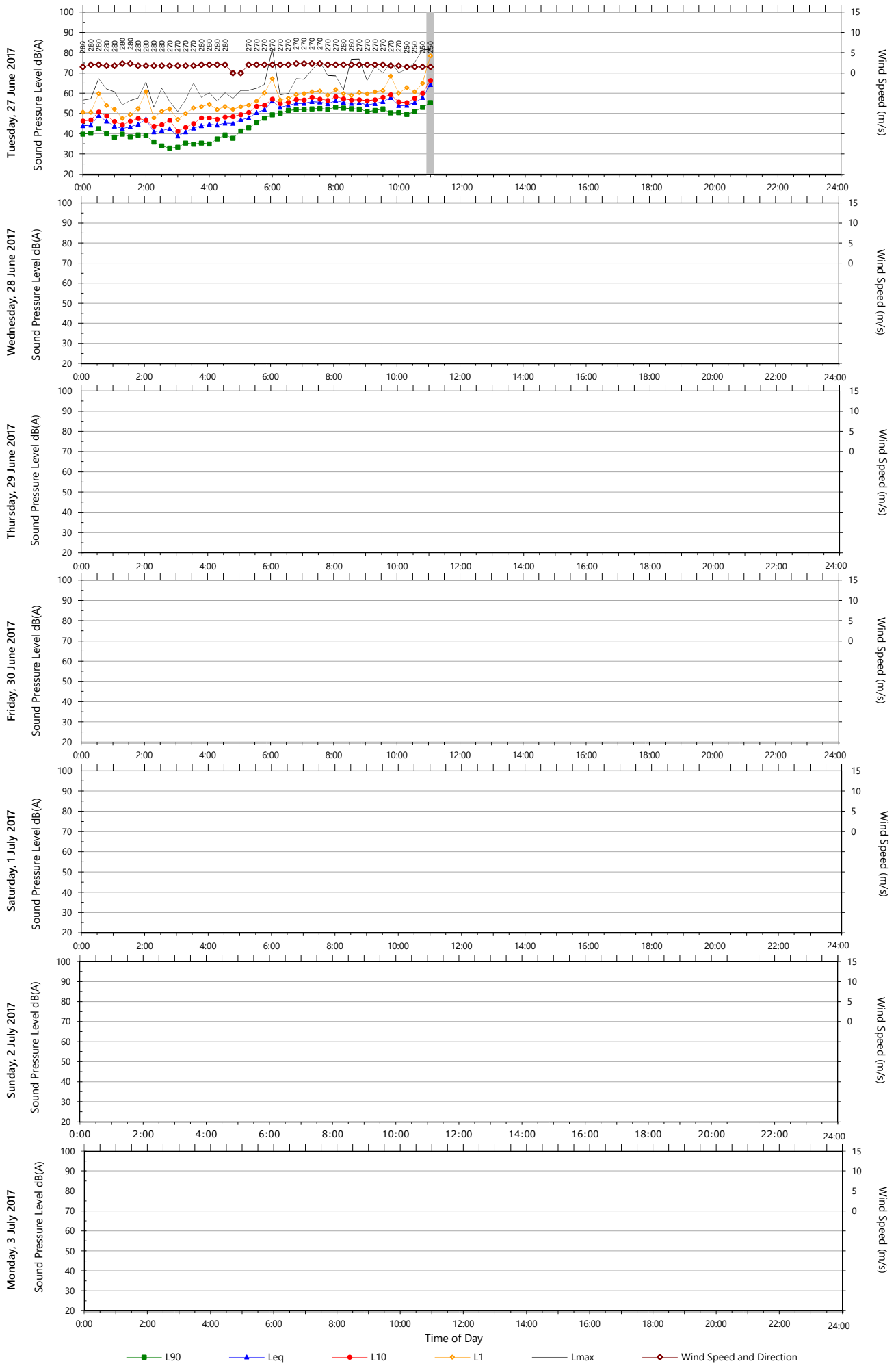


Unattended Monitoring Results

Location: 14 Pickworth Avenue, Balgowlah




Tuesday, 20 June 2017
Wednesday, 21 June 2017
Thursday, 22 June 2017
Friday, 23 June 2017
Saturday, 24 June 2017
Sunday, 25 June 2017
Monday, 26 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Tuesday, 27 June 2017
Wednesday, 28 June 2017
Thursday, 29 June 2017
Friday, 30 June 2017
Saturday, 1 July 2017
Sunday, 2 July 2017
Monday, 3 July 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L37
Address: 22 Hope Street, Seaforth
Description: Noise monitor located in the rear yard and positioned in the free-field. Noise environment dominated by traffic on Burnt Bridge Creek Deviation.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	45	42	31	53	52	48

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	56	51	

Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

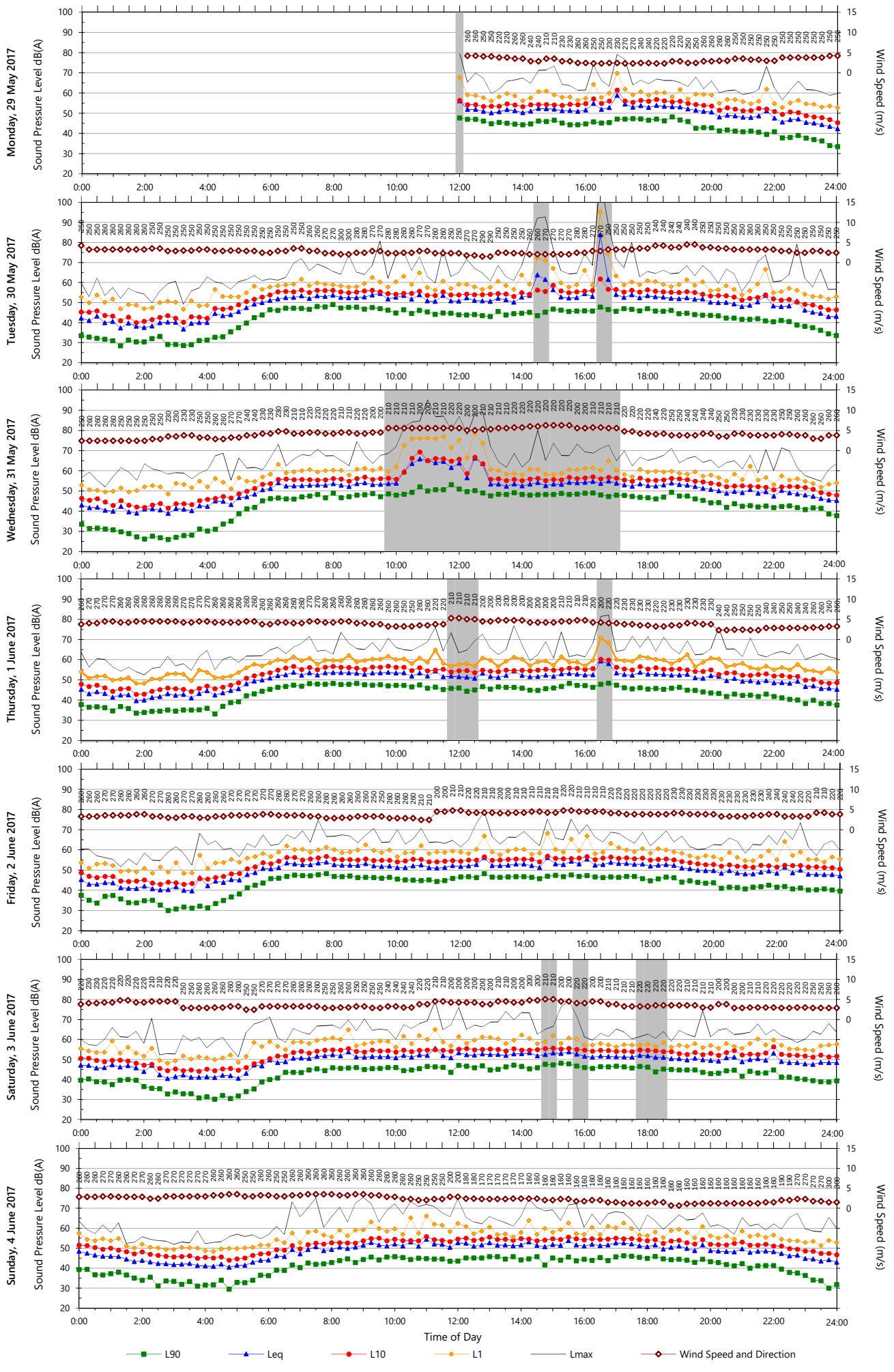
Logger Location	Aerial Photograph

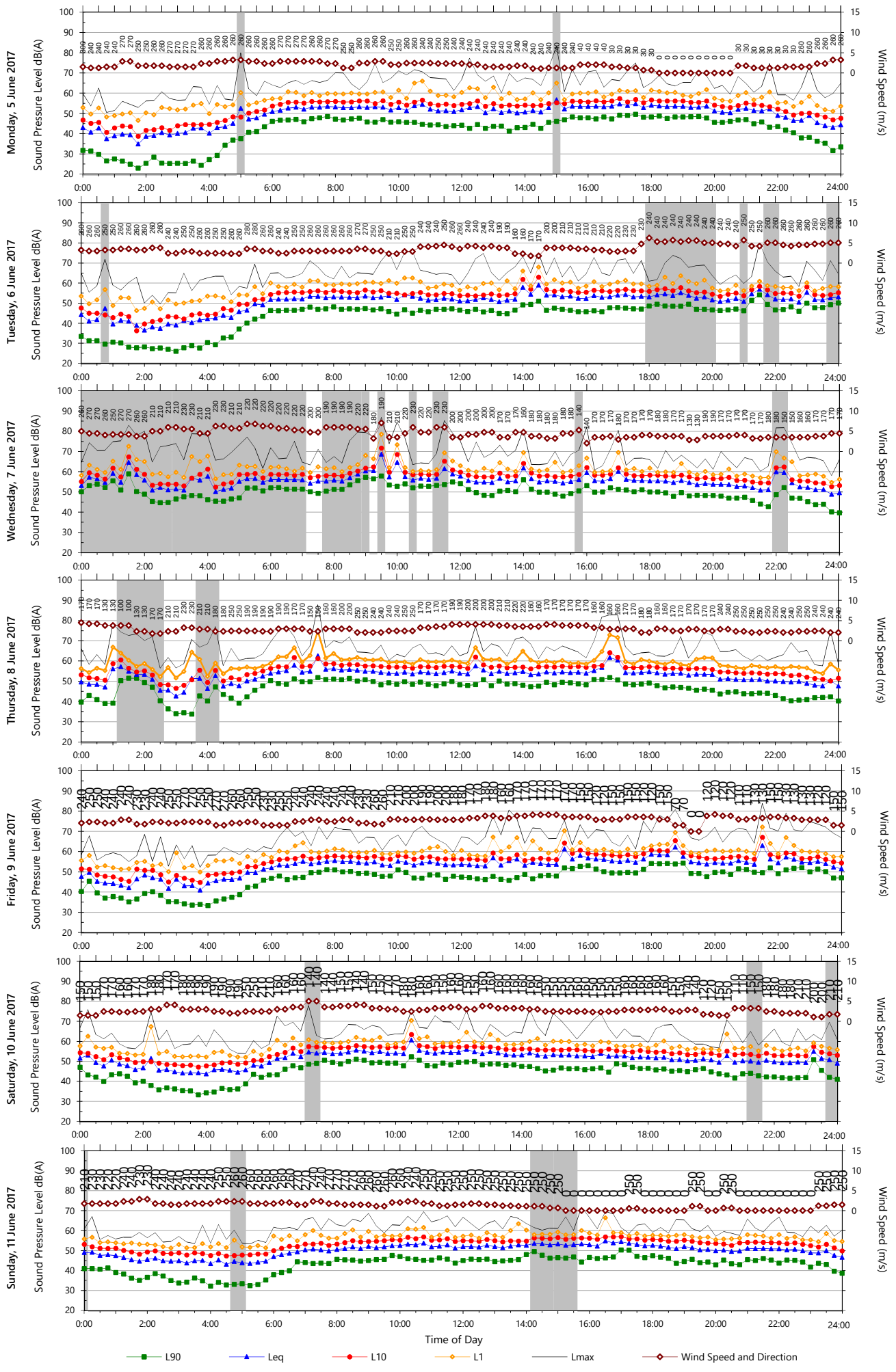




Unattended Monitoring Results

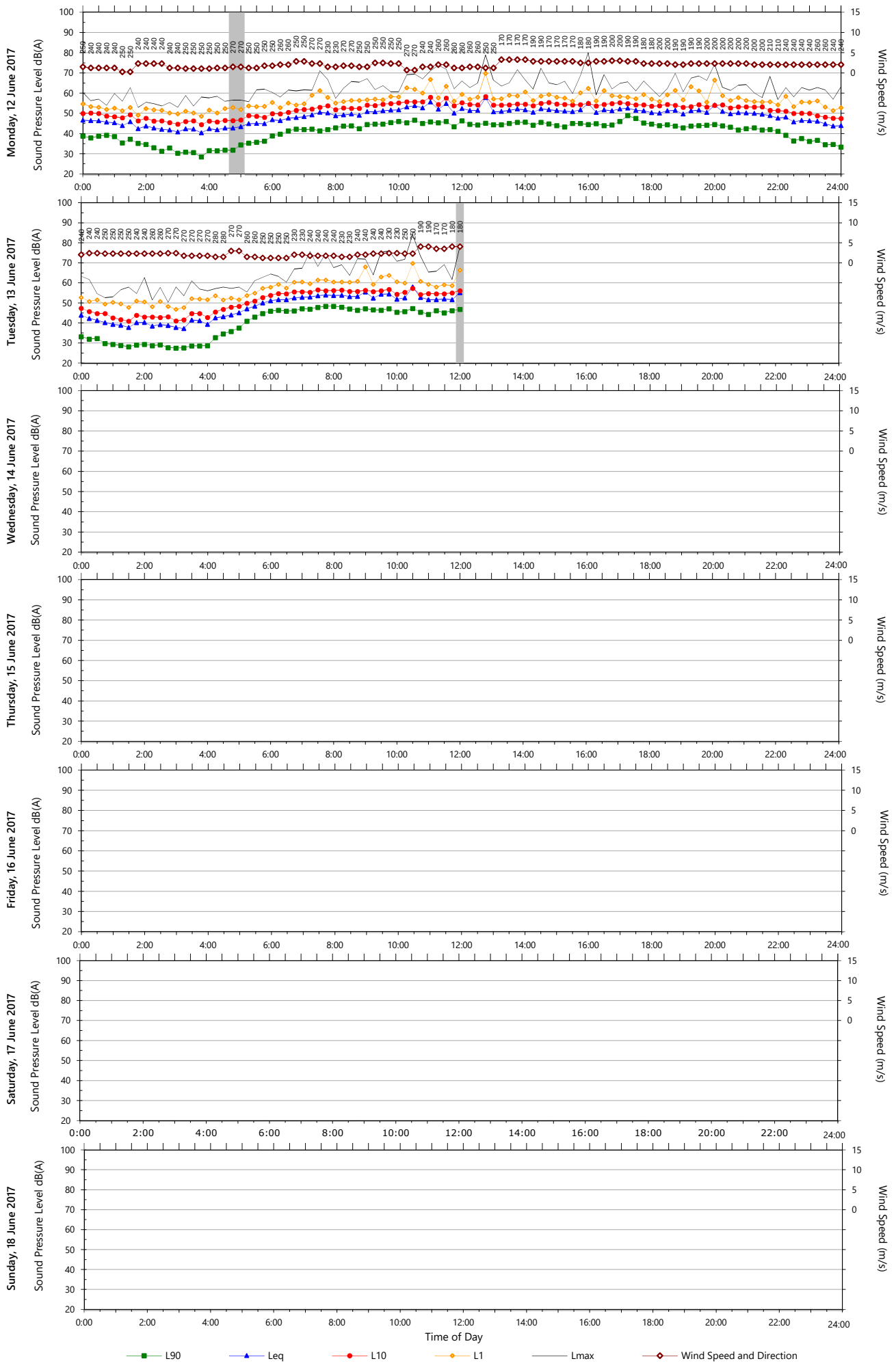
Location: 22 Hope Street, Seaforth




Monday, 5 June 2017
Tuesday, 6 June 2017
Wednesday, 7 June 2017
Thursday, 8 June 2017
Friday, 9 June 2017
Saturday, 10 June 2017
Sunday, 11 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results

Location: 22 Hope Street, Seaforth



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Monitoring ID: Location L38
Address: 49 Hope Street, Seaforth
Description: Noise monitor located in the rear yard and positioned in the free-field. Noise environment dominated by traffic on Burnt Bridge Creek Deviation.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	43	40	33	51	49	44

Notes:

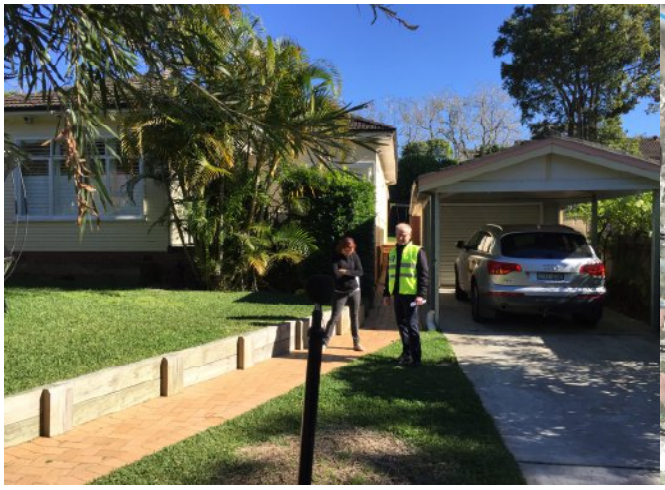
1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	54	49	

Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

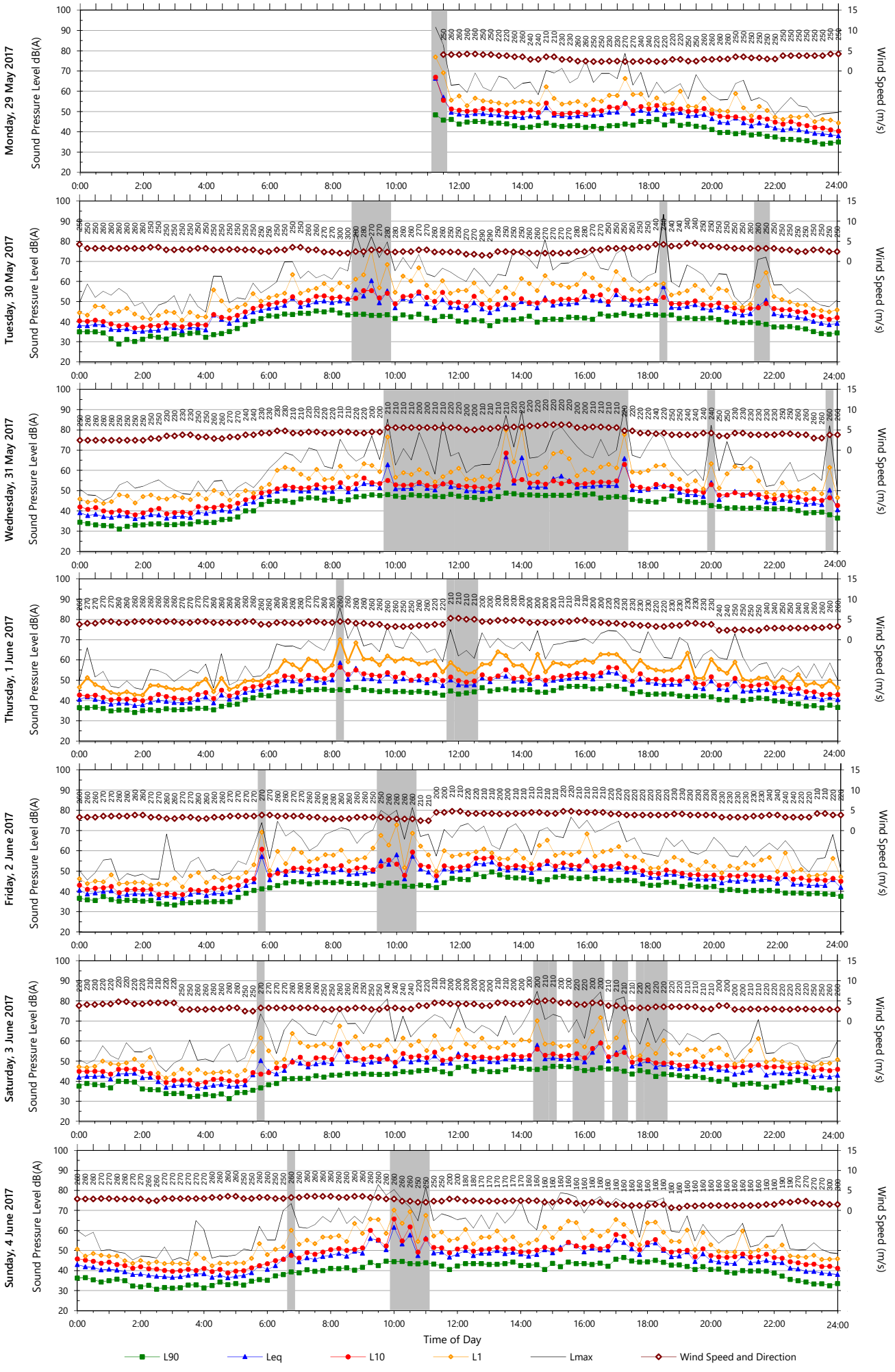
Logger Location	Aerial Photograph

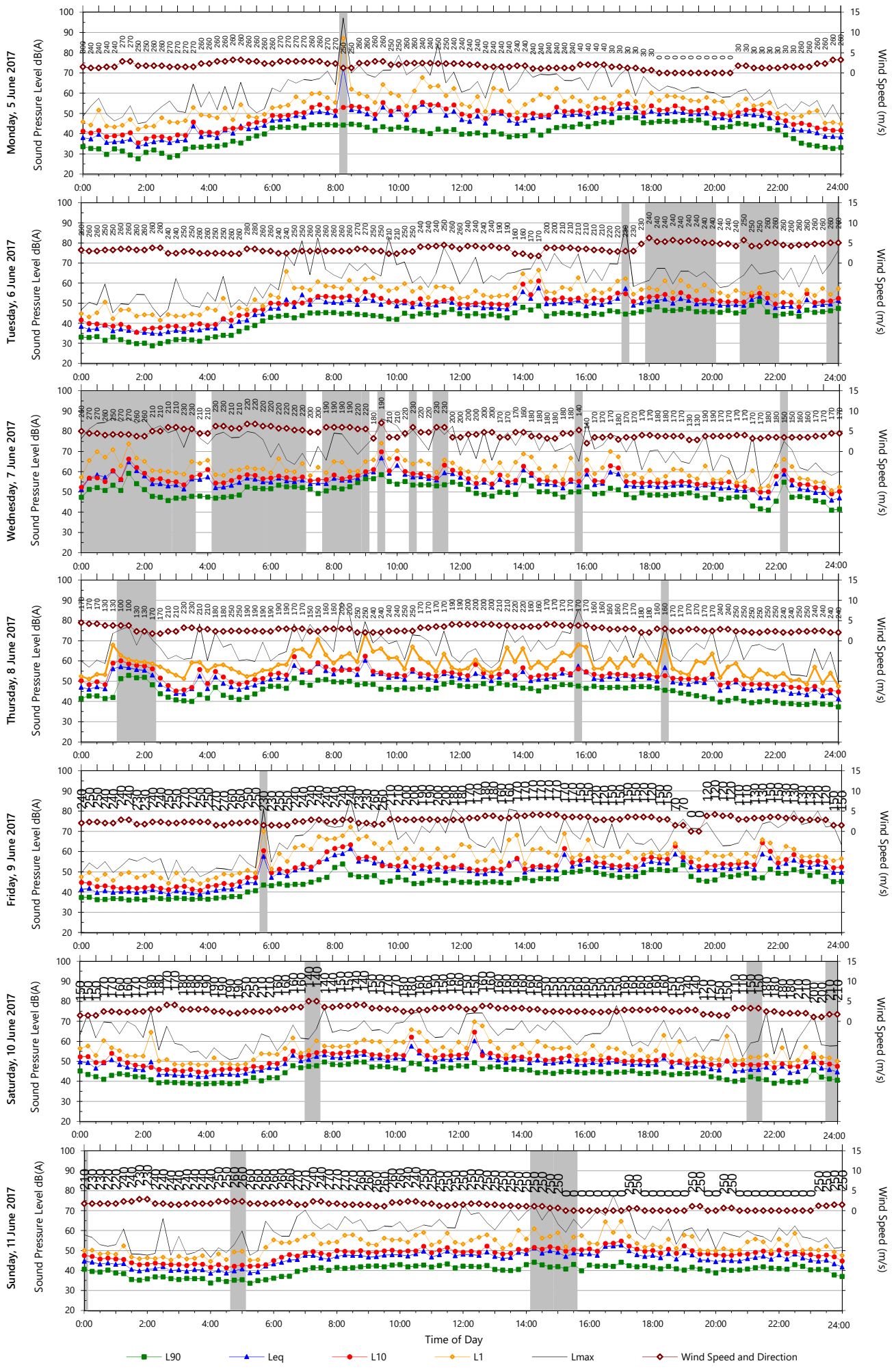




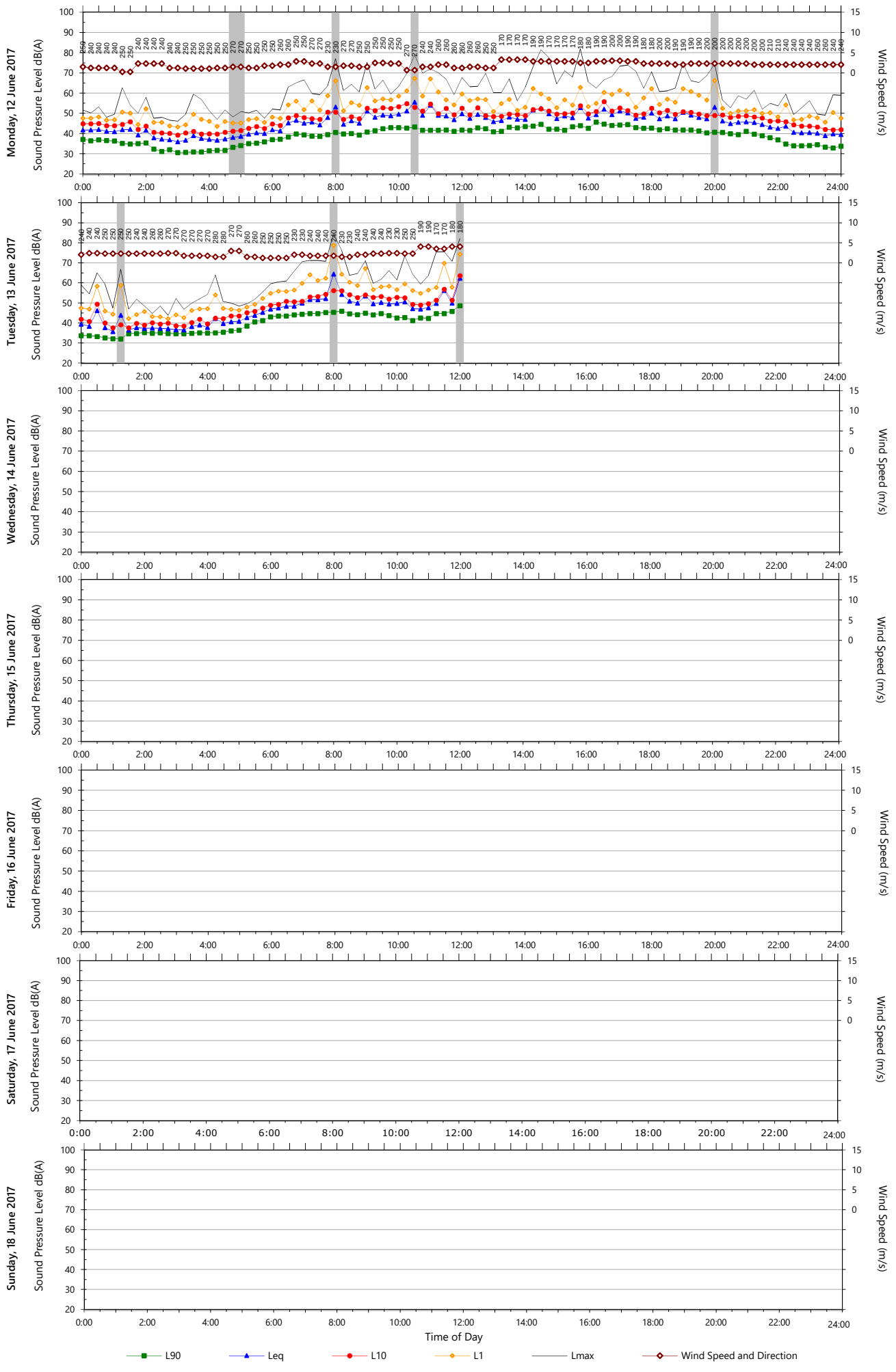
Unattended Monitoring Results

Location: 49 Hope Street, Seaforth




Monday, 5 June 2017
Tuesday, 6 June 2017
Wednesday, 7 June 2017
Thursday, 8 June 2017
Friday, 9 June 2017
Saturday, 10 June 2017
Sunday, 11 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results **Location: 49 Hope Street, Seaforth**



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Monitoring ID: Location L39
Address: 2 Pitt Street, Balgowlah
Description: Noise monitor located in the side yard and positioned 1m from the facade. Noise environment dominated by traffic on Burnt Bridge Creek Deviation.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	47	45	30	53	50	48

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)		
	L_{Aeq} Noise Levels	
	Day[1]	Night[2]
Representative Week[3]	55	51

Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

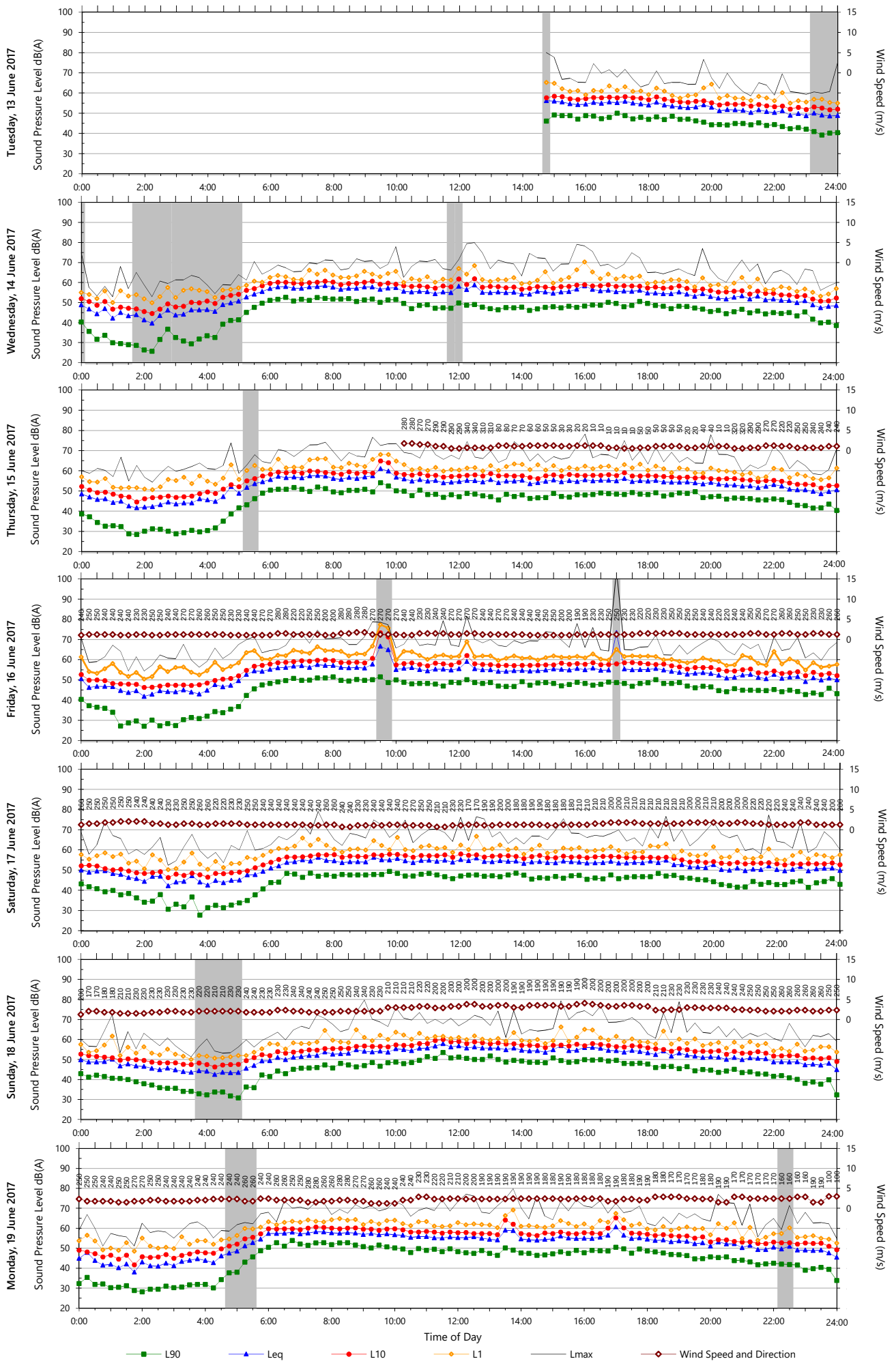
Logger Location	Aerial Photograph





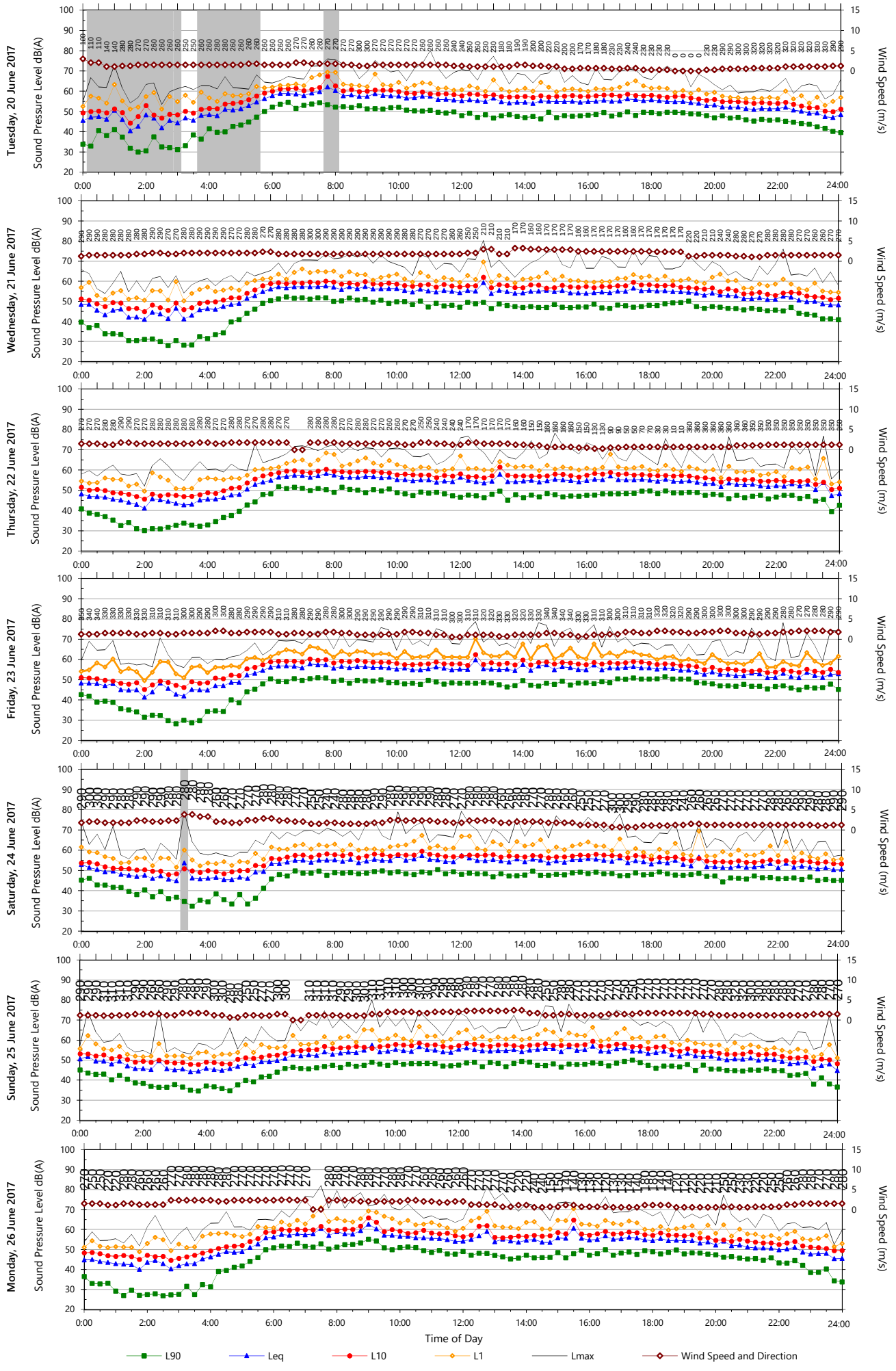
Unattended Monitoring Results

Location: 2 Pitt Street, Balgowlah



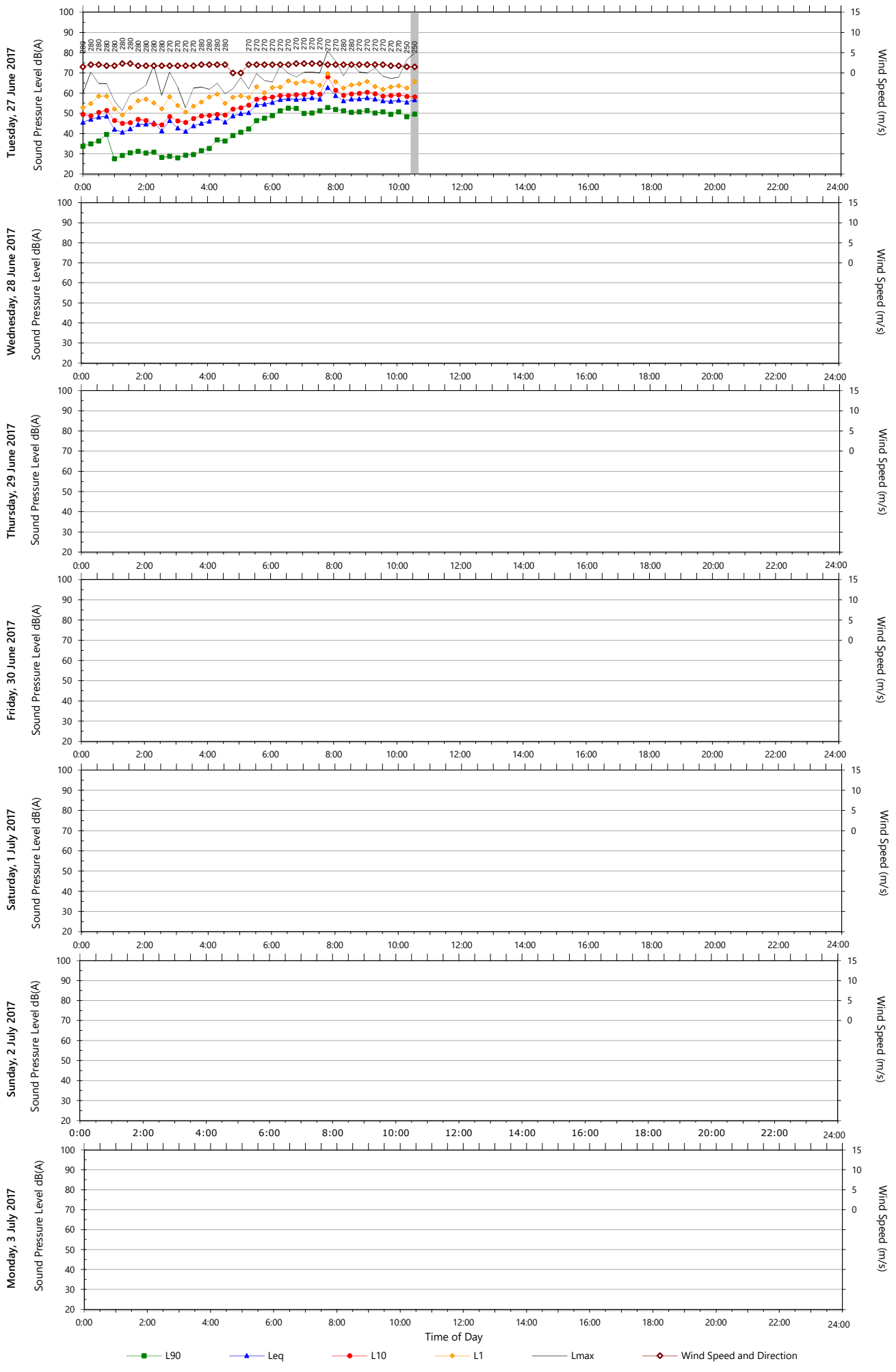
Unattended Monitoring Results

Location: 2 Pitt Street, Balgowlah



Unattended Monitoring Results

Location: 2 Pitt Street, Balgowlah



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Monitoring ID: Location L40
Address: 3A Jacaranda Place, Manly Vale
Description: Noise monitor located in the rear yard and positioned in the free-field. Noise environment dominated by traffic on Burnt Bridge Creek Deviation.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	49	45	36	59	56	54

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)		
	L_{Aeq} Noise Levels	
	Day[1]	Night[2]
Representative Week[3]	61	56

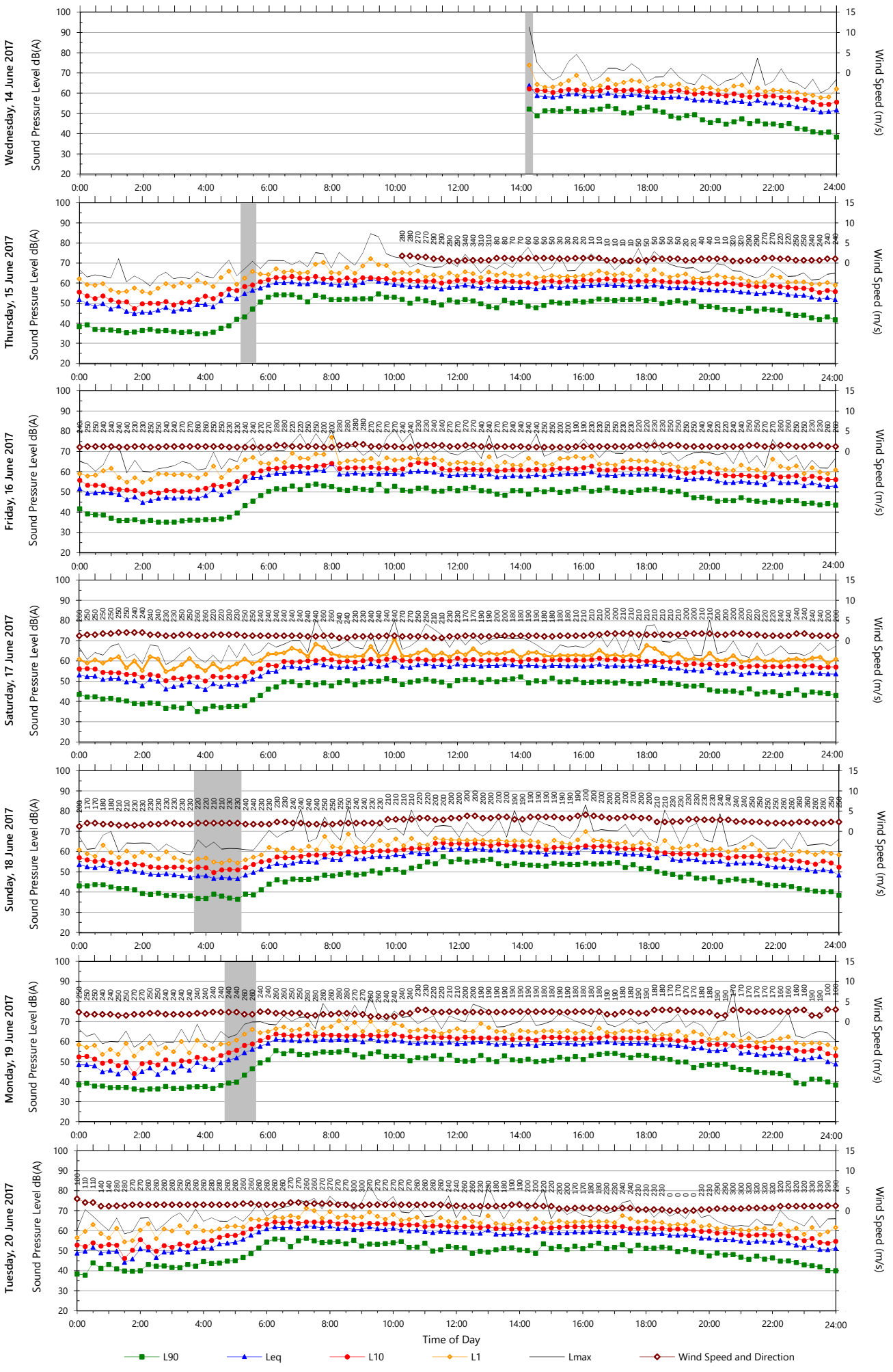
Notes:

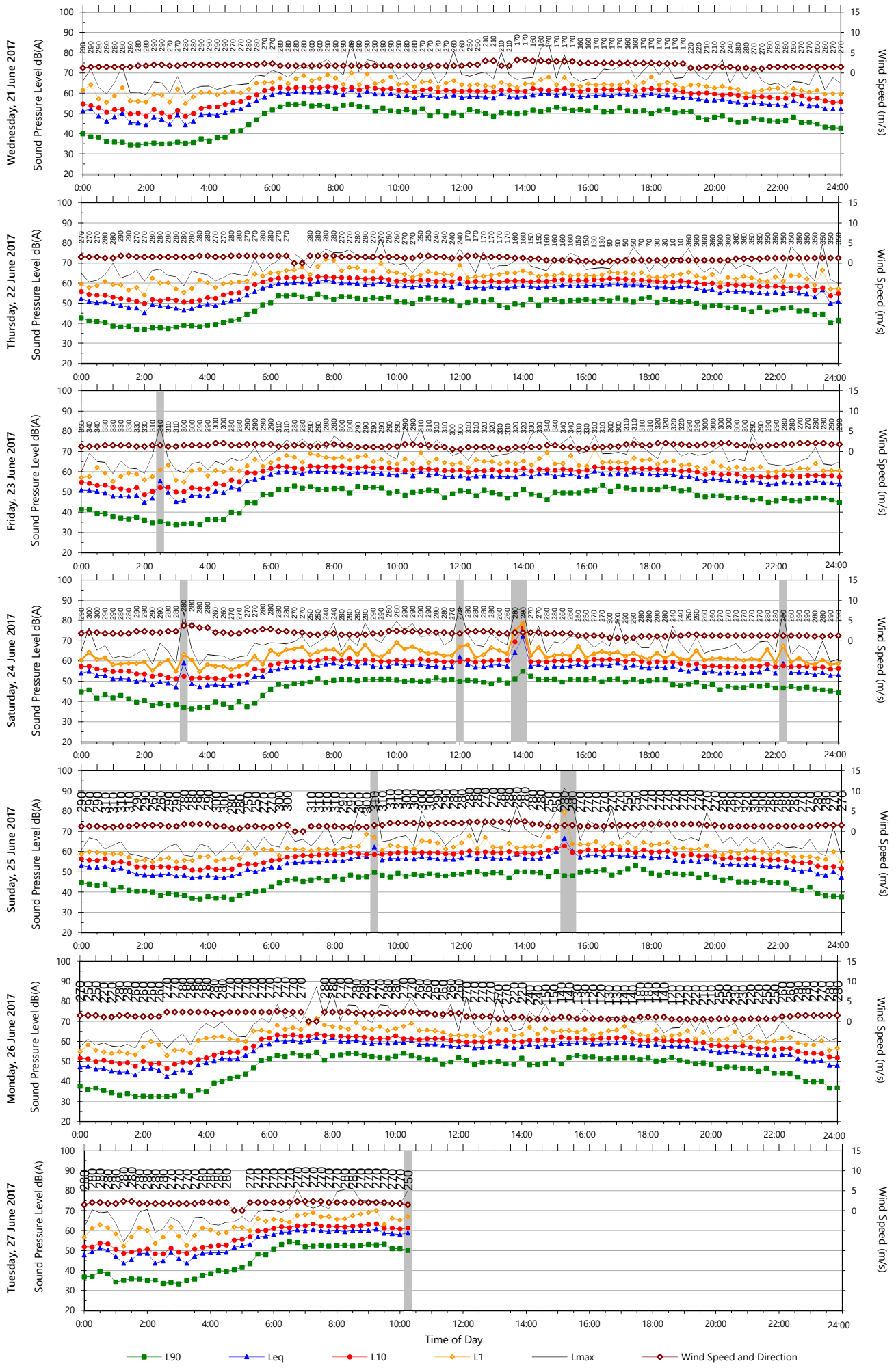
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Wednesday, 14 June 2017
Thursday, 15 June 2017
Friday, 16 June 2017
Saturday, 17 June 2017
Sunday, 18 June 2017
Monday, 19 June 2017
Tuesday, 20 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Wednesday, 21 June 2017
Thursday, 22 June 2017
Friday, 23 June 2017
Saturday, 24 June 2017
Sunday, 25 June 2017
Monday, 26 June 2017
Tuesday, 27 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L41
Address: 81 Wakehurst Parkway, Seaforth
Description: Noise monitor located in the rear yard and positioned in the free-field. Noise environment dominated by traffic on Wakehurst Parkway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	48	39	28	66	63	59

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	68	61	

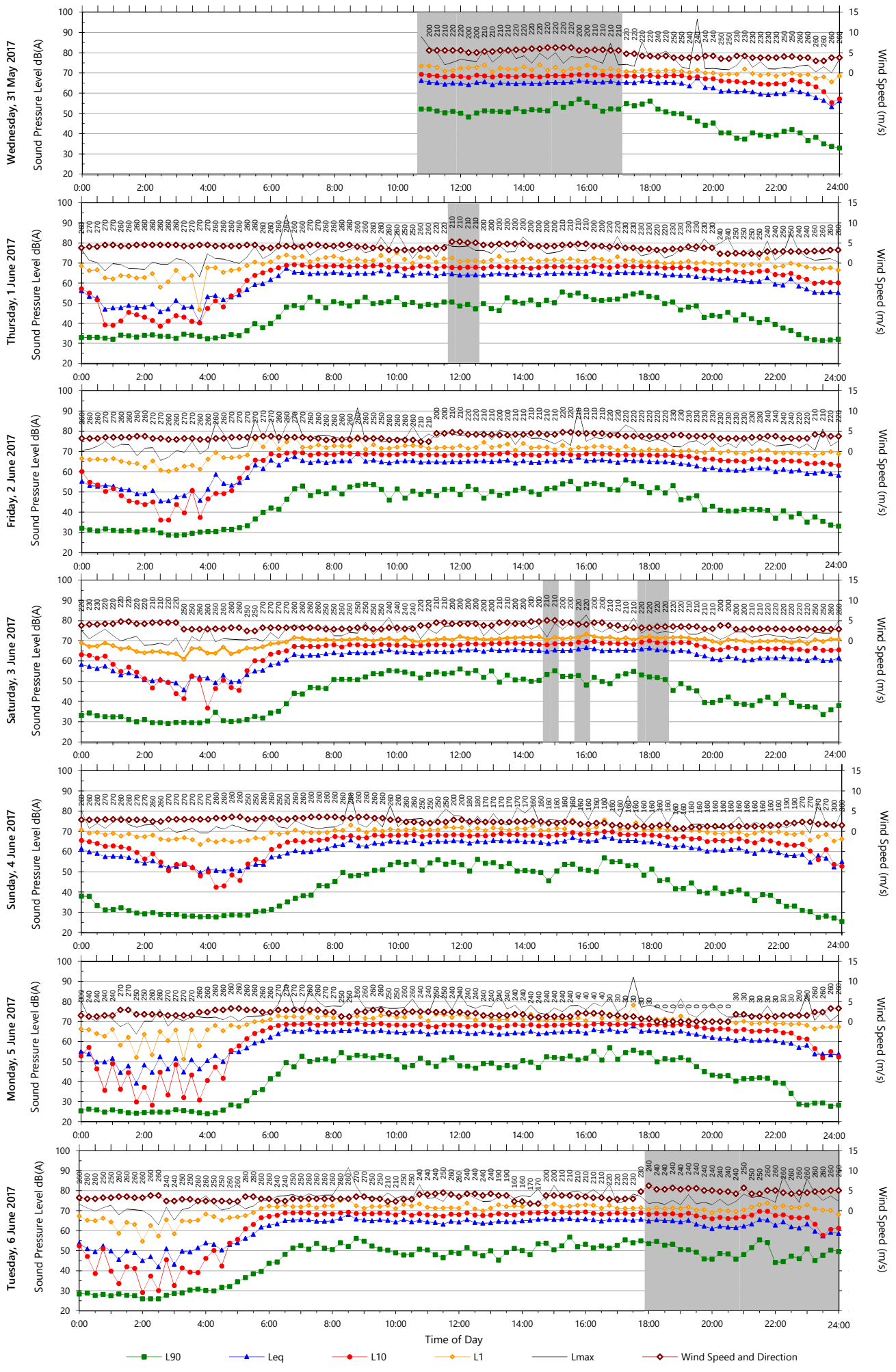
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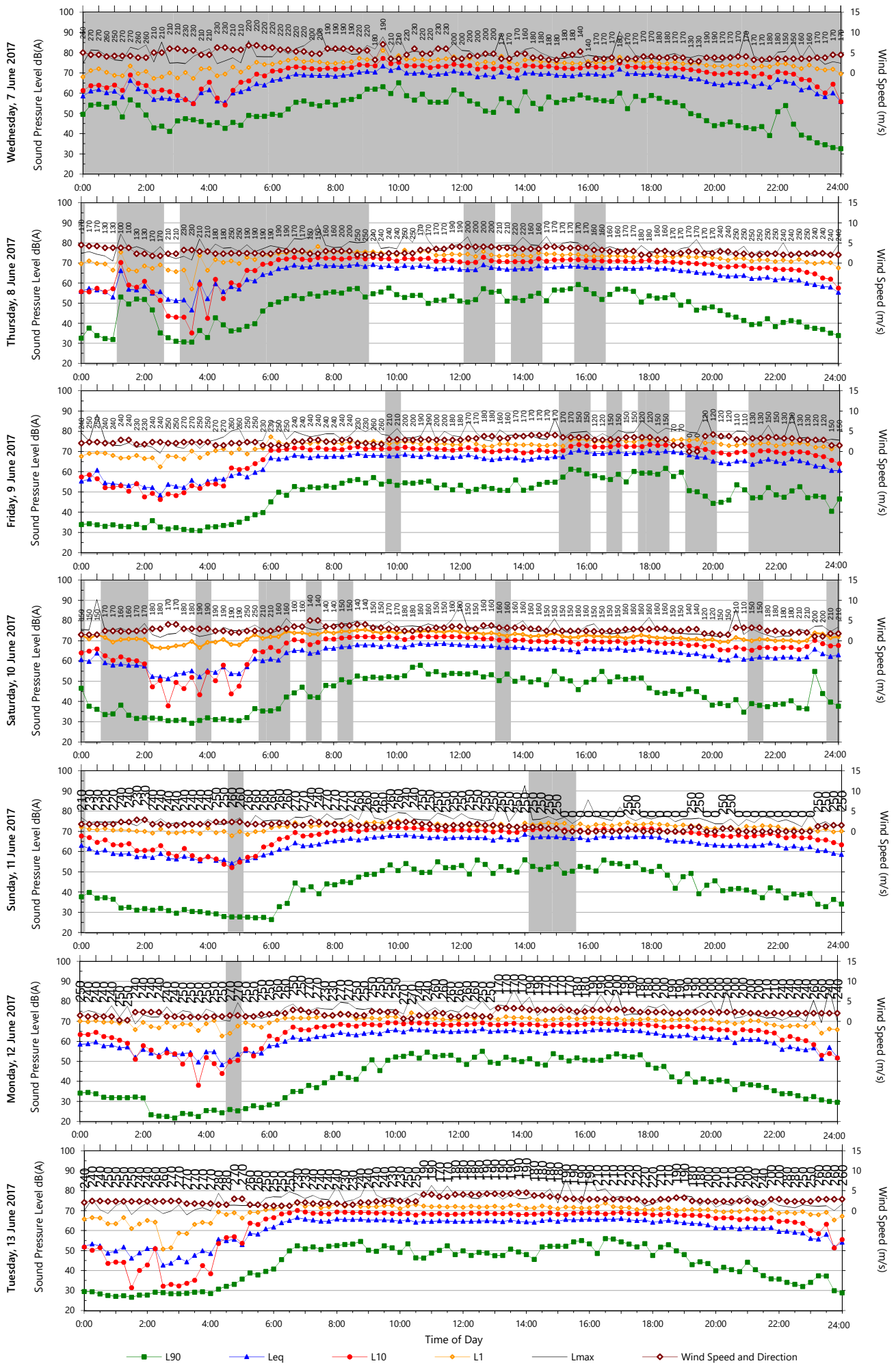
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

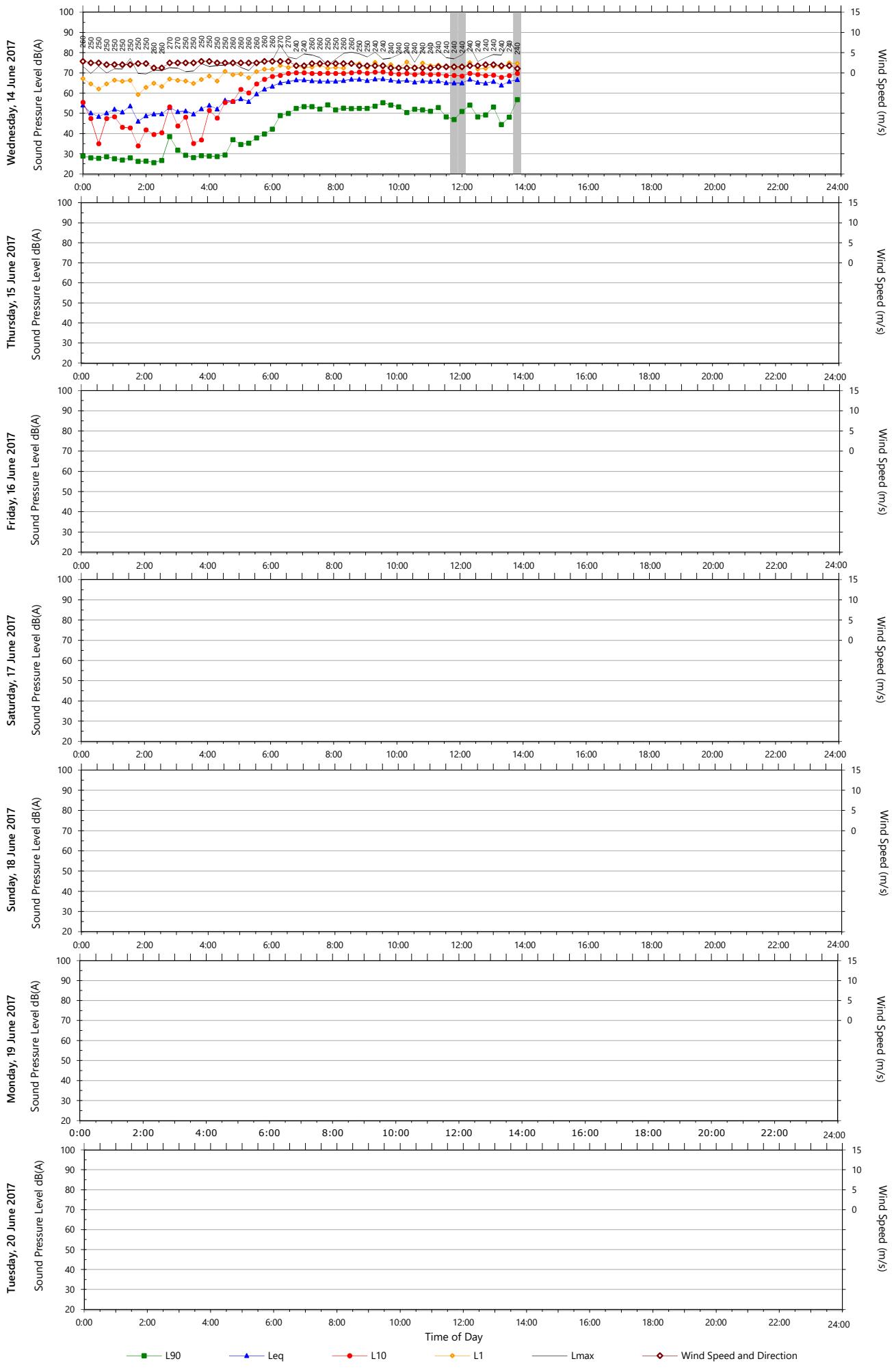
Logger Location	Aerial Photograph






Wednesday, 31 May 2017
Thursday, 1 June 2017
Friday, 2 June 2017
Saturday, 3 June 2017
Sunday, 4 June 2017
Monday, 5 June 2017
Tuesday, 6 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Wednesday, 7 June 2017
Thursday, 8 June 2017
Friday, 9 June 2017
Saturday, 10 June 2017
Sunday, 11 June 2017
Monday, 12 June 2017
Tuesday, 13 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Wednesday, 14 June 2017
Thursday, 15 June 2017
Friday, 16 June 2017
Saturday, 17 June 2017
Sunday, 18 June 2017
Monday, 19 June 2017
Tuesday, 20 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L42
Address: 96 Kirkwood Street, Seaforth
Description: Noise monitor located in the rear yard and positioned in the free-field. Noise environment dominated by traffic on Wakehurst Parkway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	45	39	29	53	51	46

Notes:

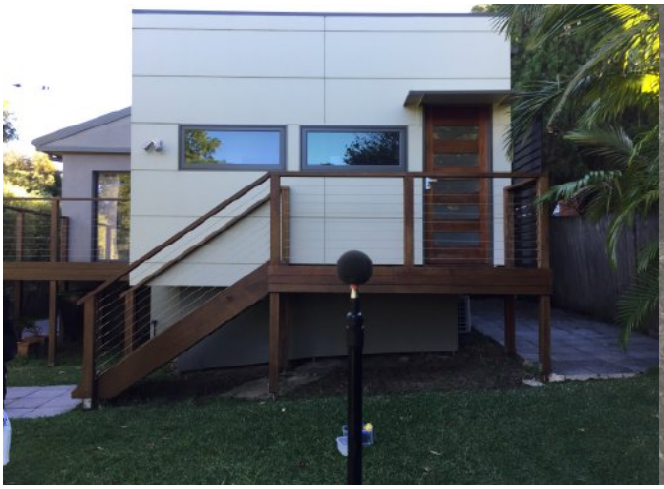
1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	55	50	

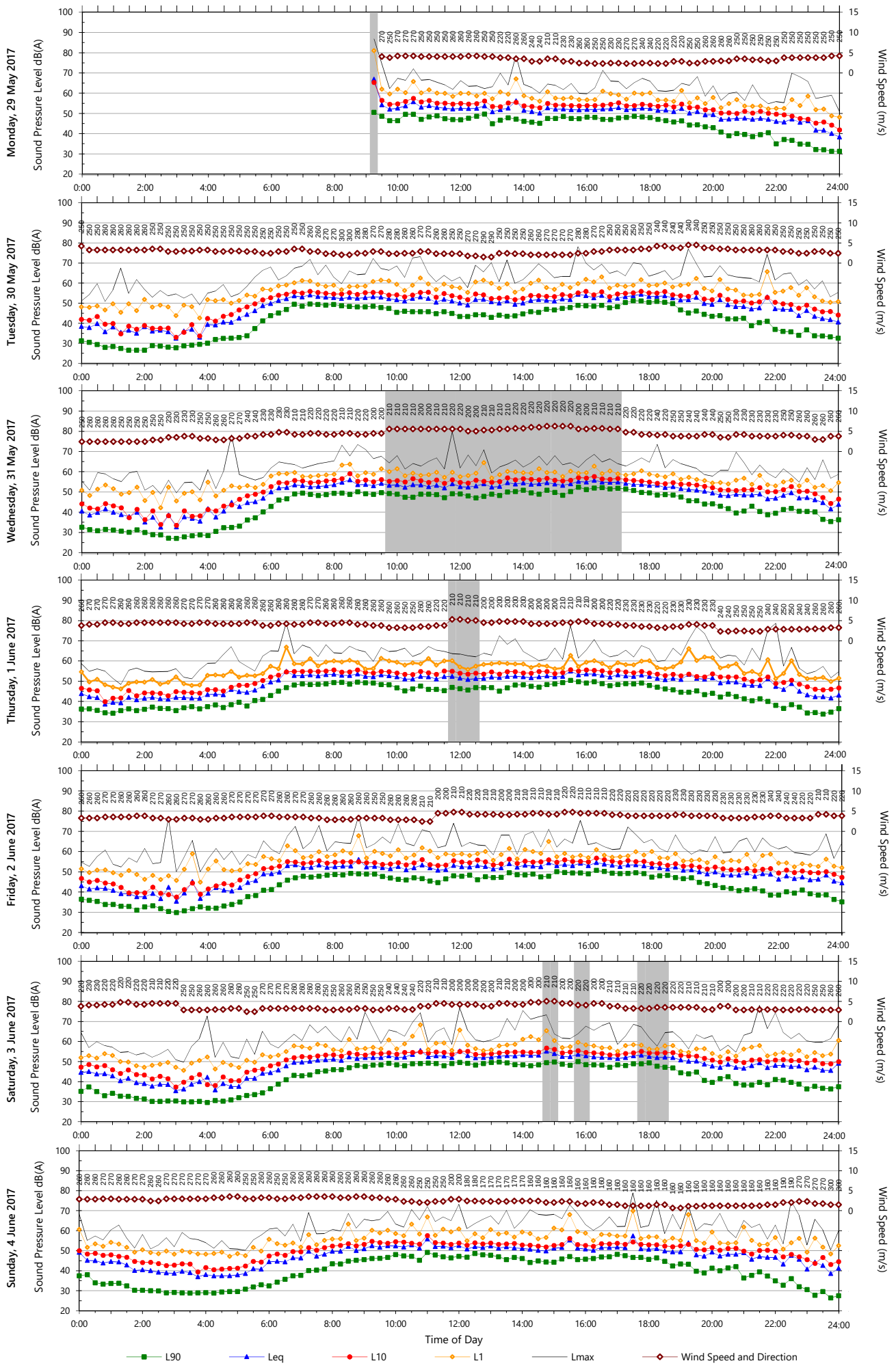
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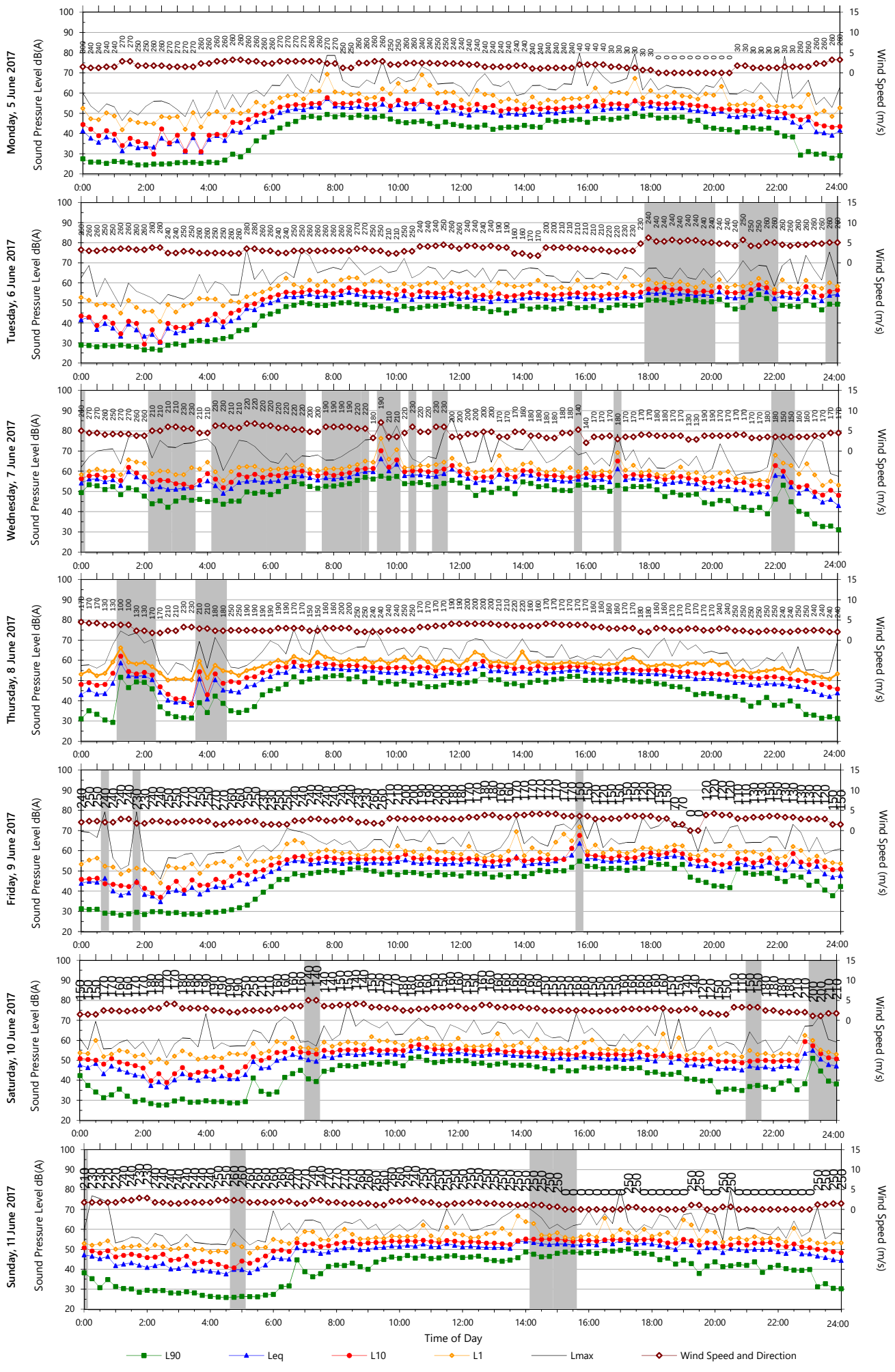
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph

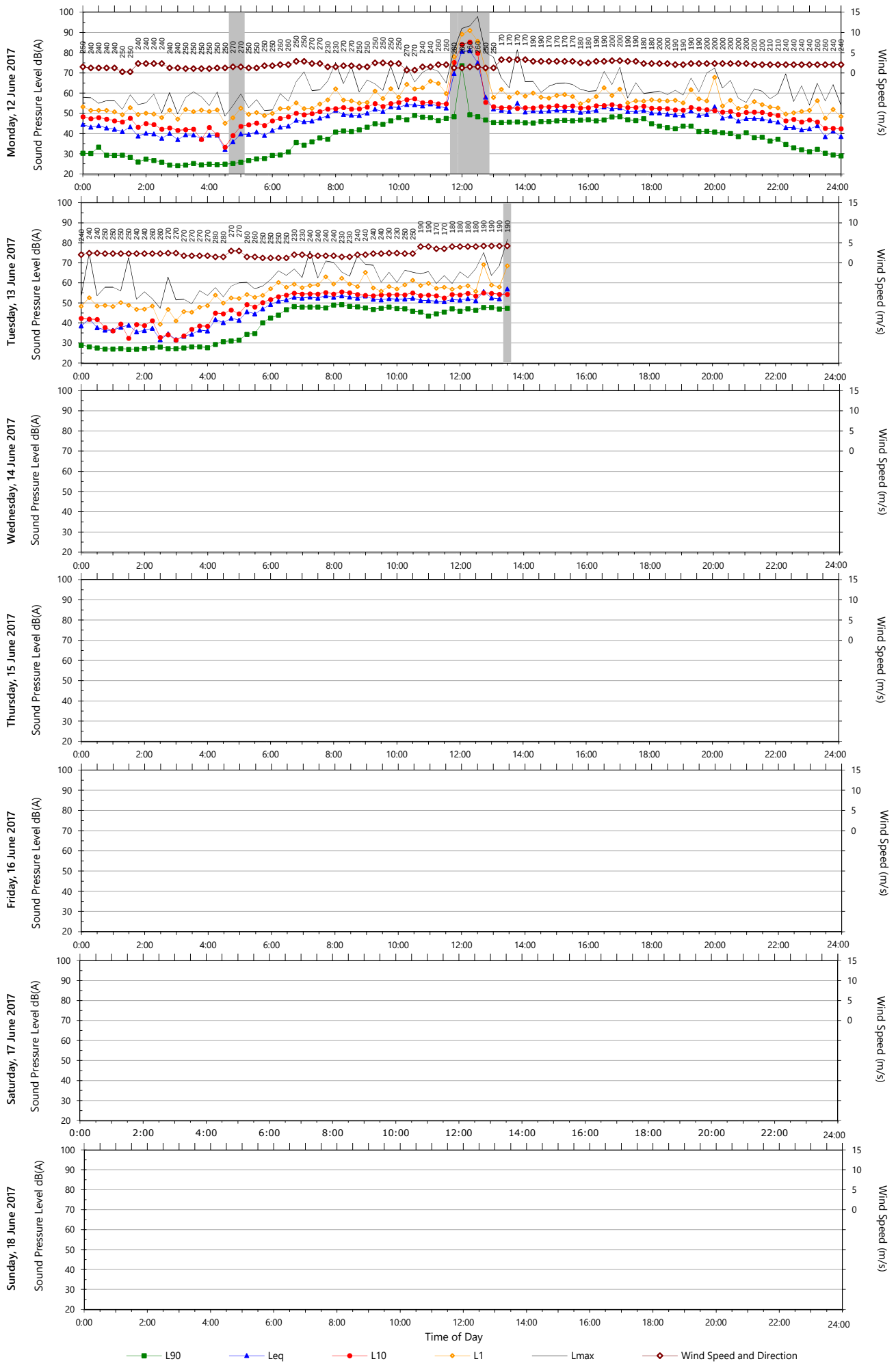





Monday, 29 May 2017
Tuesday, 30 May 2017
Wednesday, 31 May 2017
Thursday, 1 June 2017
Friday, 2 June 2017
Saturday, 3 June 2017
Sunday, 4 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Monday, 5 June 2017
Tuesday, 6 June 2017
Wednesday, 7 June 2017
Thursday, 8 June 2017
Friday, 9 June 2017
Saturday, 10 June 2017
Sunday, 11 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results **Location: 96 Kirkwood Street, Seaforth**



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Monitoring ID: Location L43
Address: 118 Bantry Bay Road, Frenchs Forest
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	46	40	30	56	54	47

Notes:

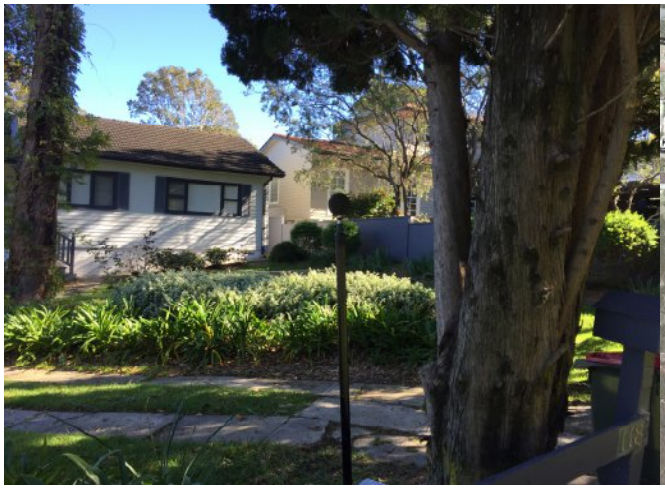
1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	58	50	

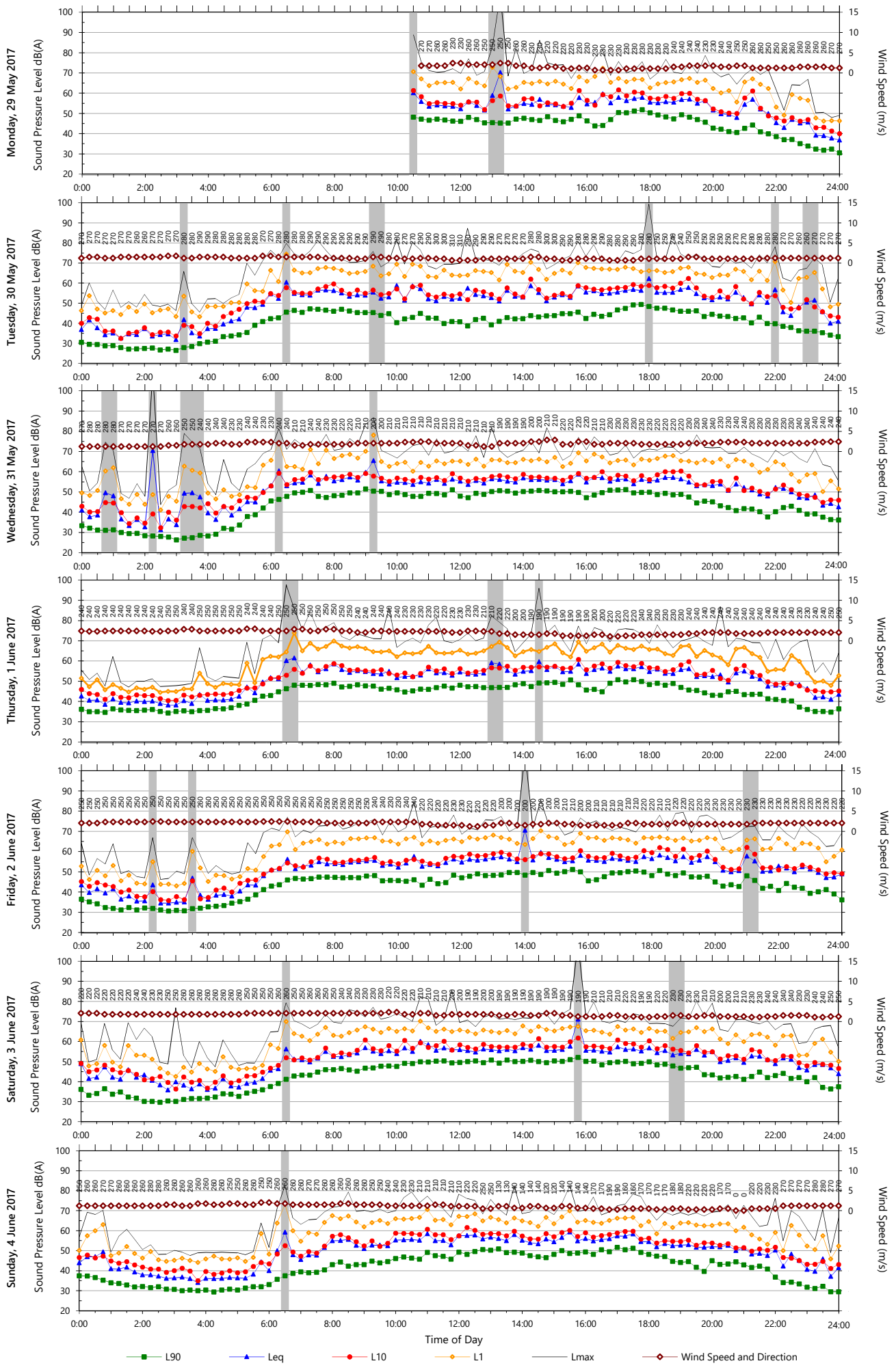
Notes:

1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph

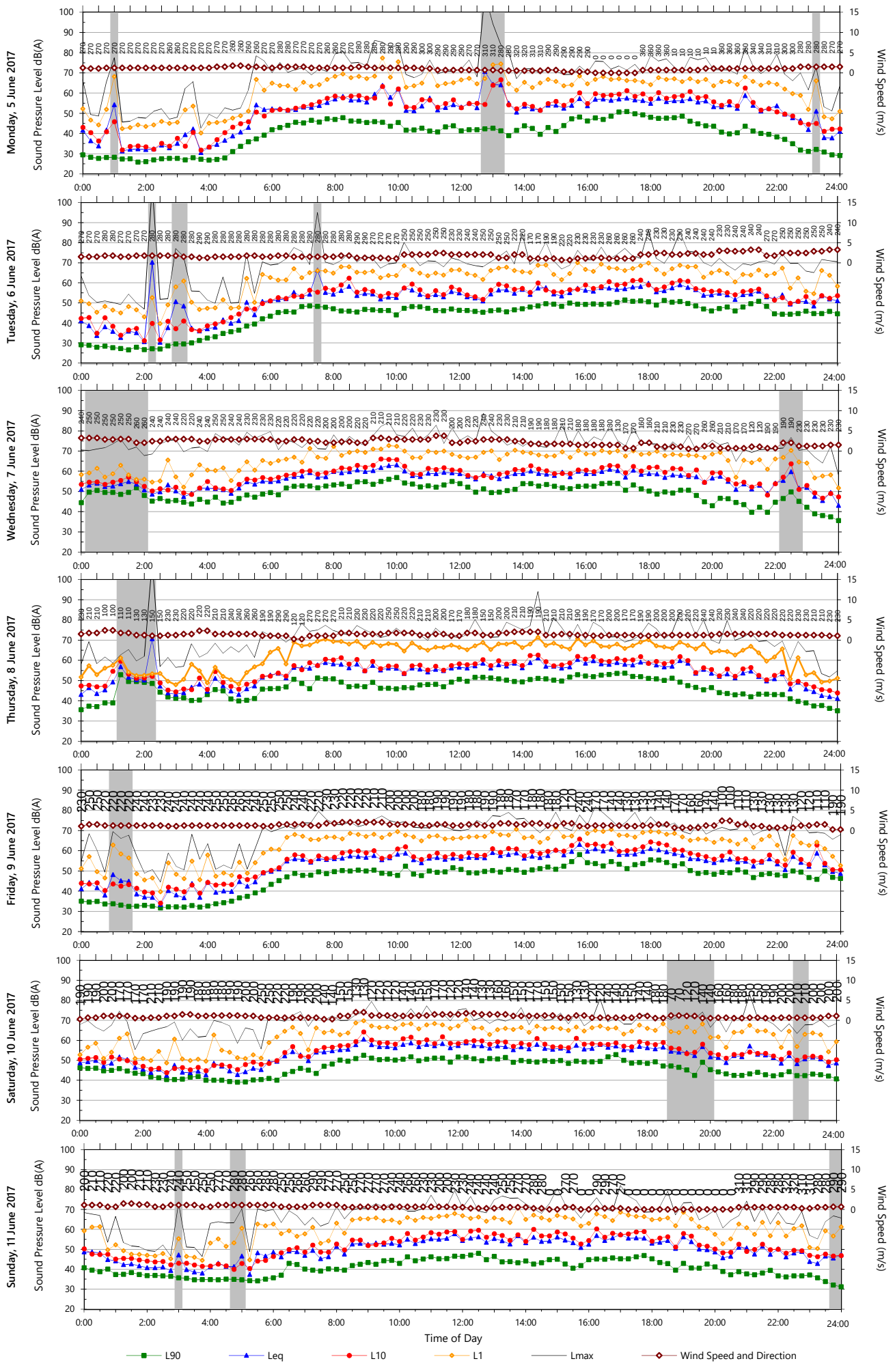


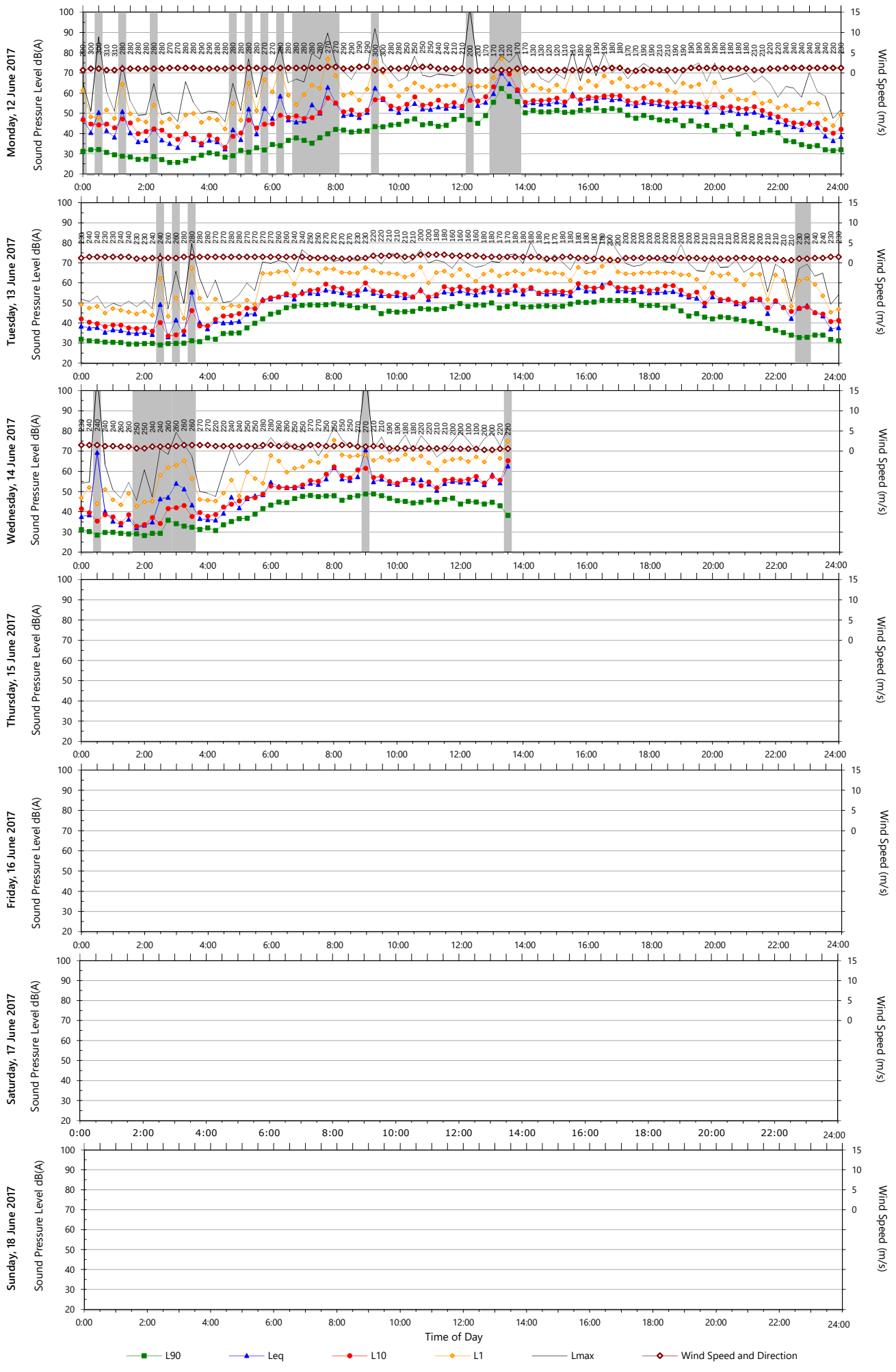



Monday, 29 May 2017
Tuesday, 30 May 2017
Wednesday, 31 May 2017
Thursday, 1 June 2017
Friday, 2 June 2017
Saturday, 3 June 2017
Sunday, 4 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results

Location: 118 Bantry Bay Road, Frenchs Forest




Monday, 12 June 2017
Tuesday, 13 June 2017
Wednesday, 14 June 2017
Thursday, 15 June 2017
Friday, 16 June 2017
Saturday, 17 June 2017
Sunday, 18 June 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L45
Address: 1/16 Munro Street, McMahons Point
Description: Noise monitor located in the rear yard and positioned in the free-field. Noise environment dominated by noise from nature.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[4]	42	41	38	52	46	44

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Rating Background Level (RBL) for L_{A90} and logarithmic average for L_{Aeq}

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	-	-	

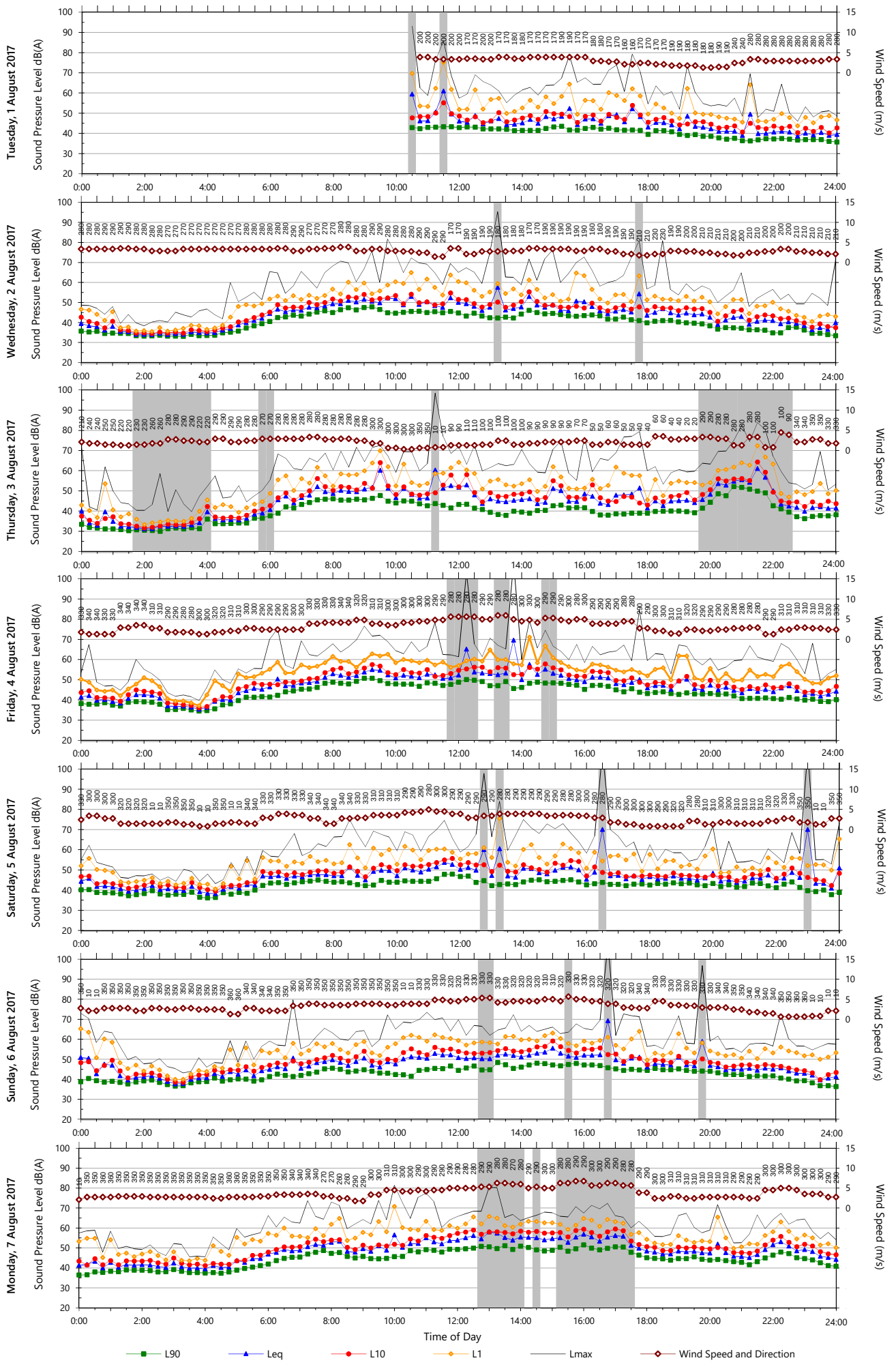
Notes:

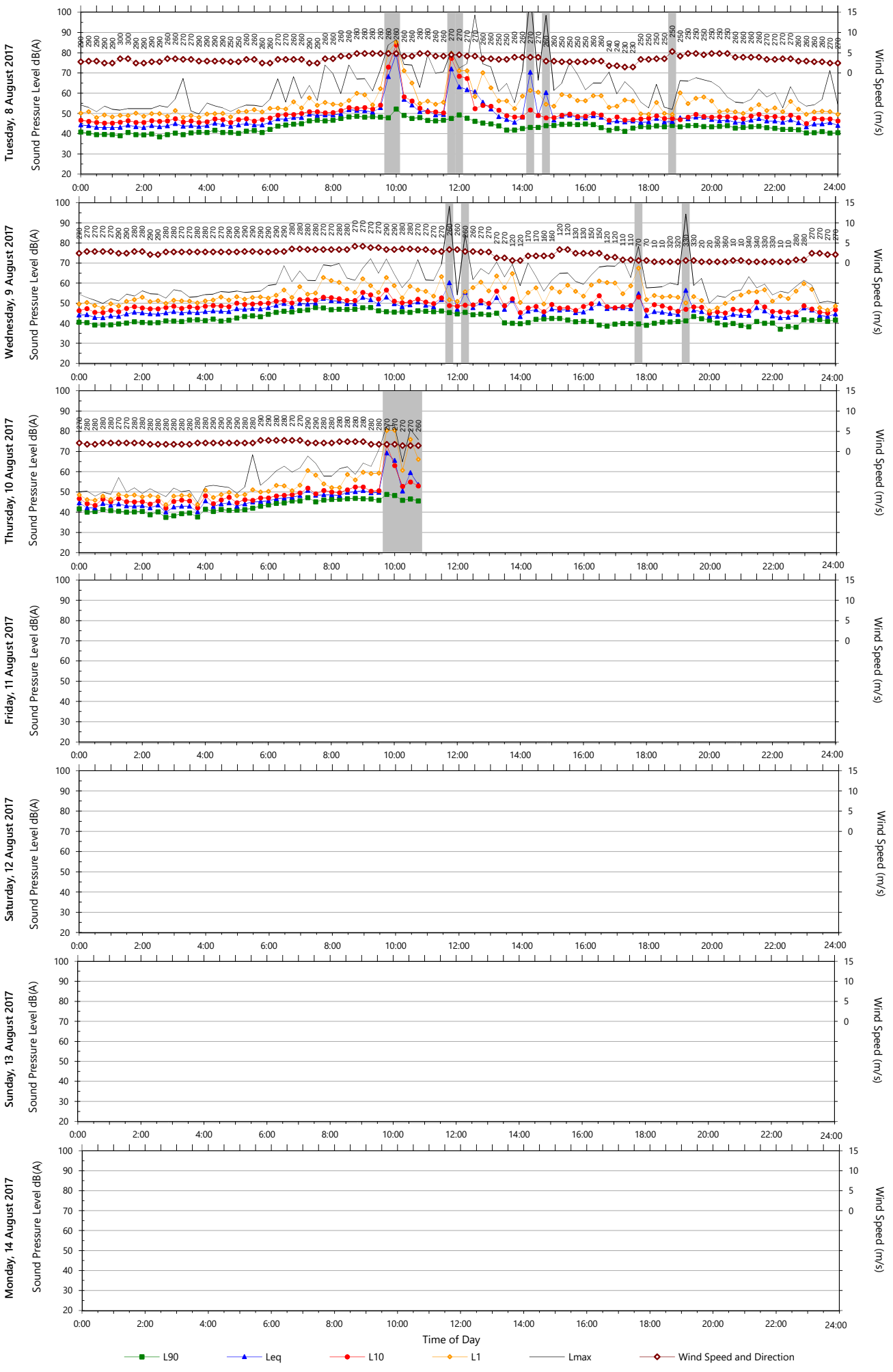
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph






Tuesday, 1 August 2017
Wednesday, 2 August 2017
Thursday, 3 August 2017
Friday, 4 August 2017
Saturday, 5 August 2017
Sunday, 6 August 2017
Monday, 7 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Tuesday, 8 August 2017
Wednesday, 9 August 2017
Thursday, 10 August 2017
Friday, 11 August 2017
Saturday, 12 August 2017
Sunday, 13 August 2017
Monday, 14 August 2017
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L46
Address: 1/298 Pacific Highway, Greenwhich
Description: Noise monitor located on the front balcony and positioned in the free-field. Noise environment dominated by traffic on the Pacific Highway.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels[4]			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[5]	60	55	40	70	69	64

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Assessment Background Level (ABL) for individual days

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	72	66	

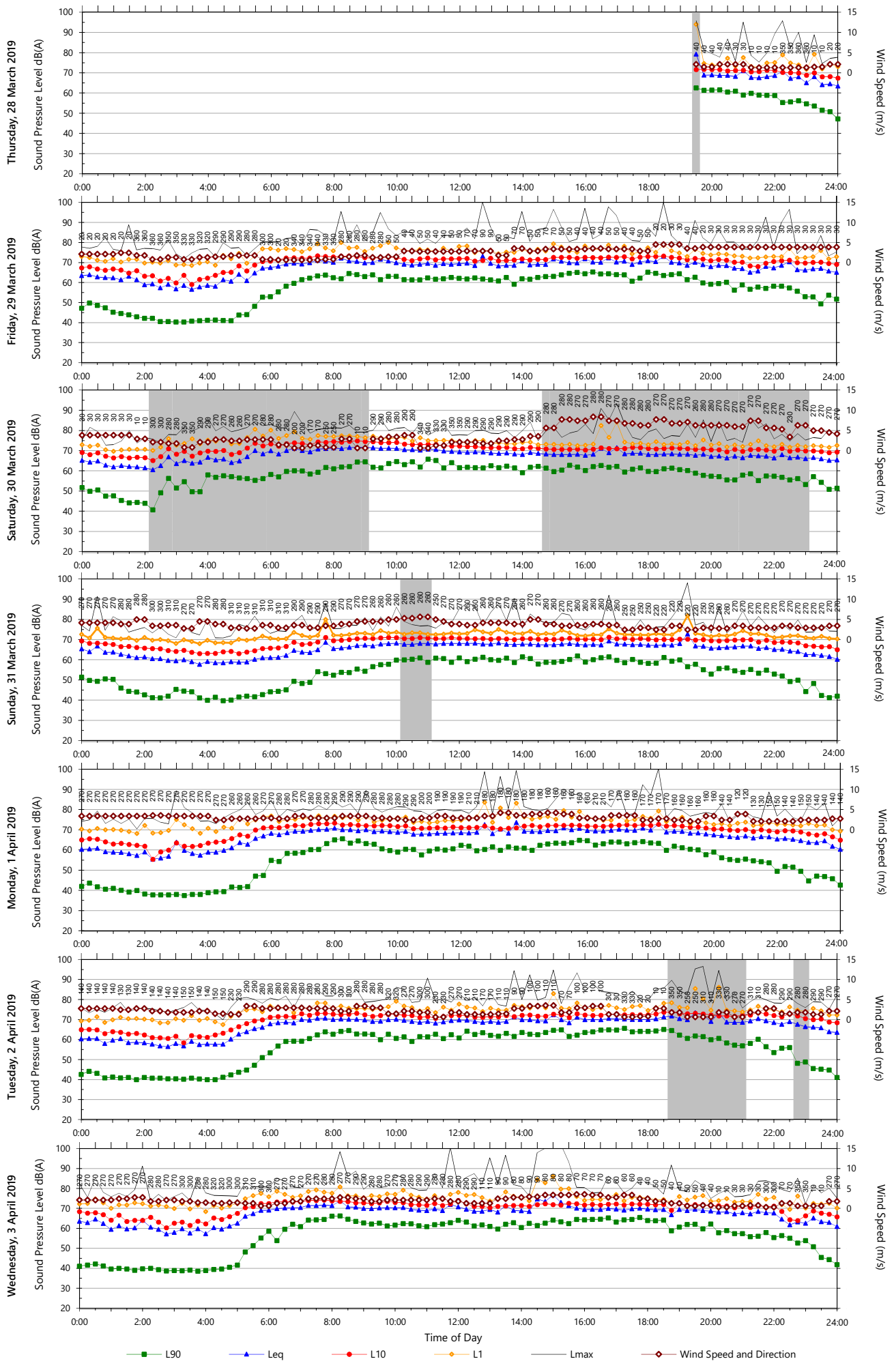
Notes:

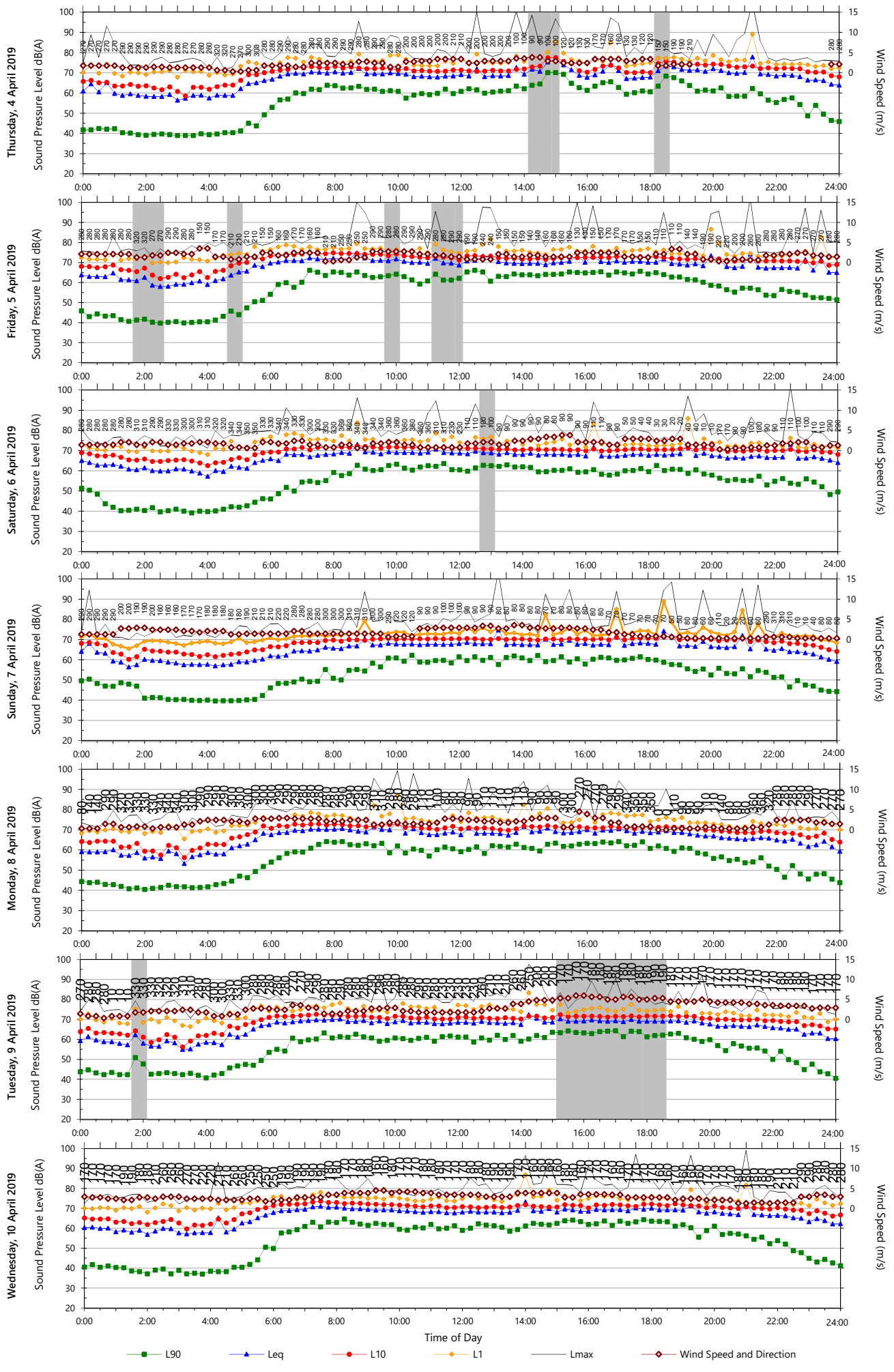
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

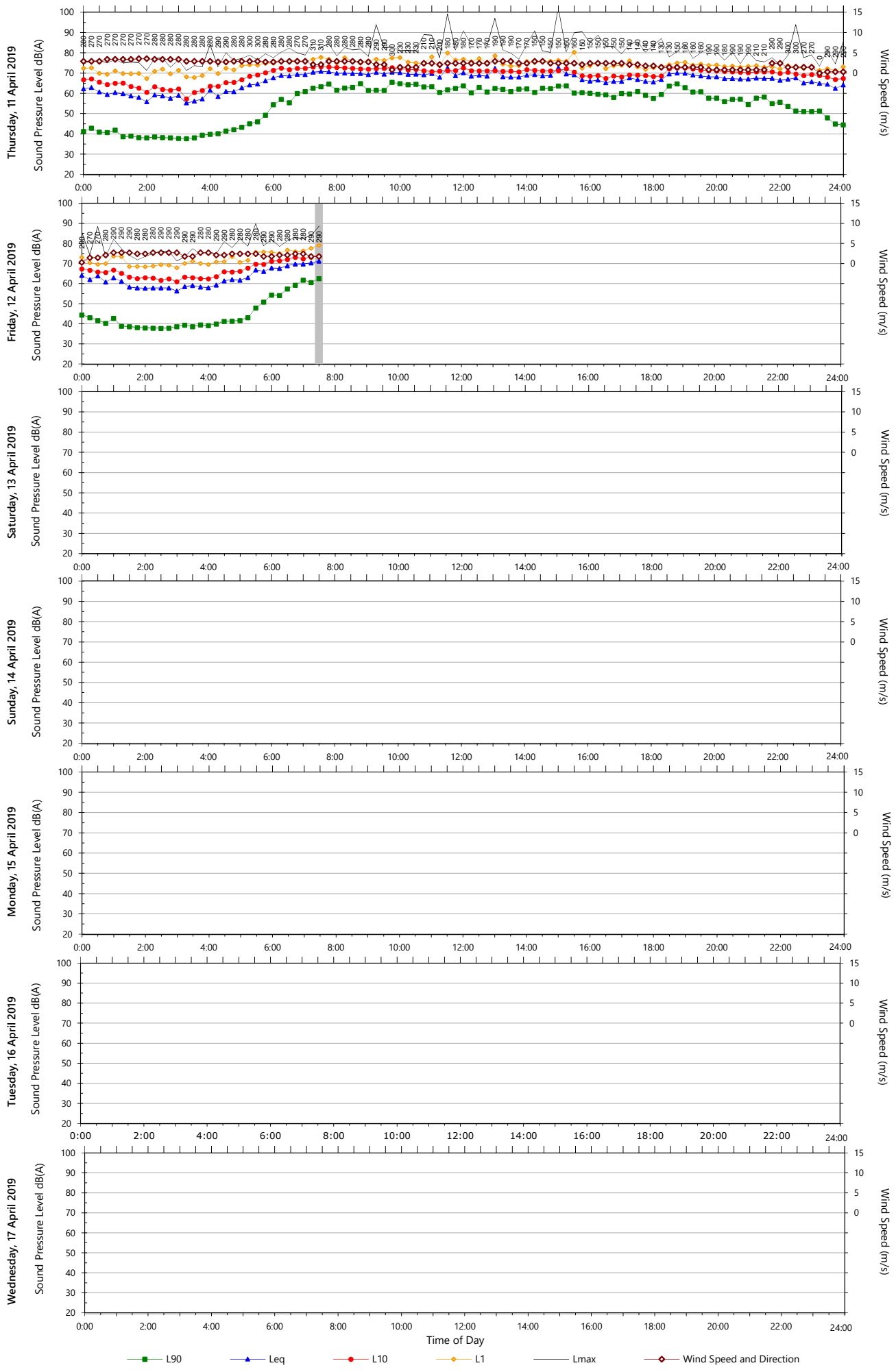
Logger Location	Aerial Photograph






Thursday, 28 March 2019
Friday, 29 March 2019
Saturday, 30 March 2019
Sunday, 31 March 2019
Monday, 1 April 2019
Tuesday, 2 April 2019
Wednesday, 3 April 2019
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Thursday, 4 April 2019
Friday, 5 April 2019
Saturday, 6 April 2019
Sunday, 7 April 2019
Monday, 8 April 2019
Tuesday, 9 April 2019
Wednesday, 10 April 2019
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Thursday, 11 April 2019
Friday, 12 April 2019
Saturday, 13 April 2019
Sunday, 14 April 2019
Monday, 15 April 2019
Tuesday, 16 April 2019
Wednesday, 17 April 2019
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

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Monitoring ID: Location L47
Address: 23 Second Avenue, Lane Cove
Description: Noise monitor located in the front yard and positioned in the free-field. Noise environment dominated by traffic on the Pacific Highway and general neighbourhood and natural sounds.

Background & Ambient Noise Monitoring Results						
	L_{A90} Background Noise Levels[4]			L_{Aeq} Ambient Noise Levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
Representative Week[5]	39	37	31	57	51	46

Notes:

1. Day is 8:00am to 6:00pm on Sunday and 7:00am to 6:00pm at other times
2. Evening is 6:00pm to 10:00pm
3. Night is the remaining periods
4. Assessment Background Level (ABL) for individual days

Road Monitoring Results (at one metre from façade)			
	L_{Aeq} Noise Levels		
	Day[1]	Night[2]	
Representative Week[3]	58	48	

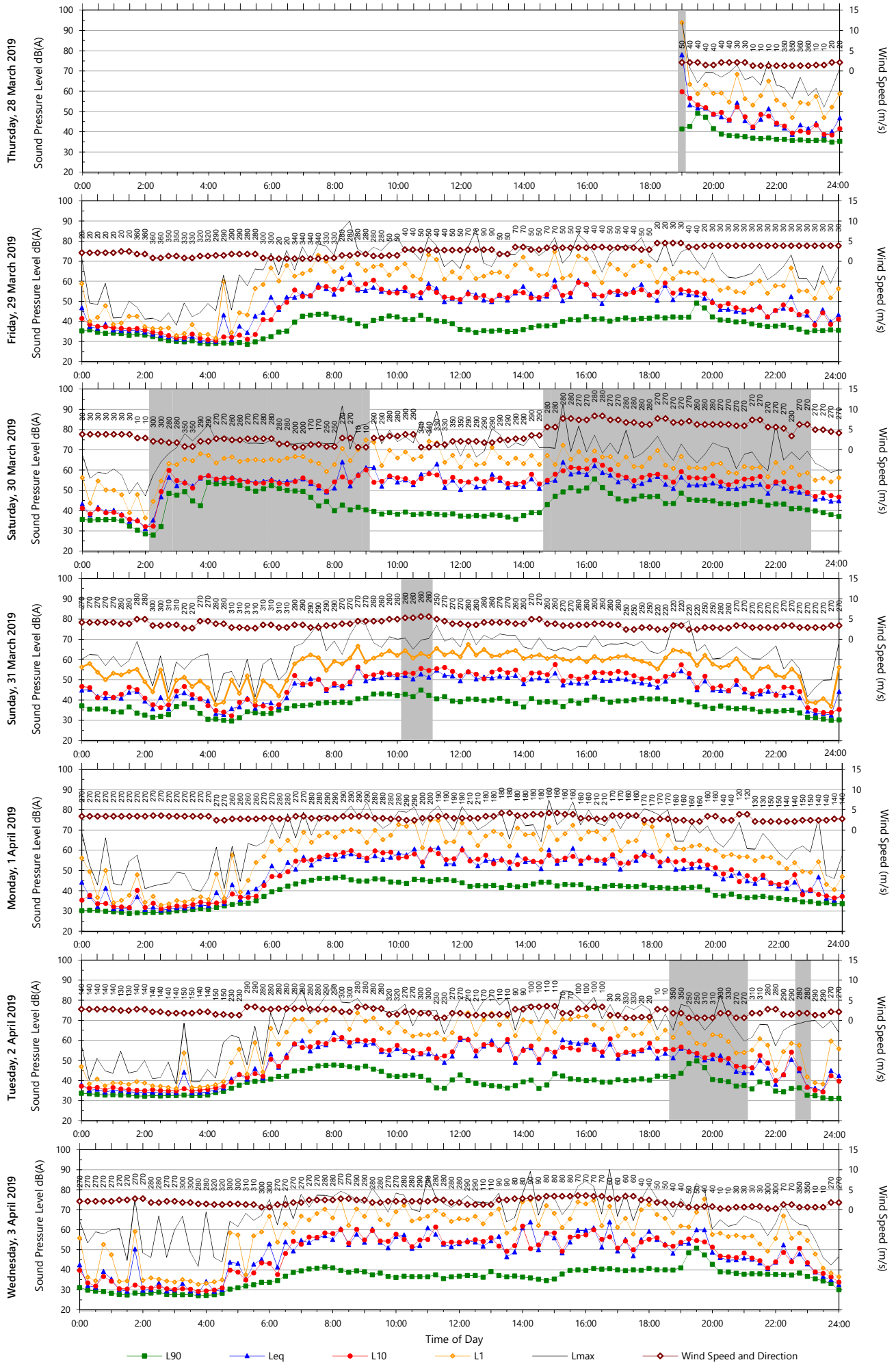
Notes:

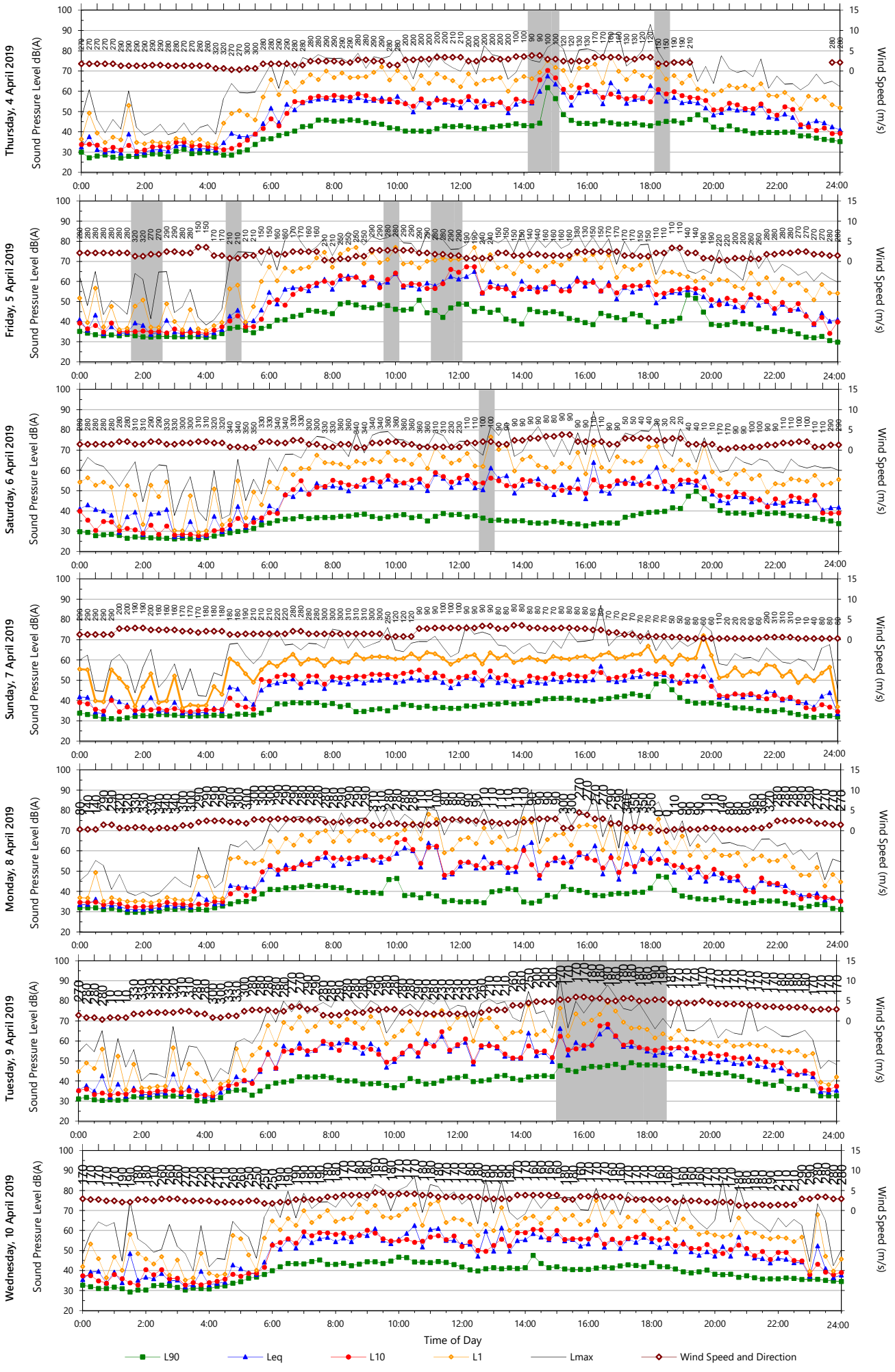
1. Day is 7:00am to 10:00pm
2. Night is 10:00pm to 7:00am
3. Logarithmic average of daily L_{Aeq}

Logger Location	Aerial Photograph

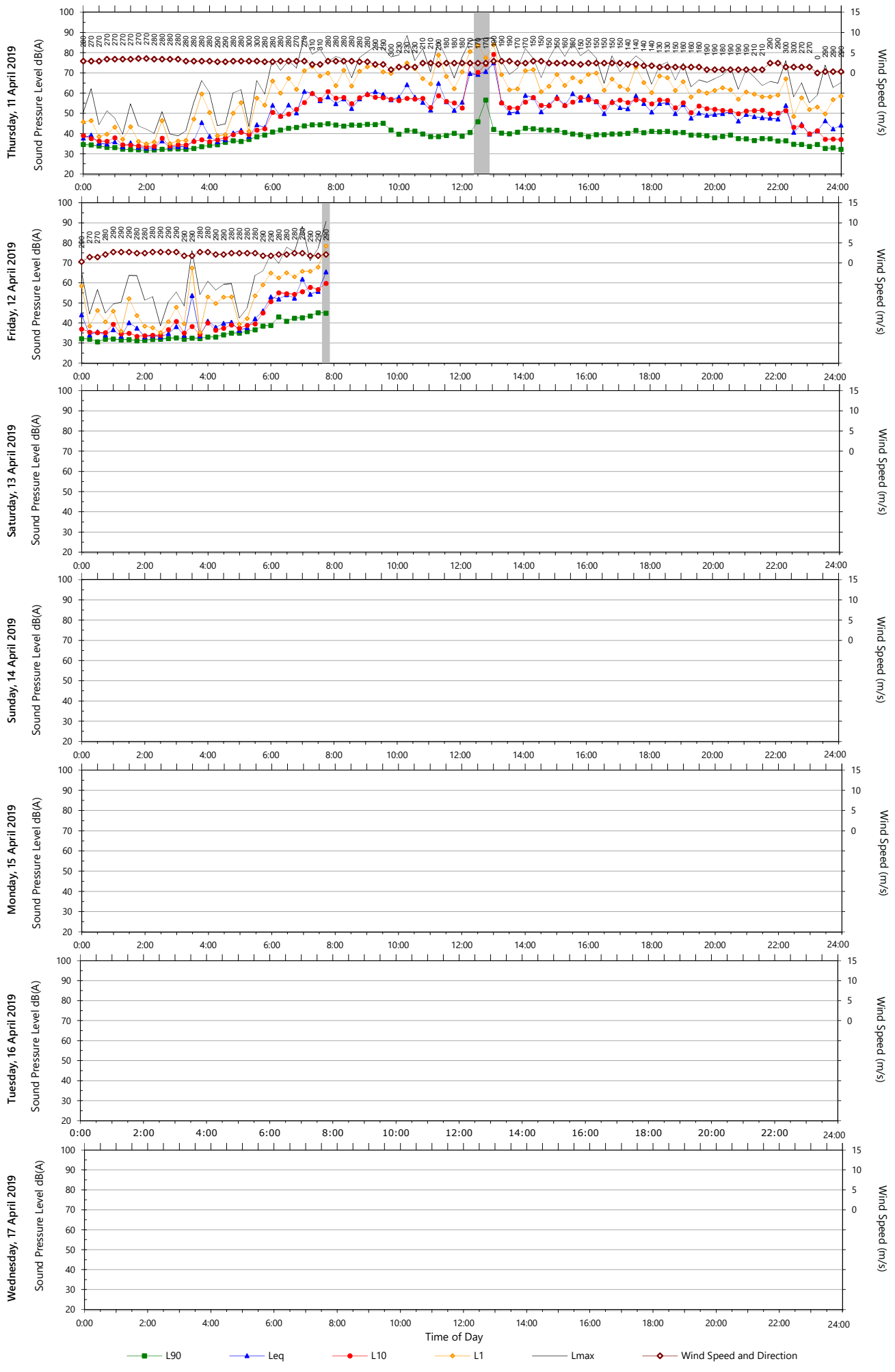





Thursday, 28 March 2019
Friday, 29 March 2019
Saturday, 30 March 2019
Sunday, 31 March 2019
Monday, 1 April 2019
Tuesday, 2 April 2019
Wednesday, 3 April 2019
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction


Thursday, 4 April 2019
Friday, 5 April 2019
Saturday, 6 April 2019
Sunday, 7 April 2019
Monday, 8 April 2019
Tuesday, 9 April 2019
Wednesday, 10 April 2019
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of Day
L90
Leq
L10
L1
Lmax
Wind Speed and Direction

Unattended Monitoring Results **Location: 23 Second Avenue, Lane Cove**



Annexure D Traffic survey results

D.1 Year 2017 traffic volumes (for validation)

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Connections to and from the Wakehurst Parkway							
Wakehurst Parkway	NB	617	5.0	74	107	5.7	78
	SB	575	4.0	74	100	7.7	78
Connections to and from Burnt Bridge Creek Deviation							
Burnt Bridge Creek Deviation	EB	1136	6.3	76	265	6.1	78
	WB	939	7.2	78	324	8.7	78
Manly Road	EB	1708	5.6	67	436	5.3	67
	WB	1697	6.8	62	594	13.1	69
Sydney Road (East of Manly Road)	EB	730	5.1	57	182	5.3	63
	WB	723	6.2	56	261	6.6	62
Gore Hill Freeway Connection							
Gore Hill Freeway (East of Hampden Road)	EB	1822	4.3	87	520	9.3	92
	WB	1702	6.5	81	383	6.4	82
Reserve Road on ramp	EB	1246	6.5	87	412	7.2	92
Reserve Road off ramp	WB	1752	4.2	81	485	5.7	82
Warringah Freeway							
Warringah Freeway (North of Ernest Street)	NB	3565	4.4	77	912	4.8	80
Warringah Freeway (North of Ernest Street)	NB	1801	5.3	77	334	5.3	80
	SB	2728	3.4	81	802	5.9	90
Warringah Freeway (North of Ernest Street)	SB	2078	6.1	81	459	7.0	90
Ernest Street on/off ramp	NB	42	0.2	77	11	0.3	80
	SB	346	1.3	81	33	1.0	90
Ernest Street off ramp	SB	469	1.8	81	90	1.6	90
Warringah Freeway (South of Falcon Street)	NB	3359	4.6	63	823	5.0	73
Warringah Freeway (South of Falcon Street)	NB	1409	4.5	63	363	5.4	73
	SB	3091	3.5	68	908	5.6	83
Warringah Freeway (South of Falcon Street)	SB	1337	7.0	68	369	6.6	84
Falcon Street off ramp	NB	354	2.6	63	83	3.2	73
Falcon Street off ramp (bus lane)	NB	46	94.3	63	6	86.7	73
Military Road off ramp	NB	1192	3.2	63	469	3.5	73
Falcon Street on ramp	SB	1131	3.5	68	407	3.2	83

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Falcon Street on ramp (bus lane)	SB	141	30.1	68	83	7.3	83
Ernest Street (West of Warringah Freeway)	EB	585	3.0	52	101	3.3	54
	WB	651	4.0	53	99	3.9	57
Ernest Street (East of Warringah Freeway)	EB	734	4.5	50	100	4.2	51
	WB	968	5.1	47	169	5.6	51
Falcon Street (West of Lytton Street)	EB	775	6.6	49	176	7.2	53
	WB	833	9.7	52	219	8.7	58
Military Road (East of Short Lane)	EB	2151	8.8	39	648	8.5	47
Falcon Street (East of Warringah Freeway)	WB	1936	8.4	41	657	7.4	51
Miller Street (North of Ridge Street)	NB	314	7.1	41	40	13.9	42
	SB	382	5.3	34	78	8.0	38
Warringah Freeway (South of High Street)	NB	3069	6.4	60	929	5.1	72
	SB	2533	2.7	63	700	4.7	80
Cahill Expressway (South of High Street)	SB	972	13.4	63	322	7.3	80
Mount Street on ramp (South of High Street)	SB	489	4.3	63	89	6.0	80
Warringah Freeway (South of Merrenburn Avenue)	NB	3442	5.3	86	868	5.9	92
	SB	3102	5.2	82	931	8.3	82
Willoughby Road off ramp	NB	668	2.7	86	177	3.1	92
Willoughby Road on ramp	SB	645	2.6	82	178	2.6	82
Warringah Freeway (East of Miller Street)	EB	4389	4.5	87	1218	6.6	93
	WB	4817	4.5	81	1111	4.9	82
Miller Street on ramp	EB	284	2.9	87	79	2.1	92
Miller Street off ramp	WB	354	2.9	81	81	3.0	82
Brook Street (South of Marks Street)	NB	788	9.7	47	136	5.5	39
	SB	841	4.6	47	183	5.9	52

Notes: 1. Based on average vehicle speeds from 2017 traffic survey.

D.2 Year 2027 (opening year) do minimum traffic volumes

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Warringah Freeway and surrounds							
Warringah Freeway (south of Merrenburn Avenue)	NB	3891	4.9	80	1345	3.4	80
	SB	3732	4.6	80	1318	4.4	80
Willoughby Road off ramp	NB	818	11.6	60	367	9.9	60
Willoughby Road on ramp	SB	795	6.0	60	306	4.4	60
Warringah Freeway (south of Brook Street)	NB	4709	6.0	80	1713	4.8	80
	SB	4527	4.9	80	1625	4.4	80
Brook Street off ramp	NB	1037	6.1	60	332	5.7	60
Brook Street on ramp	SB	772	3.5	80	154	3.5	80
Warringah Freeway (east of Miller Street)	WB	5746	6.0	80	2045	4.9	80
	EB	5300	4.7	80	1779	4.3	80
Miller Street off ramp	WB	720	3.4	60	224	4.5	60
Miller Street on ramp	EB	559	3.1	60	115	0.6	60
Warringah Freeway (north of Ernest Street)	NB	4158	4.9	80	1456	4.1	80
Warringah Freeway (north of Ernest Street)	NB	2309	7.3	80	812	6.3	80
	SB	2897	5.7	80	1152	4.9	80
Warringah Freeway (north of Ernest Street)	SB	2962	3.3	80	741	2.8	80
Ernest Street on/off ramp	NB	551	5.8	60	201	2.5	60
	SB	102	2.7	80	0	0	80
Ernest Street on ramp	SB	639	0.9	80	73	0.2	80
Warringah Freeway (south of Falcon Street)	NB	4158	4.9	80	1456	4.1	80
Warringah Freeway (south of Falcon Street)	NB	1667	8.1	80	686	6.3	80
	SB	195	4.5	80	0	0	80
Warringah Freeway (south of Falcon Street)	SB	2036	3.3	80	544	2.5	80
Falcon Street off ramp	NB	375	1.1	60	165	0.4	60
Falcon Street off ramp (bus lane)	NB	32	100	60	4	100	60
Military Road off ramp	NB	1048	3.7	60	499	2.5	60
Falcon Street on ramp	SB	1619	5.1	60	625	4.0	60
Falcon Street on ramp (bus lane)	SB	38	100	60	5	100	60
Berry Street on ramp	NB	1088	1.7	80	364	0.9	80
Alfred Street off ramp	SB	647	1.7	60	271	1.4	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Warringah Freeway (south of Mount Street)	NB	4492	5.1	80	1756	4.0	80
Warringah Freeway (south of Mount Street)	NB	2218	7.5	80	887	5.5	80
	SB	296	3.9	70	0	0	70
Warringah Freeway (south of Mount Street)	SB	5262	4.9	80	1847	4.4	80
Cahill Expressway (south of Mount Street)	SB	1087	4.1	70	276	3.5	70
Mount Street on ramp	SB	754	1.6	70	153	2.8	70
Mount Street on ramp (Cahill Expressway)	SB	602	0.5	70	301	0.4	70
Sydney Harbour Tunnel portals	NB/exit	3102	4.6	80	1079	3.6	80
	SB/entry	3049	4.6	80	1002	3.8	80
Warringah Freeway (south of High Street)	NB	1390	6.2	80	677	4.7	80
Warringah Freeway (south of High Street)	NB	2218	7.5	80	887	5.5	80
	SB	341	3.5	70	0	0	70
Warringah Freeway (south of High Street)	SB	2921	4.4	70	998	4.8	70
Cahill Expressway (south of High Street)	SB	1688	2.8	70	577	1.9	70
Pacific Highway off ramp	NB	1478	2.1	60	517	2.6	60
High Street on ramp	SB	688	0.0	70	331	0.1	70
Lavender Street off ramp	NB	366	3.1	70	136	3.1	70
Bradfield Highway (south of Lavender Street)	NB	5451	5.4	70	2217	4.4	70
	SB	3263	4.3	70	998	4.8	70
Cahill Expressway (south of Lavender Street)	SB	2376	2.0	70	908	1.2	70
Ernest Street (west of Warringah Freeway)	EB	384	0.4	50	45	0.3	50
	WB	334	0.5	50	66	0.6	50
Ernest Street (between Miller and West Street)	EB	304	0.4	50	45	0.3	50
	WB	357	0.3	50	90	0.4	50
Ernest Street (between West and Sophia Street)	EB	175	0.4	50	43	0.3	50
	WB	340	0.5	50	68	0.5	50
Ernest Street (between Sophia and Alexander Street)	EB	175	0.4	50	43	0.3	50
	WB	80	0.3	50	17	0.4	50
Ernest Street (east of Warringah Freeway)	EB	891	3.7	50	235	2.1	50
	WB	1031	1.0	50	129	0.3	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Ernest Street (between Merlin Street and Park Avenue)	EB	1089	3.3	50	347	1.6	50
	WB	1037	1.0	50	128	0.3	50
Falcon Street (west of Warringah Freeway)	EB	1027	1.4	60	226	1.0	60
	WB	959	1.0	60	308	0.8	60
Falcon Street (between Miller and West Street)	EB	900	1.4	60	212	0.9	60
	WB	685	1.0	60	229	0.7	60
Falcon Street (between West and Alexander Street)	EB	1035	1.2	60	231	0.9	60
	WB	673	0.9	60	224	0.6	60
Falcon Street (between Alexander Street and Pacific Highway)	EB	1016	1.3	60	233	0.9	60
	WB	801	1.0	60	257	0.6	60
Falcon Street (east of Warringah Freeway)	WB	2244	4.9	60	777	4.2	60
Falcon Street (between Watson Street and Tramway Lane)	WB	2213	4.9	60	778	4.1	60
Military Road (east of Warringah Freeway)	EB	2400	3.0	60	806	2.6	60
Military Road (between Watson Street and Ben Boyd Road)	EB	2233	3.1	60	746	2.7	60
	WB	2213	4.9	60	778	4.1	60
Military Road (between Ben Boyd Road and Young Street)	EB	2242	3.1	60	764	2.6	60
	WB	2035	5.2	60	738	4.3	60
Military Road (between Young Street and Wycombe Road)	EB	2068	3.2	60	747	2.6	60
	WB	1865	5.6	60	701	4.5	60
Willoughby Road (north of Warringah Freeway)	NB	1117	9.1	60	412	9.0	60
	SB	1203	4.7	60	384	4.1	60
Willoughby Road (south of Warringah Freeway)	NB	319	2.2	60	59	1.4	60
	SB	429	1.9	60	92	2.5	60
Willoughby Road (between Merrenburn Avenue and Dalleys Road)	NB	547	3.3	60	128	2.4	60
	SB	526	3.1	60	104	2.8	60
Willoughby Road (between Dalleys Road and Chandos Street)	NB	566	2.3	60	117	1.5	60
	SB	431	1.4	60	77	1.8	60
Willoughby Road (between Chandos and Atchison Street)	NB	405	1.5	60	105	1.2	60
	SB	526	1.2	60	126	1.7	60
Willoughby Road (between Atchison and Albany Street)	NB	275	1.5	60	35	0.7	60
	SB	260	1.0	60	39	1.1	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Willoughby Road (between Albany and Holtermann Street)	NB	294	0.7	60	62	0.6	60
	SB	154	0.8	60	39	1.1	60
Willoughby Road (between Holtermann and Falcon Street)	SB	24	0	60	4	0	60
Merrenburn Avenue (between Willoughby Road and Brook Street)	EB	261	4.2	50	73	3.0	50
	WB	131	6.0	50	16	4.1	50
Brook Street (between Merrenburn Avenue and Flat Rock Drive)	NB	1018	3.9	50	220	2.9	50
	SB	999	6.9	50	346	5.5	50
Brook Street (between Warringah Freeway on ramp and Merrenburn Avenue)	NB	827	7.1	50	297	5.7	50
	SB	976	3.3	50	227	2.6	50
Brook Street (between Warringah Freeway on and off ramps)	NB	1189	5.4	50	361	5.1	50
	SB	97	4.0	50	28	1.1	50
Brook Street (between Warringah Freeway on ramp and Chandos Street)	NB	530	1.7	50	109	1.7	50
	SB	475	2.7	50	108	2.5	50
Chandos Street (between Alexander and Brook Street)	EB	530	1.7	50	109	1.7	50
	WB	475	2.7	50	108	2.5	50
Chandos Street (between Brook Street and Willoughby Road)	EB	395	1.7	50	65	1.9	50
	WB	338	2.4	50	85	2.9	50
Chandos Street (between Willoughby Road and Oxley Street)	EB	452	2.6	50	59	2.4	50
	WB	139	4.4	50	18	8.1	50
Chandos Street (between Oxley and Christie Street)	EB	212	3.3	50	36	2.4	50
	WB	71	5.8	50	3	37.8	50
Alexander Street (between Brook and Albany Street)	NB	215	2.0	50	63	1.5	50
	SB	216	2.9	50	42	1.2	50
Alexander Street (between Albany and Holtermann Street)	NB	222	1.6	50	51	1.2	50
	SB	206	1.7	50	47	0.5	50
Alexander Street (between Holtermann and Ernest Street)	NB	256	1.6	50	62	1.0	50
	SB	335	1.4	50	82	0.7	50
Alexander Street (between Ernest and Burlington Street)	NB	308	1.3	50	72	0.9	50
	SB	293	1.5	50	67	0.8	50
Alexander Street (between Burlington and Falcon Street)	NB	336	1.6	50	76	0.9	50
	SB	318	1.4	50	74	0.7	50
Alexander Street (between Falcon Street and Pacific Highway)	NB	339	1.2	50	69	0.9	50
	SB	174	1.3	50	36	1.0	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Albany Street (between Alexander Street and Willoughby Road)	EB	75	0.4	50	23	0.3	50
	WB	80	2.4	50	3	0	50
Albany Street (between Willoughby Road and Oxley Street)	EB	132	0.8	50	23	0.3	50
	WB	262	0.8	50	30	0.4	50
Albany Street (between Oxley Street and Pacific Highway)	EB	353	2.3	50	91	2.2	50
	WB	411	2.0	50	81	2.0	50
Amherst Street (west of West Street)	EB	469	1.4	60	109	1.2	60
Amherst Street (between West and Miller Street)	EB	334	1.1	50	103	2.1	50
	WB	93	0.1	50	27	0	50
West Street (between Amherst and Ernest Street)	NB	95	2.7	50	29	6.9	50
	SB	318	1.7	50	61	2.0	50
West Street (between Ernest and Falcon Street)	NB	214	1.6	50	31	6.2	50
	SB	299	1.7	50	60	2.0	50
West Street (between Falcon and Ridge Street)	NB	66	5.3	50	16	11.5	50
	SB	297	2.2	50	70	2.4	50
West Street (between Ridge and Church Street)	NB	96	2.8	50	16	2.7	50
	SB	207	1.4	50	42	1.3	50
West Street (between Church Street and Pacific Highway)	NB	96	2.8	50	16	2.7	50
	SB	207	1.4	50	42	1.3	50
Miller Street (between Pine and Amherst Street)	NB	931	3.8	50	268	5.3	50
	SB	907	2.6	50	182	0.8	50
Miller Street (between Amherst Street and Warringah Freeway on ramp)	NB	831	3.4	50	235	4.4	50
	SB	892	2.7	50	156	0.8	50
Miller Street (between Warringah Freeway on and off ramps)	NB	831	3.4	50	235	4.4	50
	SB	333	2.0	50	42	1.3	50
Miller Street (between Warringah Freeway off ramp and Ernest Street)	NB	132	2.9	50	11	0.6	50
	SB	355	1.9	50	42	1.3	50
Miller Street (between Ernest and Falcon Street)	NB	208	1.8	50	37	0.2	50
	SB	328	2.1	50	44	1.1	50
Miller Street (between Falcon and Ridge Street)	NB	227	2.3	50	16	1.5	50
	SB	494	1.7	50	89	1.4	50
Miller Street (between Ridge and McLaren Street)	NB	158	3.2	50	14	9.5	50
	SB	324	1.7	50	58	1.4	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Miller Street (between McLaren and Berry Street)	NB	388	1.5	50	54	2.6	50
	SB	444	1.3	50	77	1.2	50
Miller Street (between Berry Street and Pacific Highway)	NB	629	1.2	40	136	1.5	40
	SB	202	1.9	40	38	1.1	40
Walker Street (between Ridge and McLaren Street)	NB	77	0.8	50	5	1.3	50
	SB	293	1.7	50	59	2.3	50
Walker Street (between McLaren and Berry Street)	NB	149	2.9	50	77	3.7	50
	SB	510	1.4	50	165	1.2	50
Walker Street (between Berry and Spring Street)	NB	494	2.8	50	186	2.5	50
	SB	32	0.2	50	9	0	50
Ridge Street (between Walker and Miller Street)	EB	293	1.7	50	59	2.3	50
	WB	77	0.8	50	5	1.3	50
Ridge Street (between Miller and West Street)	EB	96	4.7	50	15	10	50
	WB	210	2.8	50	41	2.6	50
McLaren Street (between Walker and Miller Street)	EB	369	0.6	50	60	0.3	50
	WB	234	0.2	50	46	0.4	50
McLaren Street (between Miller and Angelo Street)	EB	171	0.8	50	21	0.9	50
	WB	145	0.2	50	28	0.2	50
McLaren Street (between Angelo Street and Pacific Highway)	EB	171	0.8	50	21	0.9	50
	WB	145	0.2	50	28	0.2	50
Berry Street (between Walker and Arthur Street)	EB	1903	1.3	60	625	0.9	60
Berry Street (between Little Spring and Walker Street)	EB	1080	0.8	40	360	0.6	40
Berry Street (between Denison and Little Spring Street)	EB	1171	0.8	40	384	0.6	40
Berry Street (between Miller and Denison Street)	EB	1055	0.8	40	291	0.7	40
Berry Street (between Pacific Highway and Miller Street)	EB	572	0.8	40	171	0.5	40
Spring Street (between Walker and Little Spring Street)	WB	71	7.5	50	16	16.7	50
Spring Street (between Little Spring and Denison Street)	WB	162	3.6	50	40	7.0	50
Denison Street (between Spring and Berry Street)	NB	71	7.5	50	16	16.7	50
Pacific Highway (between Arthur and Walker Street)	NB	1984	2.3	60	543	3.2	60
	SB	799	1.0	60	278	1.1	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Pacific Highway (between Walker and Miller Street)	NB	1339	1.3	60	334	1.3	60
	SB	399	1.1	60	62	0.9	60
Pacific Highway (between Miller and William Street)	NB	457	1.3	60	78	0.5	60
	SB	366	1.3	60	49	1.0	60
Pacific Highway (between William and Berry Street)	NB	628	1.3	60	125	0.6	60
	SB	366	1.3	60	49	1.0	60
Pacific Highway (between Berry Street and Bay Road)	NB	486	1.2	60	82	0.6	60
	SB	795	0.9	60	177	0.6	60
Pacific Highway (between Bay Road and McLaren Street)	NB	580	1.1	60	92	0.5	60
	SB	768	1.2	60	119	1.0	60
Pacific Highway (between McLaren and West Street)	NB	678	1.0	60	108	0.5	60
	SB	892	1.2	60	129	1.0	60
Pacific Highway (between West Street and Crows Nest Road)	NB	678	1.0	60	108	0.5	60
	SB	781	1.3	60	103	1.1	60
Pacific Highway (between Crows Nest and Rocklands Road)	NB	576	1.1	60	78	0.6	60
	SB	781	1.3	60	103	1.1	60
Pacific Highway (between Rocklands Road and Bruce Street)	NB	685	1.0	60	84	0.7	60
	SB	869	1.2	60	116	1.1	60
Pacific Highway (between Bruce and Alexander Street)	NB	723	1.2	60	93	0.9	60
	SB	914	1.6	60	127	1.4	60
Pacific Highway (between Alexander and Falcon Street)	NB	444	1.1	60	36	0.9	60
	SB	800	1.5	60	104	1.4	60
Pacific Highway (between Falcon and Hume Street)	NB	563	0.7	60	101	0.5	60
	SB	1087	1.4	60	154	1.3	60
Arthur Street (between Pacific Highway and Mount Street)	NB	541	1.5	40	193	1.6	40
High Street (west of Warringah Freeway)	EB	712	0.1	70	313	0.1	70
	WB	648	1.4	70	185	1.9	70
High Street (east of Warringah Freeway)	EB	978	0.3	50	402	0.2	50
	WB	1114	0.2	50	393	0.1	50
Clark Road (between High Street and Adderstone Avenue)	NB	769	0.1	50	312	0.1	50
	SB	867	0.2	50	262	0.1	50
Clark Road (between Adderstone Avenue and Kurraba Road)	NB	658	0.1	50	275	0.1	50
	SB	771	0.2	50	220	0.1	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Kurraba Road (between Clark Road and Holdsworth Street)	EB	745	0.1	50	279	0.1	50
	WB	755	0.2	50	217	0.1	50
Kurraba Road (between Holdsworth and Ben Boyd Road)	EB	567	0.1	50	221	0.1	50
	WB	649	0.3	50	168	0.1	50
Bent Street (between Falcon Street and Alfred Street N)	SB	103	0.4	50	9	1.4	50
Alfred Street N (between Bent Street and Kurraba Road)	SB	103	0.4	50	9	1.4	50
Alfred Street N (between Kurraba Road and High Street)	SB	487	1.9	50	212	1.7	50
Gore Hill Freeway Connection							
Gore Hill Freeway (north of Willoughby Road)	NB/WB	3891	4.9	80	1345	3.4	80
	SB/EB	3732	4.6	80	1318	4.4	80
Gore Hill Freeway (to / from Longueville Road, east of Hampden Road overpass)	WB	2252	4.1	80	875	2.7	80
	EB	1686	3.2	80	656	3.0	80
Lane Cove Tunnel (east of Hampden Road overpass)	WB	1640	6.0	80	470	4.7	80
	EB	2046	5.7	80	662	5.7	80
Gore Hill Freeway on ramp (east of Reserve Road overpass)	EB	372	8.4	80	66	12.8	80
Lane Cove Tunnel (west of Reserve Road overpass)	WB	1640	6.0	80	470	4.7	80
	EB	1674	5.1	80	596	4.9	80
Lane Cove Tunnel on ramp (west of Reserve Road overpass)	WB	275	14.5	80	46	14.0	80
Lane Cove Tunnel off ramp (west of Reserve Road overpass)	EB	439	10.1	80	96	10.3	80
Lane Cove Tunnel (west of Reserve Road ramps)	WB	1915	7.2	80	516	5.5	80
	EB	2113	6.2	80	692	5.7	80
Gore Hill Freeway off ramp (east of Reserve Road)	WB	233	11.4	60	52	12.4	60
Gore Hill Freeway (west of Reserve Road overpass)	WB	2018	3.2	80	823	2.1	80
Gore Hill Freeway on ramp (west of Reserve Road)	WB	359	7.4	80	107	6.2	80
Gore Hill Freeway off ramp (to Pacific Highway)	WB	998	2.7	60	367	2.7	60
Gore Hill Freeway (west of Pacific Highway overpass)	WB	1379	4.7	60	564	2.5	60
	EB	997	4.3	60	450	3.1	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Gore Hill Freeway (east of Pacific Highway overpass, right lane)	EB	570	5.2	60	298	3.8	60
Gore Hill Freeway (east of Pacific Highway overpass, left lane)	EB	427	3.0	60	152	1.8	60
Lane Cove Tunnel off ramp (east of Pacific Highway overpass, to Gore Hill Fwy)	EB	39	5.0	60	0	0	60
Gore Hill Freeway off ramp (west of Reserve Road)	EB	295	7.8	80	96	7.8	80
Gore Hill Freeway on ramp (from Pacific Highway)	EB	945	3.5	80	303	4.5	80
Gore Hill Freeway (east of Reserve Road overpass)	EB	1686	3.2	80	656	3.0	80
Longueville Road (east of Epping Road)	WB	2200	4.5	60	787	3.0	60
	EB	1546	3.6	60	544	2.9	60
Longueville Road on ramp (from Pacific Highway)	WB	821	4.1	60	223	4.1	60
Longueville Road off ramp (to Pacific Highway)	EB	548	2.4	60	94	1.8	60
Lane Cove Tunnel on ramp, east of Pacific Highway (from Pacific Highway)	EB	327	6.8	60	53	4.0	60
Lane Cove Tunnel off ramp, east of Pacific Highway (to Pacific Highway)	WB	322	8.5	60	47	9.5	60
Pacific Highway (between Campbell Street and Dickson Avenue)	NB	910	2.2	60	153	0.8	60
	SB	934	1.4	60	123	0.8	60
Pacific Highway (between Dickson Avenue and Hotham Parade)	NB	910	2.2	60	153	0.8	60
	SB	823	1.4	60	132	0.7	60
Pacific Highway (between Hotham Parade and Cobden Avenue)	NB	830	2.4	60	139	1.0	60
	SB	764	1.5	60	117	0.8	60
Pacific Highway (between Cobden Avenue and Gore Hill Freeway overpass)	NB	965	2.5	60	154	1.1	60
	SB	764	1.5	60	117	0.8	60
Pacific Highway (between Gore Hill Freeway overpass and Gore Hill Freeway ramps)	NB	563	1.3	60	74	0.7	60
	SB	962	3.9	60	219	4.3	60
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway NB)	NB	277	5.2	60	47	2.1	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway SB)	SB	50	15.5	60	7	16.2	60
Pacific Highway (between Gore Hill Freeway ramps to Mowbray Road)	NB	1843	3.6	60	519	4.4	60
	SB	1819	3.2	60	483	3.0	60
Hampden Road (between Palmer and Brand Street)	NB	447	4.6	50	161	5.3	50
	SB	268	3.0	50	120	3.5	50
Hampden Road (between Brand Street and Jersey Road)	NB	424	4.3	50	144	3.5	50
	SB	420	5.1	50	148	5.7	50
Hampden Road (between Jersey Road and Cleg Street)	NB	219	2.2	50	77	1.4	50
	SB	209	2.2	50	72	1.8	50
Herbert Street (between Cleg and Frederick Street)	NB	284	4.2	50	91	2.7	50
	SB	373	2.8	50	143	2.4	50
Herbert Street (between Frederick and Ella Street)	NB	461	5.4	50	124	2.8	50
	SB	528	4.6	50	163	3.8	50
Herbert Street (between Ella and Westbourne Street)	NB	271	3.8	50	87	2.4	50
	SB	301	3.6	50	102	3.8	50
Frederick Street (between Herbert Street and Reserve Road)	EB	155	8.9	50	20	13.9	50
	WB	176	7.3	50	33	3.0	50
Campbell Street (between Reserve Road and Pacific Highway)	EB	168	3.0	50	22	4.2	50
	WB	317	5.3	50	89	1.1	50
Cleg Street (between Herbert and Waltham Street)	EB	288	3.9	50	104	3.2	50
	WB	189	6.6	50	48	5.2	50
Waltham Street (between Cleg Street and Dickson Avenue)	NB	286	7.0	50	76	5.3	50
	SB	273	5.9	50	102	4.7	50
Dickson Avenue (between Waltham Street and Reserve Road)	EB	273	5.9	50	102	4.7	50
	WB	286	7.0	50	76	5.3	50
Dickson Avenue (between Reserve Road and Pacific Highway)	EB	38	0.3	50	9	0	50
	WB	149	1.1	50	0	0	50
Reserve Road (between Frederick and Campbell Street)	NB	176	7.3	50	33	3.0	50
	WB	155	8.9	50	20	13.9	50
Reserve Road (between Campbell Street and Dickson Avenue)	NB	516	15.9	50	125	16.0	50
	SB	495	17.5	50	148	17.0	50
Reserve Road (between Dickson Avenue and Gore Hill Freeway)	NB	784	12.7	50	195	12.0	50
	SB	860	11.8	50	236	12.4	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Reserve Road (between Gore Hill Freeway and Jersey Road)	NB	356	5.2	50	105	4.9	50
	SB	471	5.3	50	120	7.2	50
Jersey Road (between Reserve and Abbott Road)	EB	294	5.6	50	93	5.0	50
	WB	351	6.1	50	100	7.9	50
Jersey Road (between Abbott and Hampden Road)	EB	260	5.3	50	78	5.1	50
	WB	266	6.5	50	86	8.4	50
Connections to and from Burnt Bridge Creek Deviation							
Manly Road (between Avona Crescent and Heaton Avenue)	NB	1944	5.4	60	730	3.5	60
	SB	1996	6.6	60	652	5.8	60
Manly Road (between Heaton Avenue and Sydney Road)	NB	1944	5.4	60	730	3.5	60
	SB	1931	6.8	60	634	6.0	60
Burnt Bridge Creek Deviation (between Sydney Road and Condamine Street)	NB	1340	6.9	80	468	5.0	80
	SB	1215	8.0	80	399	6.9	80
Condamine Street (between Burnt Bridge Creek Deviation and Kenneth Road)	NB	1720	5.7	60	542	4.1	60
	SB	1564	6.8	60	482	6.1	60
Frenchs Forest Road (between Montauban Avenue and Baringa Avenue)	EB	237	3.2	60	82	1.2	60
	WB	164	0.2	60	37	0	60
Frenchs Forest Road (between Baringa Avenue and Brook Road)	EB	333	2.3	60	112	0.9	60
	WB	154	0.2	60	37	0	60
Frenchs Forest Road (between Brook and Sydney Road)	NB	270	0.1	60	87	0	60
	SB	395	1.9	60	126	0.8	60
Sydney Road (between Frenchs Forest Road and Manly Road)	EB	566	1.5	60	170	0.7	60
	WB	275	0.0	60	94	0.1	60
Sydney Road (between Manly Road and Wanganella Street)	EB	762	1.7	60	302	0.7	60
	WB	583	4.4	60	198	4.7	60
Sydney Road (between Wanganella and Woodland Street)	EB	778	1.6	60	262	0.7	60
	WB	623	4.1	60	208	4.5	60
Sydney Road (Woodland and Condamine Street)	EB	865	1.3	60	3	100	60
	WB	623	1.7	60	3	100	60
Wanganella Street (Sydney Road and Kitchener Street)	NB	6	0	50	1	0	50
	SB	116	0.3	50	6	1.0	50
Kitchener Street (between Wanganella and Daisy Street)	EB	274	3.5	50	46	5.0	50
	WB	233	5.7	50	50	4.6	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Daisy Street (between Kitchener and Woodbine Street)	NB	233	5.7	50	50	4.6	50
	SB	274	3.5	50	46	5.0	50
Woodbine Street (between Daisy and Bangaroo Street)	EB	274	3.5	50	46	5.0	50
	WB	233	5.7	50	50	4.6	50
Woodbine Street (between Bangaroo and Hunter Street)	EB	305	3.1	50	57	4.2	50
	WB	249	5.4	50	62	3.7	50
Maretimo Street (between Ethel and Upper Beach Street)	NB	8	0	50	0	0	50
	SB	23	0	50	7	0	50
Upper Beach Street (between Maretimo and Wanganella Street)	EB	8	0	50	0	0	50
	WB	23	0	50	7	0	50
Connections to and from Wakehurst Parkway							
Wakehurst Parkway (between Lister Avenue and Armstrong Street)	NB	435	1.0	60	109	0.2	60
	SB	378	2.0	60	127	0.8	60
Wakehurst Parkway (between Armstrong Street and Judith Street)	NB	486	0.9	60	123	0.2	60
	SB	421	1.8	60	143	0.7	60
Wakehurst Parkway (between Judith Street and Aquatic Drive)	NB	616	2.8	80	146	1.8	80
	SB	596	2.9	80	167	2.0	80
Wakehurst Parkway (between Aquatic Drive and Warringah Road)	NB	588	2.9	70	140	1.8	70
	SB	627	4.4	70	183	3.4	70
Wakehurst Parkway (between Warringah Road and Frenchs Forest Road)	NB	627	4.2	60	201	1.4	60
	SB	758	2.4	60	216	2.4	60
Wakehurst Parkway (north of Frenchs Forest Road)	NB	712	2.6	60	218	2.4	60
	SB	697	4.4	60	235	1.7	60
Warringah Road (between Forest Way and Hilmer Street)	EB	1489	4.3	70	416	4.9	70
	WB	1233	5.3	70	421	6.1	70
Warringah Road (between Hilmer Street and Wakehurst Parkway)	EB	1211	5.3	70	408	6.2	70
	WB	1459	4.3	70	406	5.0	70
Warringah Road (between Wakehurst Parkway and underpass ramps)	EB	603	6.3	70	171	9.0	70
	WB	447	4.7	70	144	13.0	70

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Warringah Road underpass (between Forest Road and underpass ramps)	EB	988	8.4	70	310	6.4	70
	WB	957	10.5	70	324	7.6	70
Judith Street to Manning Street (between Wakehurst Parkway and Mons Road)	EB	175	5.4	50	24	9.6	50
	WB	129	10.3	50	23	10.1	50

Notes: 1. Based on posted speeds.

2. The 2027 (opening year) do minimum scenario includes the WestConnex, but without the project, Western Harbour Tunnel and Warringah Freeway Upgrade, Sydney Gateway and the M6 Motorway.

D.3 Year 2027 (opening year) do something traffic volumes

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Warringah Freeway and surrounds							
Warringah Freeway (south of Merrenburn Avenue)	NB	3927	6.3	80	1173	4.8	80
	SB	3988	5.9	80	1266	5.1	80
Willoughby Road off ramp	NB	1022	10.0	60	444	7.5	60
Willoughby Road on ramp	SB	1056	7.8	60	385	5.2	60
Warringah Freeway (south of Brook Street)	NB	4949	7.1	80	1617	5.5	80
	SB	5043	6.3	80	1651	5.1	80
Brook Street off ramp	NB	852	8.1	60	240	9.8	60
Brook Street on ramp	SB	661	2.3	80	76	3.6	80
Warringah Freeway (east of Miller Street)	WB	5802	7.3	80	1857	6.1	80
	EB	5704	5.9	80	1726	5.1	80
Miller Street off ramp	WB	551	2.6	60	190	3.6	60
Miller Street on ramp	EB	721	2.8	60	132	0.3	60
Warringah Freeway (north of Ernest Street)	NB	5154	5.1	80	1587	4.8	80
Warringah Freeway (north of Ernest St, WHT exit/entry portal)	NB/exit	1199	14.4	80	460	9.6	80
	SB/entry	850	18.7	80	183	15.2	80
Warringah Freeway (north of Ernest Street)	SB	4778	3.5	80	1459	3.6	80
Ernest Street off ramp	NB	571	2.2	50	184	1.2	50
Ernest Street on ramp	SB	567	1.3	60	26	0.0	60
Warringah Freeway (south of Falcon Street)	NB	3453	5.4	80	1116	4.9	80
Warringah Freeway (south of Falcon Street)	NB	1687	3.5	80	532	2.9	80
	SB	1938	4.3	80	623	4.2	80
Warringah Freeway (south of Falcon Street)	SB	3406	2.7	80	862	3.0	80
Falcon Street off ramp (WHT exit portal)	NB	881	5.2	60	168	6.5	60
Falcon Street off ramp (bus lane)	NB	32	100	60	4	100	60
Military Road off ramp	NB	987	4.1	70	470	2.2	70
Falcon Street on ramp	SB	1637	3.0	80	563	3.4	80
Falcon Street on ramp (bus lane)	SB	38	100	60	5	100	60
Berry Street on ramp	NB	390	1.5	80	124	1.3	80

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Berry Street on ramp (WHT entry portal)	NB	927	4.5	60	191	3.2	60
Alfred Street off ramp	SB	1002	1.8	60	301	1.7	60
Warringah Freeway (south of Mount Street)	NB	5736	4.8	80	1995	4.0	80
Warringah Freeway (south of Mount Street)	SB	5064	3.7	70	1636	4.0	70
Cahill Expressway (south of Mount Street)	SB	916	2.0	70	111	1.0	70
Mount Street on ramp	SB	605	0.3	70	98	1.6	70
Mount Street on ramp (Cahill Expressway)	SB	591	0.4	70	290	0.4	70
Sydney Harbour Tunnel portals	NB/exit	2309	4.9	80	796	3.5	80
	SB/entry	2574	3.8	80	865	3.5	80
Warringah Freeway (south of High Street)	NB	2673	5.7	70	1009	5.0	70
Warringah Freeway (south of High Street)	SB	3095	2.9	70	869	4.2	70
Cahill Expressway (south of High Street)	SB	1506	1.4	70	401	0.6	70
Pacific Highway off ramp	NB	1212	1.5	60	401	2.0	60
High Street on ramp	SB	493	0.0	70	287	0.0	70
Lavender Street off ramp	NB	354	2.8	70	140	2.8	70
Bradfield Highway (south of Lavender Street)	NB	4239	4.2	70	1551	4.0	70
	SB	3095	2.9	70	869	4.2	70
Cahill Expressway (south of Lavender Street)	SB	1999	1.0	70	688	0.3	70
Ernest Street (west of Warringah Freeway)	EB	424	4.0	50	75	2.8	50
	WB	410	0.8	50	91	0.5	50
Ernest Street (between Miller and West Street)	EB	351	4.7	50	73	2.9	50
	WB	416	0.7	50	104	0.5	50
Ernest Street (between West and Sophia Street)	EB	168	0.5	50	46	0.4	50
	WB	371	1.0	50	77	0.7	50
Ernest Street (between Sophia and Alexander Street)	EB	168	0.5	50	46	0.4	50
	WB	168	0.5	50	46	0.4	50
Ernest Street (east of Warringah Freeway)	EB	953	3.1	50	240	1.8	50
	WB	935	1.1	50	98	0.5	50
Ernest Street (between Merlin Street and Park Avenue)	EB	1153	2.7	50	355	1.4	50
	WB	977	1.1	50	97	0.5	50
	EB	1249	0.7	60	302	0.6	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Falcon Street (west of Warringah Freeway)	WB	1522	4.0	60	371	3.9	60
Falcon Street (between Miller and West Street)	EB	1113	0.5	60	263	0.5	60
	WB	836	4.1	60	227	2.6	60
Falcon Street (between West and Alexander Street)	EB	1119	0.5	60	275	0.6	60
	WB	627	2.3	60	189	1.4	60
Falcon Street (between Alexander Street and Pacific Highway)	EB	1104	0.7	60	271	0.7	60
	WB	740	1.9	60	226	1.1	60
Falcon Street (east of Warringah Freeway)	WB	2294	4.0	60	768	3.7	60
Falcon Street (between Watson Street and Tramway Lane)	WB	2306	3.9	60	787	3.6	60
Military Road (east of Warringah Freeway)	EB	2463	3.0	60	869	2.1	60
Military Road (between Watson Street and Ben Boyd Road)	EB	2222	3.2	60	769	2.3	60
	WB	2306	3.9	60	787	3.6	60
Military Road (between Ben Boyd Road and Young Street)	EB	2252	3.1	60	790	2.3	60
	WB	2079	4.3	60	732	3.9	60
Military Road (between Young Street and Wycombe Road)	EB	2082	3.3	60	772	2.3	60
	WB	1910	4.6	60	694	4.1	60
Willoughby Road (north of Warringah Freeway)	NB	1147	9.0	60	459	7.1	60
	SB	1274	6.7	60	446	4.9	60
Willoughby Road (south of Warringah Freeway)	NB	269	1.8	60	60	1.4	60
	SB	363	1.9	60	106	2.8	60
Willoughby Road (between Merrenburn Avenue and Dalleys Road)	NB	542	2.6	60	130	2.3	60
	SB	491	3.2	60	110	3.0	60
Willoughby Road (between Dalleys Road and Chandos Street)	NB	543	1.7	60	124	1.4	60
	SB	371	1.8	60	85	2.0	60
Willoughby Road (between Chandos and Atchison Street)	NB	377	1.3	60	101	0.9	60
	SB	432	1.2	60	100	1.7	60
Willoughby Road (between Atchison and Albany Street)	NB	245	1.4	60	35	0.5	60
	SB	200	0.9	60	34	0.4	60
Willoughby Road (between Albany and Holtermann Street)	NB	302	0.8	60	63	0.7	60
	SB	141	0.5	60	37	0.3	60
Willoughby Road (between Holtermann and Falcon Street)	SB	35	0.2	60	6	0.0	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Merrenburn Avenue (between Willoughby Road and Brook Street)	EB	321	3.2	50	83	2.9	50
	WB	175	5.8	50	17	4.0	50
Brook Street (between Merrenburn Avenue and Flat Rock Drive)	NB	1013	3.4	50	171	2.9	50
	SB	960	8.8	50	281	9.1	50
Brook Street (between Warringah Freeway on ramp and Merrenburn Avenue)	NB	723	10.3	50	223	10.4	50
	SB	921	2.6	50	180	2.5	50
Brook Street (between Warringah Freeway on and off ramps)	NB	1024	7.4	50	267	8.9	50
	SB	123	3.8	50	35	2.1	50
Brook Street (between Warringah Freeway on ramp and Chandos Street)	NB	504	1.8	50	89	1.3	50
	SB	455	1.5	50	97	1.6	50
Chandos Street (between Alexander and Brook Street)	EB	504	1.8	50	89	1.3	50
	WB	455	1.5	50	97	1.6	50
Chandos Street (between Brook Street and Willoughby Road)	EB	361	1.8	50	49	1.1	50
	WB	304	0.8	50	73	1.5	50
Chandos Street (between Willoughby Road and Oxley Street)	EB	427	2.3	50	44	2.5	50
	WB	143	1.7	50	29	2.8	50
Chandos Street (between Oxley and Christie Street)	EB	244	2.7	50	38	2.3	50
	WB	87	0.7	50	15	2.5	50
Alexander Street (between Brook and Albany Street)	NB	211	1.8	50	60	1.4	50
	SB	219	2.7	50	44	1.7	50
Alexander Street (between Albany and Holtermann Street)	NB	237	1.6	50	56	1.2	50
	SB	217	1.9	50	55	1.1	50
Alexander Street (between Holtermann and Ernest Street)	NB	257	1.4	50	63	1.0	50
	SB	322	1.5	50	86	0.9	50
Alexander Street (between Ernest and Burlington Street)	NB	311	1.2	50	72	0.9	50
	SB	296	1.7	50	69	0.9	50
Alexander Street (between Burlington and Falcon Street)	NB	332	1.3	50	75	0.9	50
	SB	318	1.3	50	75	0.9	50
Alexander Street (between Falcon Street and Pacific Highway)	NB	326	0.8	50	75	0.6	50
	SB	185	2.4	50	35	1.9	50
Albany Street (between Alexander Street and Willoughby Road)	EB	71	0.2	50	23	0.3	50
	WB	89	1.8	50	6	0.0	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Albany Street (between Willoughby Road and Oxley Street)	EB	115	0.5	50	23	0.3	50
	WB	249	0.8	50	31	0.8	50
Albany Street (between Oxley Street and Pacific Highway)	EB	364	2.4	50	110	1.8	50
	WB	411	2.0	50	84	1.9	50
Amherst Street (west of West Street)	EB	438	1.4	60	112	1.2	60
Amherst Street (between West and Miller Street)	EB	337	1.2	50	107	2.1	50
	WB	84	0.1	50	20	0.0	50
West Street (between Amherst and Ernest Street)	NB	101	3.1	50	36	5.4	50
	SB	283	1.8	50	61	2.0	50
West Street (between Ernest and Falcon Street)	NB	286	6.8	50	63	6.2	50
	SB	305	1.7	50	67	1.8	50
West Street (between Falcon and Ridge Street)	NB	67	6.1	50	19	10.0	50
	SB	300	3.1	50	73	3.7	50
West Street (between Ridge and Church Street)	NB	112	2.7	50	16	2.6	50
	SB	218	1.4	50	45	1.5	50
West Street (between Church Street and Pacific Highway)	NB	112	2.7	50	16	2.6	50
	SB	218	1.4	50	45	1.5	50
Miller Street (between Pine and Amherst Street)	NB	916	3.1	50	251	5.5	50
	SB	920	2.7	50	184	0.6	50
Miller Street (between Amherst Street and Warringah Freeway on ramp)	NB	800	2.6	50	207	4.8	50
	SB	942	2.6	50	174	0.5	50
Miller Street (between Warringah Freeway on and off ramps)	NB	814	2.5	50	208	4.7	50
	SB	234	1.8	50	43	1.1	50
Miller Street (between Warringah Freeway off ramp and Ernest Street)	NB	330	1.9	50	30	9.8	50
	SB	301	1.4	50	55	1.0	50
Miller Street (between Ernest and Falcon Street)	NB	410	1.9	50	43	6.9	50
	SB	303	1.9	50	52	0.9	50
Miller Street (between Falcon and Ridge Street)	NB	238	2.3	50	43	0.9	50
	SB	681	3.9	50	156	3.8	50
Miller Street (between Ridge and McLaren Street)	NB	116	2.1	50	18	2.3	50
	SB	340	3.4	50	67	3.7	50
Miller Street (between McLaren and Berry Street)	NB	351	1.1	50	78	1.7	50
	SB	539	2.5	50	90	2.8	50
Miller Street (between Berry Street and Pacific Highway)	NB	288	1.2	40	65	2.1	40
	SB	160	3.0	40	37	1.5	40

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Walker Street (between Ridge and McLaren Street)	NB	127	1.3	50	29	0.6	50
	SB	469	3.7	50	117	3.5	50
Walker Street (between McLaren and Berry Street)	NB	163	1.1	50	61	1.2	50
	SB	610	2.6	50	187	1.9	50
Walker Street (between Berry and Spring Street)	NB	324	3.2	50	83	2.5	50
	SB	10	1.3	50	1	0.0	50
Ridge Street (between Walker and Miller Street)	EB	469	3.7	50	117	3.5	50
	WB	127	1.3	50	29	0.6	50
Ridge Street (between Miller and West Street)	EB	86	1.4	50	16	3.0	50
	WB	209	2.4	50	40	2.5	50
McLaren Street (between Walker and Miller Street)	EB	353	0.7	50	78	1.5	50
	WB	265	0.4	50	60	0.4	50
McLaren Street (between Miller and Angelo Street)	EB	210	1.1	50	19	1.0	50
	WB	158	0.2	50	36	0.2	50
McLaren Street (between Angelo Street and Pacific Highway)	EB	210	1.1	50	19	1.0	50
	WB	158	0.2	50	36	0.2	50
Berry Street (between Walker and Arthur Street)	EB	1892	2.6	60	563	1.6	60
Berry Street (between Little Spring and Walker Street)	EB	1131	2.2	40	356	1.1	40
Berry Street (between Denison and Little Spring Street)	EB	1250	2.1	40	382	1.1	40
Berry Street (between Miller and Denison Street)	EB	929	2.9	40	224	2.2	40
Berry Street (between Pacific Highway and Miller Street)	EB	614	3.0	40	183	1.6	40
Spring Street (between Walker and Little Spring Street)	WB	268	1.5	50	82	2.2	50
Spring Street (between Little Spring and Denison Street)	WB	388	1.5	50	108	1.9	50
Denison Street (between Spring and Berry Street)	NB	268	1.5	50	82	2.2	50
Pacific Highway (between Arthur and Walker Street)	NB	1842	1.4	60	477	2.0	60
	SB	1318	0.9	60	372	0.8	60
Pacific Highway (between Walker and Miller Street)	NB	1230	1.0	60	340	1.2	60
	SB	590	1.1	60	90	0.8	60
Pacific Highway (between Miller and William Street)	NB	537	0.3	60	138	0.3	60
	SB	472	0.8	60	77	0.7	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Pacific Highway (between William and Berry Street)	NB	693	0.8	60	177	0.8	60
	SB	472	0.8	60	77	0.7	60
Pacific Highway (between Berry Street and Bay Road)	NB	428	0.3	60	112	0.3	60
	SB	821	2.2	60	195	1.2	60
Pacific Highway (between Bay Road and McLaren Street)	NB	531	0.3	60	134	0.2	60
	SB	792	2.5	60	146	1.8	60
Pacific Highway (between McLaren and West Street)	NB	645	0.3	60	159	0.2	60
	SB	958	2.3	60	154	1.8	60
Pacific Highway (between West Street and Crows Nest Road)	NB	645	0.3	60	159	0.2	60
	SB	852	2.6	60	125	2.0	60
Pacific Highway (between Crows Nest and Rocklands Road)	NB	566	0.3	60	130	0.3	60
	SB	852	2.6	60	125	2.0	60
Pacific Highway (between Rocklands Road and Bruce Street)	NB	656	0.3	60	133	0.3	60
	SB	891	2.4	60	124	2.1	60
Pacific Highway (between Bruce and Alexander Street)	NB	693	0.7	60	140	0.6	60
	SB	935	2.8	60	134	2.3	60
Pacific Highway (between Alexander and Falcon Street)	NB	433	0.5	60	77	0.5	60
	SB	816	2.6	60	111	2.2	60
Pacific Highway (between Falcon and Hume Street)	NB	507	1.5	60	90	1.4	60
	SB	1137	1.7	60	162	1.6	60
Arthur Street (between Pacific Highway and Mount Street)	NB	1186	1.0	60	364	1.4	60
High Street (west of Warringah Freeway)	EB	653	1.5	70	186	0.8	70
	WB	879	1.7	70	207	2.2	70
High Street (east of Warringah Freeway)	EB	924	0.4	50	327	0.3	50
	WB	1095	0.2	50	377	0.1	50
Clark Road (between High Street and Adderstone Avenue)	NB	717	0.2	50	263	0.1	50
	SB	858	0.2	50	252	0.1	50
Clark Road (between Adderstone Avenue and Kurraba Road)	NB	596	0.2	50	226	0.1	50
	SB	749	0.3	50	209	0.1	50
Kurraba Road (between Clark Road and Holdsworth Street)	EB	678	0.2	50	230	0.1	50
	WB	742	0.3	50	205	0.1	50
Kurraba Road (between Holdsworth and Ben Boyd Road)	EB	490	0.2	50	169	0.1	50
	WB	614	0.3	50	154	0.1	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Bent Street (between Falcon Street and Alfred Street N)	SB	144	0.2	50	24	0.5	50
Alfred Street N (between Bent Street and Kurraba Road)	SB	144	0.2	50	24	0.5	50
Alfred Street N (between Kurraba Road and Mount Street)	SB	54	0.6	60	17	0.7	60
Alfred Street N (between Mount and High Street)	SB	1302	1.4	60	448	1.2	60
Gore Hill Freeway Connection							
Gore Hill Freeway (north of Willoughby Road)	NB/WB	3562	4.8	80	1202	3.3	80
	SB/EB	3914	4.0	80	1245	4.2	80
Gore Hill Freeway (to / from Longueville Road, east of Hampden Road overpass)	WB	2111	4.3	80	785	2.8	80
	EB	3914	4.0	80	1245	4.2	80
Lane Cove Tunnel (west of Hampden Road overpass)	WB	1451	5.5	80	416	4.3	80
Gore Hill Freeway (west of Hampden Road overpass)	EB	3154	3.8	80	1141	3.9	80
Gore Hill Freeway on ramp (east of Reserve Road overpass)	EB	930	6.0	60	140	8.2	60
Beaches Link off ramp (to Lane Cove Tunnel)	WB	363	20.6	80	86	17.8	80
Beaches Link on ramp (from Reserve Road)	EB	170	9.8	60	36	10.2	60
Beaches Link on ramp (from Gore Hill Freeway)	EB	593	13.1	80	173	10.2	80
Lane Cove Tunnel (west of Reserve Road overpass)	WB	1814	8.5	80	502	6.6	80
Gore Hill Freeway (west of Reserve Road overpass)	EB	1771	4.3	80	584	4.4	80
Lane Cove Tunnel on ramp (west of Reserve Road overpass)	WB	221	16.2	80	78	8.4	80
Lane Cove Tunnel (west of Reserve Road ramps)	WB	2035	9.3	80	581	6.9	80
	EB	1771	4.3	80	584	4.4	80
Gore Hill Freeway off ramp (east of Reserve Road)	WB	203	11.5	60	47	11.3	60
Gore Hill Freeway (west of Reserve Road overpass)	WB	1908	3.5	80	739	2.3	80
Gore Hill Freeway on ramp (west of Reserve Road)	WB	336	7.1	80	110	6.1	80

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Gore Hill Freeway off ramp (to Pacific Highway)	WB	962	3.2	60	323	3.3	60
Gore Hill Freeway (west of Pacific Highway overpass)	WB	1282	4.7	60	525	2.4	60
	EB	1178	5.0	60	487	3.4	60
Gore Hill Freeway (east of Pacific Highway overpass, right lane)	EB	327	2.6	60	264	1.8	60
Gore Hill Freeway (east of Pacific Highway overpass, left lane)	EB	851	5.9	60	222	5.3	60
Lane Cove Tunnel off ramp (east of Pacific Highway overpass, to Gore Hill Fwy)	EB	698	13.9	60	178	12.6	60
Gore Hill Freeway off ramp (west of Reserve Road)	EB	956	7.2	80	227	7.4	80
Gore Hill Freeway on ramp (from Pacific Highway)	EB	1056	3.2	60	293	4.7	60
Gore Hill Freeway (after Pacific Highway on ramp)	EB	1383	3.1	80	557	3.3	80
Longueville Road (east of Epping Road)	WB	2134	4.5	60	742	2.9	60
	EB	1653	4.2	60	582	3.1	60
Longueville Road on ramp (from Pacific Highway)	WB	852	4.1	60	217	3.9	60
Longueville Road off ramp (to Pacific Highway)	EB	475	2.2	60	95	1.5	60
Lane Cove Tunnel on ramp, east of Pacific Highway (from Pacific Highway)	EB	328	6.3	60	17	8.6	60
Lane Cove Tunnel off ramp, east of Pacific Highway (to Pacific Highway)	WB	227	5.7	60	38	6.1	60
Pacific Highway (between Campbell Street and Dickson Avenue)	NB	864	2.4	60	98	0.6	60
	SB	659	1.8	60	110	1.0	60
Pacific Highway (between Dickson Avenue and Hotham Parade)	NB	1008	3.6	60	134	3.0	60
	SB	687	1.6	60	118	0.8	60
Pacific Highway (between Hotham Parade and Cobden Avenue)	NB	895	3.9	60	114	3.5	60
	SB	631	1.7	60	102	0.9	60
Pacific Highway (between Cobden Avenue and Gore Hill Freeway overpass)	NB	1031	3.8	60	131	3.3	60
	SB	631	1.7	60	102	0.9	60
Pacific Highway (between Gore Hill Freeway overpass and Gore Hill Freeway ramps)	NB	502	1.3	60	78	1.2	60
	SB	807	2.9	60	188	3.2	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway NB)	NB	298	5.1	60	11	3.4	60
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway SB)	SB	30	17.9	60	6	17.1	60
Pacific Highway (between Gore Hill Freeway ramps to Mowbray Road)	NB	1644	2.9	60	436	3.2	60
	SB	1816	3.0	60	478	4.0	60
Hampden Road (between Palmer and Brand Street)	NB	320	3.1	50	124	2.6	50
	SB	456	3.3	50	165	4.2	50
Hampden Road (between Brand Street and Jersey Road)	NB	451	3.0	50	146	2.6	50
	SB	446	3.6	50	151	4.5	50
Hampden Road (between Jersey Road and Cleg Street)	NB	263	1.8	50	87	1.2	50
	SB	227	1.9	50	77	1.9	50
Herbert Street (between Cleg and Frederick Street)	NB	328	3.8	50	102	3.1	50
	SB	397	3.8	50	122	3.0	50
Herbert Street (between Frederick and Ella Street)	NB	483	5.0	50	156	2.7	50
	SB	495	5.7	50	171	3.9	50
Herbert Street (between Ella and Westbourne Street)	NB	263	3.0	50	99	2.2	50
	SB	265	3.9	50	105	2.9	50
Frederick Street (between Herbert Street and Reserve Road)	EB	248	11.9	50	95	7.4	50
	WB	305	9.1	50	100	4.9	50
Campbell Street (between Reserve Road and Pacific Highway)	EB	236	3.7	50	64	3.0	50
	WB	379	4.4	50	87	2.8	50
Cleg Street (between Herbert and Waltham Street)	EB	370	4.2	50	87	3.6	50
	WB	265	4.9	50	58	5.4	50
Waltham Street (between Cleg Street and Dickson Avenue)	NB	0	0	50	0	0	50
	SB	0	0	50	0	0	50
Beaches Link of ramp (to Dickson Avenue)	WB	222	16.1	60	46	20.5	60
Dickson Avenue (between Reserve Road and Pacific Highway)	EB	41	1.2	50	8	0.0	50
	WB	157	10.7	50	36	9.7	50
Reserve Road (between Frederick and Campbell Street)	NB	305	9.1	50	100	4.9	50
	WB	248	11.9	50	95	7.4	50
Reserve Road (between Campbell Street and Dickson Avenue)	NB	785	12.9	50	234	10.5	50
	SB	713	14.5	50	220	13.9	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Reserve Road (between Dickson Avenue and Gore Hill Freeway)	NB	824	12.4	50	242	10.1	50
	SB	647	13.0	50	210	11.7	50
Reserve Road (between Gore Hill Freeway and Jersey Road)	NB	367	4.4	50	98	4.4	50
	SB	517	4.2	50	119	5.9	50
Jersey Road (between Reserve and Abbott Road)	EB	303	4.3	50	89	4.1	50
	WB	388	4.4	50	103	6.1	50
Jersey Road (between Abbott and Hampden Road)	EB	286	3.3	50	80	3.6	50
	WB	317	3.9	50	94	5.7	50
Connections to and from Burnt Bridge Creek Deviation							
Manly Road (between Avona Crescent and Heaton Avenue)	NB	1134	2.2	60	428	1.0	60
	SB	1360	2.9	60	461	2.9	60
Manly Road (between Heaton Avenue and Sydney Road)	NB	1134	2.2	60	428	1.0	60
	SB	1327	3.0	60	453	2.9	60
Burnt Bridge Creek Deviation (between Sydney Road and Link Road)	NB	759	3.0	60	271	1.5	60
	SB	802	3.4	60	279	4.0	60
Beaches Link off ramp (to Burnt Bridge Creek Deviation)	NB	1039	10.4	80	356	8.5	80
Beaches Link on ramp (from Burnt Bridge Creek Deviation)	SB	818	13.5	80	232	15.6	80
Burnt Bridge Creek Deviation (between Link Road and Condamine Street)	NB	1591	8.1	80	583	5.9	80
	SB	1438	9.4	80	472	9.8	80
Condamine Street (between Burnt Bridge Creek Deviation and Kenneth Road)	NB	1888	6.8	60	618	5.2	60
	SB	1756	7.3	60	538	7.8	60
Frenchs Forest Road (between Montauban Avenue and Baringa Avenue)	EB	215	3.2	60	61	1.6	60
	WB	130	0.3	60	17	0	60
Frenchs Forest Road (between Baringa Avenue and Brook Road)	EB	308	2.2	60	91	1.1	60
	WB	122	0.3	60	17	0	60
Frenchs Forest Road (between Brook and Sydney Road)	NB	228	0.2	60	61	0.1	60
	SB	361	1.9	60	102	1.0	60
Sydney Road (between Frenchs Forest Road and Manly Road)	EB	512	1.5	60	137	0.9	60
	WB	239	0.1	60	70	0.1	60
Sydney Road (between Manly Road and Link Road)	EB	515	0.5	60	177	0.3	60
	WB	392	1.5	60	128	0.8	60
Sydney Road (between Link Road and Wanganella Street)	EB	608	0.5	60	193	0.3	60
	WB	460	1.5	60	138	1.1	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Sydney Road (between Wanganella and Woodland Street)	EB	678	0.4	60	197	0.3	60
	WB	462	1.4	60	140	1.0	60
Sydney Road (Woodland and Condamine Street)	EB	781	0.4	60	199	0.2	60
	WB	542	0.8	60	149	0.8	60
Wanganella Street (Sydney Road and Kitchener Street)	NB	17	0	50	7	0	50
	SB	165	0.1	50	41	0.1	50
Kitchener Street (between Wanganella and Daisy Street)	EB	337	2.7	50	87	2.5	50
	WB	305	4.1	50	87	2.7	50
Daisy Street (between Kitchener and Woodbine Street)	NB	305	4.1	50	87	2.7	50
	SB	337	2.7	50	87	2.5	50
Woodbine Street (between Daisy and Bangaroo Street)	EB	337	2.7	50	87	2.5	50
	WB	305	4.1	50	87	2.7	50
Woodbine Street (between Bangaroo and Hunter Street)	EB	358	2.5	50	94	2.3	50
	WB	313	4.0	50	94	2.5	50
Maretimo Street (between Ethel and Upper Beach Street)	NB	30	0	50	7	0	50
	SB	34	0	50	8	0	50
Upper Beach Street (between Maretimo and Wanganella Street)	EB	30	0	50	7	0	50
	WB	34	0	50	8	0	50
Connections to and from Wakehurst Parkway							
Wakehurst Parkway (between Lister Avenue and Armstrong Street)	NB	425	1.3	60	117	1.1	60
	SB	360	1.9	60	110	0.9	60
Wakehurst Parkway (between Armstrong Street and Judith Street)	NB	481	1.1	60	131	1.0	60
	SB	404	1.7	60	125	0.8	60
Wakehurst Parkway (between Judith Street and Beaches Link ramps)	NB	673	2.7	80	184	2.0	80
	SB	633	2.5	80	186	1.7	80
Beaches Link off ramp (to Wakehurst Parkway)	NB	753	19.6	80	208	14.4	80
Beaches Link on ramp (from Wakehurst Parkway)	SB	735	20.0	80	136	15.0	80
Wakehurst Parkway (between Beaches Link ramps and Aquatic Drive)	NB	1426	11.6	80	392	8.6	80
	SB	1367	11.9	80	322	7.3	80
Wakehurst Parkway (between Aquatic Drive and Warringah Road)	NB	1364	11.5	70	376	8.4	70
	SB	1368	11.5	70	326	7.2	70

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Wakehurst Parkway (between Warringah Road and Frenchs Forest Road)	NB	730	8.6	60	263	4.1	60
	SB	885	7.3	60	242	4.9	60
Wakehurst Parkway (north of Frenchs Forest Road)	NB	778	8.2	60	241	4.9	60
	SB	770	8.6	60	292	4.0	60
Warringah Road (between Forest Way and Hilmer Street)	EB	1299	6.7	70	403	6.3	70
	WB	1043	7.5	70	369	5.5	70
Warringah Road (between Hilmer Street and Wakehurst Parkway)	EB	1048	7.5	70	363	5.6	70
	WB	1295	6.8	70	400	6.4	70
Warringah Road (between Wakehurst Parkway and underpass ramps)	EB	667	9.7	70	192	9.2	70
	WB	570	10.0	70	184	11.7	70
Warringah Road underpass (between Forest Road and underpass ramps)	EB	740	3.9	70	215	3.3	70
	WB	817	5.6	70	268	4.2	70
Judith Street to Manning Street (between Wakehurst Parkway and Mons Road)	EB	229	4.0	50	61	3.5	50
	WB	192	6.5	50	54	4.3	50

Notes: 1. Based on posted speeds

2. The 2027 (opening year) do something scenario includes the project and WestConnex, but without the Western Harbour Tunnel and Warringah Freeway Upgrade, Sydney Gateway and the M6 Motorway.

D.4 Year 2027 (opening year) do something cumulative traffic volumes

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Warringah Freeway and surrounds							
Warringah Freeway (south of Merrenburn Avenue)	NB	3780	6.0	80	1098	4.6	80
	SB	4079	5.4	80	1148	5.0	80
Willoughby Road off ramp	NB	1057	4.7	60	435	5.4	60
Willoughby Road on ramp	SB	922	2.9	60	293	2.5	60
Warringah Freeway (south of Brook Street)	NB	4838	5.7	80	1533	4.8	80
	SB	5001	5.0	80	1442	4.5	80
Brook Street off ramp	NB	704	4.1	60	195	4.9	60
Brook Street on ramp	SB	554	1.7	80	80	3.7	80
Warringah Freeway (east of Miller Street)	WB	5541	5.5	80	1728	4.8	80
	EB	5555	4.6	80	1521	4.4	80
Miller Street off ramp	WB	402	2.2	60	136	4.1	60
Miller Street on ramp	EB	494	0.5	60	132	0.3	60
Warringah Freeway (north of Ernest Street)	NB	4601	3.8	80	1399	3.6	80
Warringah Freeway (north of Ernest St, WHT exit/entry portal)	NB/exit	1343	10.2	80	464	8.1	80
	SB/entry	814	16.3	80	160	15.1	80
Warringah Freeway (north of Ernest St, WHT exit/entry portal)	NB/exit	564	14.8	80	215	9.7	80
	SB/entry	635	9.3	80	141	11.0	80
Warringah Freeway (north of Ernest Street)	SB	4535	2.6	80	1353	3.1	80
Ernest Street off ramp	NB	330	0.9	50	130	0.6	50
Ernest Street on ramp	SB	317	0.3	60	26	0.0	60
Warringah Freeway (south of Falcon Street)	NB	3302	5.8	80	1102	4.7	80
Warringah Freeway (south of Falcon Street)	NB	1718	3.5	80	562	3.3	80
	SB	1665	3.5	80	556	3.7	80
Warringah Freeway (south of Falcon Street)	SB	3822	3.1	80	964	3.8	80
Falcon Street off ramp (WHT exit portal)	NB	797	3.8	60	172	5.3	60
Falcon Street off ramp (bus lane)	NB	32	100	60	4	100	60
Military Road off ramp	NB	849	1.0	70	390	0.6	70
Falcon Street on ramp	SB	1633	0.6	80	483	1.1	80
Falcon Street on ramp (bus lane)	SB	38	100	60	5	100	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Berry Street on ramp	NB	520	2.4	80	162	2.0	80
Berry Street on ramp (WHT entry portal)	NB	862	3.5	60	189	2.5	60
Alfred Street off ramp	SB	1191	2.3	60	320	2.1	60
Warringah Freeway (south of Mount Street)	NB	5349	4.6	80	1892	3.7	80
Warringah Freeway (south of Mount Street)	SB	4960	2.7	70	1540	3.4	70
Cahill Expressway (south of Mount Street)	SB	969	2.8	70	142	2.2	70
Mount Street on ramp	SB	582	0.3	70	98	1.6	70
Mount Street on ramp (Cahill Expressway)	SB	565	0.3	70	281	0.4	70
Sydney Harbour Tunnel portals	NB/exit	1889	3.8	80	656	2.6	80
	SB/entry	2420	2.7	80	768	2.9	80
Warringah Freeway (south of High Street)	NB	2679	6.1	70	1040	4.9	70
Warringah Freeway (south of High Street)	SB	3122	2.2	70	870	3.7	70
Cahill Expressway (south of High Street)	SB	1534	1.9	70	424	1.0	70
Pacific Highway off ramp	NB	1114	1.5	60	373	2.2	60
High Street on ramp	SB	437	0.0	70	249	0.0	70
Lavender Street off ramp	NB	355	2.8	70	139	2.9	70
Bradfield Highway (south of Lavender Street)	NB	4149	4.6	70	1552	4.1	70
	SB	3122	2.2	70	870	3.7	70
Cahill Expressway (south of Lavender Street)	SB	1971	1.5	70	673	0.6	70
Ernest Street (west of Warringah Freeway)	EB	355	0.3	50	63	0.2	50
	WB	383	0.5	50	84	0.4	50
Ernest Street (between Miller and West Street)	EB	314	0.3	50	61	0.2	50
	WB	403	0.5	50	101	0.4	50
Ernest Street (between West and Sophia Street)	EB	138	0.5	50	43	0.3	50
	WB	363	0.8	50	73	0.5	50
Ernest Street (between Sophia and Alexander Street)	EB	138	0.5	50	43	0.3	50
	WB	138	0.5	50	43	0.3	50
Ernest Street (east of Warringah Freeway)	EB	631	0.5	50	174	0.5	50
	WB	646	0.4	50	91	0.3	50
Ernest Street (between Merlin Street and Park Avenue)	EB	823	0.6	50	289	0.5	50
	WB	669	0.3	50	90	0.3	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Falcon Street (west of Warringah Freeway)	EB	1193	0.6	60	275	0.5	60
	WB	1403	2.5	60	352	2.9	60
Falcon Street (between Miller and West Street)	EB	1034	0.4	60	240	0.4	60
	WB	801	2.3	60	214	1.7	60
Falcon Street (between West and Alexander Street)	EB	1065	0.4	60	256	0.5	60
	WB	623	2.1	60	185	1.2	60
Falcon Street (between Alexander Street and Pacific Highway)	EB	1035	0.5	60	254	0.5	60
	WB	740	1.6	60	223	1.0	60
Falcon Street (east of Warringah Freeway)	WB	2070	1.1	60	623	1.1	60
Falcon Street (between Watson Street and Tramway Lane)	WB	2094	1.0	60	638	1.0	60
Military Road (east of Warringah Freeway)	EB	2098	1.0	60	684	0.6	60
Military Road (between Watson Street and Ben Boyd Road)	EB	1835	0.9	60	574	0.6	60
	WB	2094	1.0	60	638	1.0	60
Military Road (between Ben Boyd Road and Young Street)	EB	1833	0.9	60	592	0.6	60
	WB	1856	1.0	60	580	1.1	60
Military Road (between Young Street and Wycombe Road)	EB	1670	0.9	60	574	0.5	60
	WB	1691	1.0	60	541	1.1	60
Willoughby Road (north of Warringah Freeway)	NB	1178	4.0	60	441	4.9	60
	SB	1225	2.4	60	376	2.3	60
Willoughby Road (south of Warringah Freeway)	NB	335	1.4	60	71	1.1	60
	SB	518	1.9	60	147	2.7	60
Willoughby Road (between Merrenburn Avenue and Dalleys Road)	NB	554	2.7	60	141	2.2	60
	SB	577	2.7	60	142	2.2	60
Willoughby Road (between Dalleys Road and Chandos Street)	NB	542	1.8	60	132	1.0	60
	SB	408	1.5	60	106	1.6	60
Willoughby Road (between Chandos and Atchison Street)	NB	363	1.1	60	99	0.9	60
	SB	467	1.0	60	118	1.4	60
Willoughby Road (between Atchison and Albany Street)	NB	219	1.3	60	33	0.9	60
	SB	209	0.8	60	40	0.6	60
Willoughby Road (between Albany and Holtermann Street)	NB	287	0.6	60	58	0.7	60
	SB	132	0.5	60	43	0.6	60
Willoughby Road (between Holtermann and Falcon Street)	SB	34	0.0	60	7	0.0	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Merrenburn Avenue (between Willoughby Road and Brook Street)	EB	281	4.3	50	92	4.0	50
	WB	121	6.0	50	17	3.3	50
Brook Street (between Merrenburn Avenue and Flat Rock Drive)	NB	898	2.4	50	157	2.5	50
	SB	795	5.4	50	241	5.3	50
Brook Street (between Warringah Freeway on ramp and Merrenburn Avenue)	NB	614	5.2	50	174	5.4	50
	SB	876	1.7	50	166	2.2	50
Brook Street (between Warringah Freeway on and off ramps)	NB	892	3.7	50	218	4.5	50
	SB	162	2.0	50	26	1.2	50
Brook Street (between Warringah Freeway on ramp and Chandos Street)	NB	484	1.3	50	85	1.4	50
	SB	458	1.1	50	88	1.3	50
Chandos Street (between Alexander and Brook Street)	EB	484	1.3	50	85	1.4	50
	WB	458	1.1	50	88	1.3	50
Chandos Street (between Brook Street and Willoughby Road)	EB	368	1.6	50	52	2.2	50
	WB	336	1.0	50	73	1.6	50
Chandos Street (between Willoughby Road and Oxley Street)	EB	416	2.1	50	52	2.1	50
	WB	147	1.5	50	28	2.2	50
Chandos Street (between Oxley and Christie Street)	EB	223	2.7	50	37	2.4	50
	WB	85	0.9	50	14	2.2	50
Alexander Street (between Brook and Albany Street)	NB	207	1.2	50	55	1.0	50
	SB	212	1.9	50	37	1.2	50
Alexander Street (between Albany and Holtermann Street)	NB	223	1.1	50	52	0.7	50
	SB	212	1.1	50	47	0.6	50
Alexander Street (between Holtermann and Ernest Street)	NB	242	1.0	50	57	0.8	50
	SB	310	1.0	50	83	0.7	50
Alexander Street (between Ernest and Burlington Street)	NB	287	0.8	50	66	0.7	50
	SB	312	1.0	50	70	0.7	50
Alexander Street (between Burlington and Falcon Street)	NB	304	1.1	50	71	0.8	50
	SB	329	0.9	50	78	0.7	50
Alexander Street (between Falcon Street and Pacific Highway)	NB	315	0.6	50	69	0.4	50
	SB	194	1.9	50	37	1.7	50
Albany Street (between Alexander Street and Willoughby Road)	EB	69	0.2	50	23	0.3	50
	WB	74	2.0	50	6	0.0	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Albany Street (between Willoughby Road and Oxley Street)	EB	114	0.4	50	23	0.3	50
	WB	264	0.7	50	28	0.4	50
Albany Street (between Oxley Street and Pacific Highway)	EB	358	2.6	50	101	2.3	50
	WB	406	2.1	50	78	2.3	50
Amherst Street (west of West Street)	EB	438	0.8	60	104	0.8	60
Amherst Street (between West and Miller Street)	EB	307	0.8	50	98	1.2	50
	WB	78	0.0	50	20	0.0	50
West Street (between Amherst and Ernest Street)	NB	113	1.6	50	35	3.0	50
	SB	320	0.9	50	60	1.2	50
West Street (between Ernest and Falcon Street)	NB	265	1.2	50	52	2.1	50
	SB	311	1.1	50	65	1.3	50
West Street (between Falcon and Ridge Street)	NB	69	3.6	50	17	5.7	50
	SB	324	2.4	50	76	2.9	50
West Street (between Ridge and Church Street)	NB	103	2.0	50	14	3.0	50
	SB	227	1.0	50	46	1.1	50
West Street (between Church Street and Pacific Highway)	NB	103	2.0	50	14	3.0	50
	SB	227	1.0	50	46	1.1	50
Miller Street (between Pine and Amherst Street)	NB	712	2.8	50	189	6.0	50
	SB	712	0.7	50	174	0.5	50
Miller Street (between Amherst Street and Warringah Freeway on ramp)	NB	599	2.4	50	151	5.8	50
	SB	753	0.7	50	168	0.5	50
Miller Street (between Warringah Freeway on and off ramps)	NB	603	2.4	50	152	5.8	50
	SB	263	1.0	50	37	1.2	50
Miller Street (between Warringah Freeway off ramp and Ernest Street)	NB	245	2.3	50	28	11.2	50
	SB	307	0.9	50	50	0.9	50
Miller Street (between Ernest and Falcon Street)	NB	308	2.0	50	43	7.5	50
	SB	310	1.0	50	46	0.9	50
Miller Street (between Falcon and Ridge Street)	NB	229	1.6	50	38	0.8	50
	SB	673	2.1	50	143	2.7	50
Miller Street (between Ridge and McLaren Street)	NB	120	2.9	50	19	3.9	50
	SB	378	2.1	50	67	3.0	50
Miller Street (between McLaren and Berry Street)	NB	359	1.5	50	76	2.3	50
	SB	570	1.6	50	90	2.4	50
Miller Street (between Berry Street and Pacific Highway)	NB	299	1.7	40	63	2.6	40
	SB	191	1.7	40	38	1.0	40

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Walker Street (between Ridge and McLaren Street)	NB	126	1.0	50	25	0.7	50
	SB	440	2.6	50	108	3.3	50
Walker Street (between McLaren and Berry Street)	NB	175	0.9	50	61	1.5	50
	SB	602	1.8	50	180	1.7	50
Walker Street (between Berry and Spring Street)	NB	367	2.8	50	95	2.6	50
	SB	10	1.4	50	1	0.0	50
Ridge Street (between Walker and Miller Street)	EB	440	2.6	50	108	3.3	50
	WB	126	1.0	50	25	0.7	50
Ridge Street (between Miller and West Street)	EB	89	3.4	50	17	4.7	50
	WB	216	3.2	50	43	4.6	50
McLaren Street (between Walker and Miller Street)	EB	355	1.0	50	76	1.5	50
	WB	260	0.4	50	59	0.4	50
McLaren Street (between Miller and Angelo Street)	EB	200	1.2	50	19	1.0	50
	WB	152	0.2	50	36	0.2	50
McLaren Street (between Angelo Street and Pacific Highway)	EB	200	1.2	50	19	1.0	50
	WB	152	0.2	50	36	0.2	50
Berry Street (between Walker and Arthur Street)	EB	1933	2.3	60	586	1.5	60
Berry Street (between Little Spring and Walker Street)	EB	1148	2.1	40	373	1.2	40
Berry Street (between Denison and Little Spring Street)	EB	1270	2.0	40	399	1.2	40
Berry Street (between Miller and Denison Street)	EB	924	2.8	40	229	2.1	40
Berry Street (between Pacific Highway and Miller Street)	EB	605	3.3	40	190	1.6	40
Spring Street (between Walker and Little Spring Street)	WB	294	1.8	50	92	2.3	50
Spring Street (between Little Spring and Denison Street)	WB	416	1.6	50	118	2.0	50
Denison Street (between Spring and Berry Street)	NB	294	1.8	50	92	2.3	50
Pacific Highway (between Arthur and Walker Street)	NB	1908	1.8	60	477	2.3	60
	SB	1316	0.9	60	368	0.7	60
Pacific Highway (between Walker and Miller Street)	NB	1250	1.6	60	331	1.5	60
	SB	595	0.9	60	92	0.7	60
Pacific Highway (between Miller and William Street)	NB	498	0.6	60	127	0.4	60
	SB	436	0.7	60	78	0.7	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Pacific Highway (between William and Berry Street)	NB	662	1.1	60	169	1.0	60
	SB	436	0.7	60	78	0.7	60
Pacific Highway (between Berry Street and Bay Road)	NB	390	0.5	60	107	0.4	60
	SB	768	2.3	60	207	1.2	60
Pacific Highway (between Bay Road and McLaren Street)	NB	482	0.5	60	126	0.3	60
	SB	715	2.5	60	155	1.6	60
Pacific Highway (between McLaren and West Street)	NB	591	0.4	60	151	0.3	60
	SB	872	2.3	60	163	1.6	60
Pacific Highway (between West Street and Crows Nest Road)	NB	591	0.4	60	151	0.3	60
	SB	749	2.7	60	131	2.0	60
Pacific Highway (between Crows Nest and Rocklands Road)	NB	515	0.5	60	122	0.4	60
	SB	749	2.7	60	131	2.0	60
Pacific Highway (between Rocklands Road and Bruce Street)	NB	597	0.4	60	123	0.4	60
	SB	780	2.5	60	134	2.0	60
Pacific Highway (between Bruce and Alexander Street)	NB	633	0.6	60	129	0.5	60
	SB	823	2.8	60	143	2.1	60
Pacific Highway (between Alexander and Falcon Street)	NB	385	0.5	60	72	0.5	60
	SB	696	2.8	60	118	2.1	60
Pacific Highway (between Falcon and Hume Street)	NB	469	1.4	60	86	1.1	60
	SB	977	1.5	60	160	1.4	60
Arthur Street (between Pacific Highway and Mount Street)	NB	1137	1.0	60	354	1.5	60
High Street (west of Warringah Freeway)	EB	668	1.4	70	184	0.7	70
	WB	999	2.4	70	224	2.7	70
High Street (east of Warringah Freeway)	EB	889	0.5	50	312	0.3	50
	WB	955	0.2	50	343	0.1	50
Clark Road (between High Street and Adderstone Avenue)	NB	646	0.2	50	243	0.2	50
	SB	706	0.1	50	215	0.1	50
Clark Road (between Adderstone Avenue and Kurraba Road)	NB	519	0.2	50	204	0.1	50
	SB	594	0.1	50	171	0.1	50
Kurraba Road (between Clark Road and Holdsworth Street)	EB	601	0.2	50	208	0.1	50
	WB	584	0.1	50	168	0.1	50
Kurraba Road (between Holdsworth and Ben Boyd Road)	EB	418	0.2	50	154	0.2	50
	WB	448	0.1	50	116	0.1	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Bent Street (between Falcon Street and Alfred Street N)	SB	167	0.1	50	23	0.3	50
Alfred Street N (between Bent Street and Kurraba Road)	SB	167	0.1	50	23	0.3	50
Alfred Street N (between Kurraba Road and Mount Street)	SB	76	0.2	60	16	0.4	60
Alfred Street N (between Mount and High Street)	SB	1484	1.9	60	454	1.6	60
Gore Hill Freeway Connection							
Gore Hill Freeway (north of Willoughby Road)	NB/WB	3780	6.0	80	1098	4.6	80
	SB/EB	4079	5.4	80	1148	5.0	80
Gore Hill Freeway (to / from Longueville Road, east of Hampden Road overpass)	WB	2259	5.3	80	682	4.0	80
	EB	4079	5.4	80	1148	5.0	80
Lane Cove Tunnel (west of Hampden Road overpass)	WB	1521	7.0	80	416	5.4	80
Gore Hill Freeway (west of Hampden Road overpass)	EB	3251	5.1	80	1085	4.5	80
Gore Hill Freeway on ramp (east of Reserve Road overpass)	EB	999	7.2	60	99	12.1	60
Beaches Link off ramp (to Lane Cove Tunnel)	WB	313	21.7	80	80	18.6	80
Beaches Link on ramp (from Reserve Road)	EB	171	9.8	60	35	10.0	60
Beaches Link on ramp (from Gore Hill Freeway)	EB	563	13.1	80	175	9.8	80
Lane Cove Tunnel (west of Reserve Road overpass)	WB	1834	9.6	80	496	7.5	80
Gore Hill Freeway (west of Reserve Road overpass)	EB	1846	6.4	80	543	5.7	80
Lane Cove Tunnel on ramp (west of Reserve Road overpass)	WB	209	15.2	80	69	8.6	80
Lane Cove Tunnel (west of Reserve Road ramps)	WB	2043	10.1	80	565	7.7	80
	EB	1846	6.4	80	543	5.7	80
Gore Hill Freeway off ramp (east of Reserve Road)	WB	274	9.8	60	51	11.7	60
Gore Hill Freeway (west of Reserve Road overpass)	WB	1984	4.6	80	631	3.4	80
Gore Hill Freeway on ramp (west of Reserve Road)	WB	316	7.0	80	113	6.1	80

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Gore Hill Freeway off ramp (to Pacific Highway)	WB	1032	3.6	60	334	3.6	60
Gore Hill Freeway (west of Pacific Highway overpass)	WB	1268	6.1	60	410	4.0	60
	EB	1186	5.8	60	434	4.2	60
Gore Hill Freeway (east of Pacific Highway overpass, right lane)	EB	327	4.0	60	242	2.7	60
Gore Hill Freeway (east of Pacific Highway overpass, left lane)	EB	859	6.5	60	192	6.0	60
Lane Cove Tunnel off ramp (east of Pacific Highway overpass, to Gore Hill Fwy)	EB	648	13.9	60	169	12.5	60
Gore Hill Freeway off ramp (west of Reserve Road)	EB	944	7.7	80	185	8.4	80
Gore Hill Freeway on ramp (from Pacific Highway)	EB	1078	3.1	60	300	3.7	60
Gore Hill Freeway (after Pacific Highway on ramp)	EB	1405	3.3	80	542	3.3	80
Longueville Road (east of Epping Road)	WB	2087	5.2	60	629	4.0	60
	EB	1668	4.7	60	521	3.8	60
Longueville Road on ramp (from Pacific Highway)	WB	818	4.0	60	219	3.9	60
Longueville Road off ramp (to Pacific Highway)	EB	483	2.1	60	87	1.7	60
Lane Cove Tunnel on ramp, east of Pacific Highway (from Pacific Highway)	EB	244	7.0	60	15	8.9	60
Lane Cove Tunnel off ramp, east of Pacific Highway (to Pacific Highway)	WB	199	5.7	60	37	5.9	60
Pacific Highway (between Campbell Street and Dickson Avenue)	NB	776	2.4	60	99	0.7	60
	SB	692	1.7	60	113	1.0	60
Pacific Highway (between Dickson Avenue and Hotham Parade)	NB	919	3.6	60	133	3.1	60
	SB	736	1.5	60	122	0.9	60
Pacific Highway (between Hotham Parade and Cobden Avenue)	NB	797	4.0	60	114	3.5	60
	SB	666	1.6	60	106	0.9	60
Pacific Highway (between Cobden Avenue and Gore Hill Freeway overpass)	NB	929	3.8	60	131	3.3	60
	SB	666	1.6	60	106	0.9	60
Pacific Highway (between Gore Hill Freeway overpass and Gore Hill Freeway ramps)	NB	468	1.4	60	70	1.4	60
	SB	785	2.8	60	192	3.1	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway NB)	NB	223	5.6	60	9	3.3	60
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway SB)	SB	21	21.5	60	6	17.5	60
Pacific Highway (between Gore Hill Freeway ramps to Mowbray Road)	NB	1662	3.2	60	437	3.4	60
	SB	1826	2.9	60	489	3.4	60
Hampden Road (between Palmer and Brand Street)	NB	299	3.2	50	100	3.0	50
	SB	453	3.4	50	162	4.4	50
Hampden Road (between Brand Street and Jersey Road)	NB	437	3.1	50	128	3.0	50
	SB	446	3.8	50	148	4.7	50
Hampden Road (between Jersey Road and Cleg Street)	NB	250	1.7	50	74	1.4	50
	SB	232	1.8	50	77	1.8	50
Herbert Street (between Cleg and Frederick Street)	NB	315	4.1	50	86	3.7	50
	SB	403	3.8	50	119	3.0	50
Herbert Street (between Frederick and Ella Street)	NB	452	5.1	50	132	3.1	50
	SB	499	5.2	50	168	3.8	50
Herbert Street (between Ella and Westbourne Street)	NB	248	2.9	50	88	2.5	50
	SB	266	3.7	50	102	3.0	50
Frederick Street (between Herbert Street and Reserve Road)	EB	246	11.7	50	96	7.3	50
	WB	287	10.0	50	92	5.6	50
Campbell Street (between Reserve Road and Pacific Highway)	EB	220	3.8	50	61	3.1	50
	WB	372	4.1	50	87	2.7	50
Cleg Street (between Herbert and Waltham Street)	EB	372	4.2	50	88	3.6	50
	WB	266	4.8	50	58	5.4	50
Waltham Street (between Cleg Street and Dickson Avenue)	NB	0	#DIV/0!	50	0	#DIV/0!	50
	SB	0	#DIV/0!	50	0	#DIV/0!	50
Beaches Link of ramp (to Dickson Avenue)	WB	209	16.5	60	44	21.6	60
Dickson Avenue (between Reserve Road and Pacific Highway)	EB	55	1.6	50	10	0.6	50
	WB	154	10.1	50	35	10.3	50
Reserve Road (between Frederick and Campbell Street)	NB	287	10.0	50	92	5.6	50
	WB	246	11.7	50	96	7.3	50
Reserve Road (between Campbell Street and Dickson Avenue)	NB	769	13.4	50	225	11.1	50
	SB	720	14.2	50	223	13.7	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Reserve Road (between Dickson Avenue and Gore Hill Freeway)	NB	824	12.7	50	234	10.7	50
	SB	665	12.5	50	214	11.5	50
Reserve Road (between Gore Hill Freeway and Jersey Road)	NB	376	4.5	50	96	4.5	50
	SB	523	4.4	50	120	6.1	50
Jersey Road (between Reserve and Abbott Road)	EB	310	4.4	50	87	4.2	50
	WB	391	4.7	50	104	6.3	50
Jersey Road (between Abbott and Hampden Road)	EB	284	3.6	50	76	3.9	50
	WB	310	4.4	50	93	6.1	50
Connections to and from Burnt Bridge Creek Deviation							
Manly Road (between Avona Crescent and Heaton Avenue)	NB	1063	1.9	60	406	0.8	60
	SB	1323	2.6	60	440	2.7	60
Manly Road (between Heaton Avenue and Sydney Road)	NB	1063	1.9	60	406	0.8	60
	SB	1292	2.6	60	433	2.7	60
Burnt Bridge Creek Deviation (between Sydney Road and Link Road)	NB	714	2.6	60	259	1.1	60
	SB	781	2.9	60	266	3.7	60
Beaches Link off ramp (to Burnt Bridge Creek Deviation)	NB	1124	10.0	80	375	8.3	80
Beaches Link on ramp (from Burnt Bridge Creek Deviation)	SB	906	13.0	80	253	14.5	80
Burnt Bridge Creek Deviation (between Link Road and Condamine Street)	NB	1611	8.0	80	585	5.8	80
	SB	1476	9.3	80	474	9.7	80
Condamine Street (between Burnt Bridge Creek Deviation and Kenneth Road)	NB	1900	6.7	60	619	5.2	60
	SB	1793	7.3	60	540	7.7	60
Frenchs Forest Road (between Montauban Avenue and Baringa Avenue)	EB	211	3.2	60	61	1.6	60
	WB	118	0.3	60	17	0.0	60
Frenchs Forest Road (between Baringa Avenue and Brook Road)	EB	305	2.2	60	91	1.1	60
	WB	110	0.3	60	17	0.0	60
Frenchs Forest Road (between Brook and Sydney Road)	NB	216	0.2	60	60	0.1	60
	SB	358	1.9	60	101	1.0	60
Sydney Road (between Frenchs Forest Road and Manly Road)	EB	510	1.5	60	136	0.9	60
	WB	230	0.1	60	70	0.1	60
Sydney Road (between Manly Road and Link Road)	EB	508	0.5	60	170	0.3	60
	WB	391	1.3	60	125	0.7	60
Sydney Road (between Link Road and Wanganella Street)	EB	603	0.5	60	186	0.3	60
	WB	470	1.4	60	138	1.0	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Sydney Road (between Wanganella and Woodland Street)	EB	672	0.4	60	191	0.3	60
	WB	465	1.2	60	138	0.9	60
Sydney Road (Woodland and Condamine Street)	EB	773	0.4	60	192	0.3	60
	WB	538	0.7	60	146	0.8	60
Wanganella Street (Sydney Road and Kitchener Street)	NB	18	0.0	50	7	0.0	50
	SB	167	0.0	50	41	0.1	50
Kitchener Street (between Wanganella and Daisy Street)	EB	337	2.7	50	86	2.5	50
	WB	302	4.2	50	85	2.7	50
Daisy Street (between Kitchener and Woodbine Street)	NB	302	4.2	50	85	2.7	50
	SB	337	2.7	50	86	2.5	50
Woodbine Street (between Daisy and Bangaroo Street)	EB	337	2.7	50	86	2.5	50
	WB	302	4.2	50	85	2.7	50
Woodbine Street (between Bangaroo and Hunter Street)	EB	357	2.5	50	93	2.4	50
	WB	308	4.1	50	92	2.5	50
Maretimo Street (between Ethel and Upper Beach Street)	NB	29	0.0	50	7	0.0	50
	SB	33	0.0	50	8	0.0	50
Upper Beach Street (between Maretimo and Wanganella Street)	EB	29	0.0	50	7	0.0	50
	WB	33	0.0	50	8	0.0	50
Connections to and from Wakehurst Parkway							
Wakehurst Parkway (between Lister Avenue and Armstrong Street)	NB	410	1.2	60	116	1.2	60
	SB	356	1.9	60	110	0.9	60
Wakehurst Parkway (between Armstrong Street and Judith Street)	NB	465	1.1	60	129	1.0	60
	SB	400	1.7	60	126	0.8	60
Wakehurst Parkway (between Judith Street and Beaches Link ramps)	NB	652	2.7	80	181	2.0	80
	SB	627	2.5	80	186	1.7	80
Beaches Link off ramp (to Wakehurst Parkway)	NB	831	18.4	80	219	14.3	80
Beaches Link on ramp (from Wakehurst Parkway)	SB	823	18.3	80	145	14.5	80
Wakehurst Parkway (between Beaches Link ramps and Aquatic Drive)	NB	1483	11.5	80	400	8.7	80
	SB	1450	11.5	80	331	7.3	80
Wakehurst Parkway (between Aquatic Drive and Warringah Road)	NB	1421	11.4	70	384	8.6	70
	SB	1450	11.1	70	335	7.2	70

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Wakehurst Parkway (between Warringah Road and Frenchs Forest Road)	NB	741	8.9	60	266	4.3	60
	SB	910	7.2	60	247	5.0	60
Wakehurst Parkway (north of Frenchs Forest Road)	NB	792	8.2	60	246	5.0	60
	SB	778	8.8	60	294	4.2	60
Warringah Road (between Forest Way and Hilmer Street)	EB	1294	7.0	70	402	6.6	70
	WB	1038	7.9	70	361	5.6	70
Warringah Road (between Hilmer Street and Wakehurst Parkway)	EB	1044	8.0	70	355	5.7	70
	WB	1292	7.1	70	400	6.6	70
Warringah Road (between Wakehurst Parkway and underpass ramps)	EB	667	9.7	70	193	9.2	70
	WB	560	10.2	70	178	12.0	70
Warringah Road underpass (between Forest Road and underpass ramps)	EB	761	3.8	70	229	3.3	70
	WB	810	5.6	70	271	4.4	70
Judith Street to Manning Street (between Wakehurst Parkway and Mons Road)	EB	227	4.0	50	60	3.6	50
	WB	187	6.8	50	52	4.5	50

Notes: 1. Based on posted speeds

2. The 2027 (opening year) do something cumulative scenario includes the project, WestConnex, Western Harbour Tunnel and Warringah Freeway Upgrade, Sydney Gateway and the M6 Motorway.

D.5 Year 2037 (design year) do minimum traffic volumes

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Warringah Freeway and surrounds							
Warringah Freeway (south of Merrenburn Avenue)	NB	4143	5.2	80	1449	3.6	80
	SB	4016	4.6	80	1493	4.4	80
Willoughby Road off ramp	NB	825	11.1	60	370	11.0	60
Willoughby Road on ramp	SB	850	4.9	60	328	4.6	60
Warringah Freeway (south of Brook Street)	NB	4968	6.2	80	1819	5.1	80
	SB	4867	4.6	80	1821	4.5	80
Brook Street off ramp	NB	1099	7.4	60	387	5.3	60
Brook Street on ramp	SB	771	4.1	80	154	3.8	80
Warringah Freeway (east of Miller Street)	WB	6066	6.4	80	2206	5.2	80
	EB	5637	4.6	80	1975	4.4	80
Miller Street off ramp	WB	781	2.4	60	241	4.4	60
Miller Street on ramp	EB	586	3.5	60	117	0.7	60
Warringah Freeway (north of Ernest Street)	NB	4295	5.2	80	1587	4.7	80
Warringah Freeway (north of Ernest Street)	NB	2553	7.3	80	861	5.8	80
	SB	3046	5.6	80	1163	5.4	80
Warringah Freeway (north of Ernest Street)	SB	3178	3.4	80	929	2.8	80
Ernest Street on/off ramp	NB	603	6.8	60	260	1.8	60
	SB	117	3.1	80	0	0	80
Ernest Street on ramp	SB	695	1.6	80	94	0.1	80
Warringah Freeway (south of Falcon Street)	NB	4295	5.2	80	1587	4.7	80
Warringah Freeway (south of Falcon Street)	NB	1872	7.9	80	720	5.8	80
	SB	223	4.1	80	0	0	80
Warringah Freeway (south of Falcon Street)	SB	2176	3.3	80	685	2.5	80
Falcon Street off ramp	NB	420	1.1	60	190	0.5	60
Falcon Street off ramp (bus lane)	NB	36	100	60	5	100	60
Military Road off ramp	NB	1096	4.5	60	500	3.1	60
Falcon Street on ramp	SB	1773	5.3	60	667	4.2	60
Falcon Street on ramp (bus lane)	SB	43	100	60	6	100	60
Berry Street on ramp	NB	1085	1.8	80	399	1.0	80
Alfred Street off ramp	SB	629	2.0	60	251	1.7	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Warringah Freeway (south of Mount Street)	NB	4725	5.4	80	1878	4.6	80
Warringah Freeway (south of Mount Street)	NB	2475	7.7	80	979	4.7	80
	SB	341	3.7	70	0	0	70
Warringah Freeway (south of Mount Street)	SB	5665	4.9	80	1996	4.5	80
Cahill Expressway (south of Mount Street)	SB	1172	4.2	70	361	3.8	70
Mount Street on ramp	SB	856	1.7	70	175	2.9	70
Mount Street on ramp (Cahill Expressway)	SB	608	0.6	70	318	0.4	70
Sydney Harbour Tunnel portals	NB/exit	3336	5.1	80	1176	4.0	80
	SB/entry	3337	4.7	80	1094	4.1	80
Warringah Freeway (south of High Street)	NB	1389	6.3	80	702	5.7	80
Warringah Freeway (south of High Street)	NB	2475	7.7	80	979	4.7	80
	SB	390	3.4	70	0	0	70
Warringah Freeway (south of High Street)	SB	3134	4.3	70	1077	4.7	70
Cahill Expressway (south of High Street)	SB	1780	3.0	70	678	2.2	70
Pacific Highway off ramp	NB	1645	2.3	60	564	2.8	60
High Street on ramp	SB	800	0.1	70	353	0.1	70
Lavender Street off ramp	NB	390	3.3	70	141	3.6	70
Bradfield Highway (south of Lavender Street)	NB	5900	5.6	70	2386	4.5	70
	SB	3524	4.2	70	1077	4.7	70
Cahill Expressway (south of Lavender Street)	SB	2580	2.1	70	1031	1.5	70
Ernest Street (west of Warringah Freeway)	EB	418	0.4	50	56	0.2	50
	WB	357	0.5	50	69	0.6	50
Ernest Street (between Miller and West Street)	EB	326	0.4	50	56	0.2	50
	WB	374	0.4	50	96	0.4	50
Ernest Street (between West and Sophia Street)	EB	200	0.4	50	43	0.3	50
	WB	372	0.6	50	74	0.7	50
Ernest Street (between Sophia and Alexander Street)	EB	200	0.4	50	43	0.3	50
	WB	85	0.3	50	19	0.3	50
Ernest Street (east of Warringah Freeway)	EB	970	4.4	50	294	1.6	50
	WB	1118	1.5	50	142	0.3	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Ernest Street (between Merlin Street and Park Avenue)	EB	1167	3.8	50	410	1.3	50
	WB	1124	1.5	50	141	0.3	50
Falcon Street (west of Warringah Freeway)	EB	1159	1.2	60	254	1.0	60
	WB	1050	1.0	60	335	0.8	60
Falcon Street (between Miller and West Street)	EB	986	1.2	60	240	0.9	60
	WB	713	1.0	60	246	0.7	60
Falcon Street (between West and Alexander Street)	EB	1128	1.1	60	261	0.9	60
	WB	700	1.0	60	240	0.6	60
Falcon Street (between Alexander Street and Pacific Highway)	EB	1122	1.2	60	256	0.9	60
	WB	829	1.0	60	279	0.5	60
Falcon Street (east of Warringah Freeway)	WB	2372	5.4	60	821	4.5	60
Falcon Street (between Watson Street and Tramway Lane)	WB	2349	5.3	60	822	4.5	60
Military Road (east of Warringah Freeway)	EB	2545	3.5	60	866	2.9	60
Military Road (between Watson Street and Ben Boyd Road)	EB	2352	3.6	60	778	3.1	60
	WB	2349	5.3	60	822	4.5	60
Military Road (between Ben Boyd Road and Young Street)	EB	2358	3.6	60	799	3.0	60
	WB	2132	5.8	60	779	4.7	60
Military Road (between Young Street and Wycombe Road)	EB	2169	3.8	60	780	3.0	60
	WB	1948	6.2	60	737	4.9	60
Willoughby Road (north of Warringah Freeway)	NB	1155	8.6	60	418	9.9	60
	SB	1270	4.0	60	401	4.4	60
Willoughby Road (south of Warringah Freeway)	NB	338	2.4	60	63	1.5	60
	SB	428	2.1	60	88	2.6	60
Willoughby Road (between Merrenburn Avenue and Dalleys Road)	NB	574	3.3	60	136	2.4	60
	SB	536	3.4	60	100	3.1	60
Willoughby Road (between Dalleys Road and Chandos Street)	NB	622	2.3	60	124	1.5	60
	SB	457	1.5	60	72	1.7	60
Willoughby Road (between Chandos and Atchison Street)	NB	427	1.6	60	108	1.2	60
	SB	546	1.3	60	126	1.7	60
Willoughby Road (between Atchison and Albany Street)	NB	297	1.6	60	38	0.8	60
	SB	275	1.0	60	37	0.3	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Willoughby Road (between Albany and Holtermann Street)	NB	316	0.9	60	67	0.6	60
	SB	167	0.8	60	34	0.4	60
Willoughby Road (between Holtermann and Falcon Street)	SB	29	0	60	3	0	60
Merrenburn Avenue (between Willoughby Road and Brook Street)	EB	268	4.1	50	78	3.1	50
	WB	141	6.6	50	17	4.4	50
Brook Street (between Merrenburn Avenue and Flat Rock Drive)	NB	1054	4.4	50	227	3.2	50
	SB	1071	8.1	50	395	5.3	50
Brook Street (between Warringah Freeway on ramp and Merrenburn Avenue)	NB	894	8.6	50	344	5.4	50
	SB	1004	3.7	50	237	2.8	50
Brook Street (between Warringah Freeway on and off ramps)	NB	1263	6.5	50	414	4.8	50
	SB	104	4.0	50	37	2.0	50
Brook Street (between Warringah Freeway on ramp and Chandos Street)	NB	543	1.8	50	117	1.8	50
	SB	482	2.8	50	127	2.7	50
Chandos Street (between Alexander and Brook Street)	EB	543	1.8	50	117	1.8	50
	WB	482	2.8	50	127	2.7	50
Chandos Street (between Brook Street and Willoughby Road)	EB	401	1.7	50	71	1.9	50
	WB	333	2.5	50	94	3.0	50
Chandos Street (between Willoughby Road and Oxley Street)	EB	475	2.7	50	67	2.4	50
	WB	124	5.1	50	20	8.1	50
Chandos Street (between Oxley and Christie Street)	EB	223	3.3	50	38	2.6	50
	WB	51	8.0	50	3	32.1	50
Alexander Street (between Brook and Albany Street)	NB	221	2.1	50	67	1.6	50
	SB	228	3.1	50	54	1.8	50
Alexander Street (between Albany and Holtermann Street)	NB	248	1.4	50	55	1.3	50
	SB	228	1.7	50	57	1.1	50
Alexander Street (between Holtermann and Ernest Street)	NB	277	1.6	50	68	1.1	50
	SB	367	1.4	50	88	0.8	50
Alexander Street (between Ernest and Burlington Street)	NB	334	1.3	50	77	0.9	50
	SB	309	1.5	50	74	0.9	50
Alexander Street (between Burlington and Falcon Street)	NB	375	1.6	50	83	1.0	50
	SB	345	1.4	50	83	0.8	50
Alexander Street (between Falcon Street and Pacific Highway)	NB	382	1.2	50	87	0.8	50
	SB	216	1.3	50	42	1.0	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Albany Street (between Alexander Street and Willoughby Road)	EB	94	0.4	50	24	0.3	50
	WB	106	2.0	50	4	0	50
Albany Street (between Willoughby Road and Oxley Street)	EB	145	0.8	50	24	0.3	50
	WB	284	0.8	50	37	0.5	50
Albany Street (between Oxley Street and Pacific Highway)	EB	372	2.4	50	106	2.1	50
	WB	444	2.1	50	90	2.0	50
Amherst Street (west of West Street)	EB	498	1.5	60	116	1.3	60
Amherst Street (between West and Miller Street)	EB	359	1.1	50	100	2.3	50
	WB	105	0.1	50	29	0	50
West Street (between Amherst and Ernest Street)	NB	99	2.5	50	32	6.4	50
	SB	337	1.8	50	75	1.8	50
West Street (between Ernest and Falcon Street)	NB	233	1.5	50	35	5.7	50
	SB	319	1.8	50	65	2.1	50
West Street (between Falcon and Ridge Street)	NB	79	4.6	50	19	10.6	50
	SB	320	2.2	50	76	2.4	50
West Street (between Ridge and Church Street)	NB	127	2.8	50	18	3.1	50
	SB	225	1.4	50	46	1.3	50
West Street (between Church Street and Pacific Highway)	NB	127	2.8	50	18	3.1	50
	SB	225	1.4	50	46	1.3	50
Miller Street (between Pine and Amherst Street)	NB	994	3.1	50	284	5.2	50
	SB	964	3.0	50	199	1.0	50
Miller Street (between Amherst Street and Warringah Freeway on ramp)	NB	904	2.6	50	252	4.2	50
	SB	955	3.0	50	162	1.1	50
Miller Street (between Warringah Freeway on and off ramps)	NB	904	2.6	50	252	4.2	50
	SB	369	2.1	50	45	1.9	50
Miller Street (between Warringah Freeway off ramp and Ernest Street)	NB	156	3.0	50	10	0.6	50
	SB	403	1.9	50	45	1.9	50
Miller Street (between Ernest and Falcon Street)	NB	229	2.0	50	41	0.1	50
	SB	367	2.2	50	49	1.6	50
Miller Street (between Falcon and Ridge Street)	NB	282	2.3	50	17	1.8	50
	SB	583	1.8	50	99	1.7	50
Miller Street (between Ridge and McLaren Street)	NB	190	3.4	50	16	10.9	50
	SB	373	1.8	50	65	1.8	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Miller Street (between McLaren and Berry Street)	NB	422	1.9	50	75	2.4	50
	SB	522	1.4	50	90	1.4	50
Miller Street (between Berry Street and Pacific Highway)	NB	636	1.5	40	167	1.2	40
	SB	230	2.1	40	43	1.7	40
Walker Street (between Ridge and McLaren Street)	NB	103	0.9	50	6	1.1	50
	SB	358	1.7	50	66	2.3	50
Walker Street (between McLaren and Berry Street)	NB	159	3.2	50	66	5.2	50
	SB	541	1.5	50	177	1.3	50
Walker Street (between Berry and Spring Street)	NB	505	3.1	50	188	2.9	50
	SB	38	0.4	50	7	0.8	50
Ridge Street (between Walker and Miller Street)	EB	358	1.7	50	66	2.3	50
	WB	103	0.9	50	6	1.1	50
Ridge Street (between Miller and West Street)	EB	109	5.2	50	16	11.2	50
	WB	245	2.9	50	44	2.9	50
McLaren Street (between Walker and Miller Street)	EB	384	0.8	50	85	0.3	50
	WB	273	0.2	50	58	0.3	50
McLaren Street (between Miller and Angelo Street)	EB	198	0.8	50	26	0.7	50
	WB	170	0.2	50	33	0.2	50
McLaren Street (between Angelo Street and Pacific Highway)	EB	198	0.8	50	26	0.7	50
	WB	170	0.2	50	33	0.2	50
Berry Street (between Walker and Arthur Street)	EB	1972	1.4	60	685	1.0	60
Berry Street (between Little Spring and Walker Street)	EB	1123	0.9	40	392	0.7	40
Berry Street (between Denison and Little Spring Street)	EB	1235	0.9	40	422	0.6	40
Berry Street (between Miller and Denison Street)	EB	1103	0.8	40	318	0.5	40
Berry Street (between Pacific Highway and Miller Street)	EB	596	0.9	40	179	0.5	40
Spring Street (between Walker and Little Spring Street)	WB	86	8.2	50	18	20.5	50
Spring Street (between Little Spring and Denison Street)	WB	198	3.8	50	48	8.3	50
Denison Street (between Spring and Berry Street)	NB	86	8.2	50	18	20.5	50
Pacific Highway (between Arthur and Walker Street)	NB	2147	2.5	60	589	3.4	60
	SB	871	1.1	60	295	1.2	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Pacific Highway (between Walker and Miller Street)	NB	1478	1.4	60	384	1.2	60
	SB	464	1.2	60	72	1.2	60
Pacific Highway (between Miller and William Street)	NB	597	1.2	60	89	0.5	60
	SB	423	1.4	60	57	1.3	60
Pacific Highway (between William and Berry Street)	NB	776	1.2	60	133	0.7	60
	SB	423	1.4	60	57	1.3	60
Pacific Highway (between Berry Street and Bay Road)	NB	633	1.2	60	93	0.6	60
	SB	877	1.0	60	196	0.7	60
Pacific Highway (between Bay Road and McLaren Street)	NB	743	1.1	60	105	0.5	60
	SB	867	1.3	60	139	1.1	60
Pacific Highway (between McLaren and West Street)	NB	864	1.0	60	125	0.5	60
	SB	1016	1.2	60	151	1.1	60
Pacific Highway (between West Street and Crows Nest Road)	NB	864	1.0	60	125	0.5	60
	SB	918	1.4	60	123	1.3	60
Pacific Highway (between Crows Nest and Rocklands Road)	NB	748	1.1	60	93	0.7	60
	SB	918	1.4	60	123	1.3	60
Pacific Highway (between Rocklands Road and Bruce Street)	NB	863	1.0	60	105	0.6	60
	SB	1012	1.3	60	147	1.1	60
Pacific Highway (between Bruce and Alexander Street)	NB	900	1.2	60	114	0.9	60
	SB	1057	1.7	60	160	1.5	60
Pacific Highway (between Alexander and Falcon Street)	NB	614	1.0	60	46	0.8	60
	SB	937	1.6	60	137	1.4	60
Pacific Highway (between Falcon and Hume Street)	NB	723	0.6	60	116	0.5	60
	SB	1309	1.4	60	183	1.4	60
Arthur Street (between Pacific Highway and Mount Street)	NB	577	1.6	40	207	1.7	40
High Street (west of Warringah Freeway)	EB	776	0.1	70	329	0.1	70
	WB	634	1.8	70	189	2.0	70
High Street (east of Warringah Freeway)	EB	1045	0.3	50	417	0.2	50
	WB	1218	0.2	50	417	0.1	50
Clark Road (between High Street and Adderstone Avenue)	NB	819	0.2	50	310	0.1	50
	SB	939	0.2	50	274	0.1	50
Clark Road (between Adderstone Avenue and Kurraba Road)	NB	695	0.2	50	270	0.1	50
	SB	831	0.2	50	229	0.1	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Kurraba Road (between Clark Road and Holdsworth Street)	EB	806	0.2	50	277	0.1	50
	WB	820	0.2	50	225	0.1	50
Kurraba Road (between Holdsworth and Ben Boyd Road)	EB	616	0.2	50	213	0.1	50
	WB	711	0.3	50	175	0.1	50
Bent Street (between Falcon Street and Alfred Street N)	SB	122	0.3	50	13	1.4	50
Alfred Street N (between Bent Street and Kurraba Road)	SB	122	0.3	50	13	1.4	50
Alfred Street N (between Kurraba Road and High Street)	SB	485	2.3	50	213	1.9	50
Gore Hill Freeway Connection							
Gore Hill Freeway (north of Willoughby Road)	NB/WB	4143	5.2	80	1449	3.6	80
	SB/EB	4016	4.6	80	1493	4.4	80
Gore Hill Freeway (to / from Longueville Road, east of Hampden Road overpass)	WB	2250	4.5	80	847	3.3	80
	EB	1728	3.4	80	653	3.7	80
Lane Cove Tunnel (east of Hampden Road overpass)	WB	1892	6.1	80	601	4.1	80
	EB	2288	5.5	80	840	5.0	80
Gore Hill Freeway on ramp (east of Reserve Road overpass)	EB	360	8.4	80	66	13.2	80
Lane Cove Tunnel (west of Reserve Road overpass)	WB	1892	6.1	80	601	4.1	80
	EB	1928	5.0	80	773	4.3	80
Lane Cove Tunnel on ramp (west of Reserve Road overpass)	WB	270	16.7	80	56	14.7	80
Lane Cove Tunnel off ramp (west of Reserve Road overpass)	EB	492	10.8	80	123	10.1	80
Lane Cove Tunnel (west of Reserve Road ramps)	WB	2162	7.5	80	657	5.0	80
	EB	2420	6.1	80	897	5.1	80
Gore Hill Freeway off ramp (east of Reserve Road)	WB	242	11.8	60	55	12.9	60
Gore Hill Freeway (west of Reserve Road overpass)	WB	2008	3.6	80	792	2.6	80
Gore Hill Freeway on ramp (west of Reserve Road)	WB	378	7.9	80	113	6.1	80
Gore Hill Freeway off ramp (to Pacific Highway)	WB	999	3.2	60	381	3.2	60
Gore Hill Freeway (west of Pacific Highway overpass)	WB	1387	5.0	60	524	2.9	60
	EB	986	4.5	60	459	3.2	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Gore Hill Freeway (east of Pacific Highway overpass, right lane)	EB	551	5.7	60	302	3.9	60
Gore Hill Freeway (east of Pacific Highway overpass, left lane)	EB	435	3.1	60	157	2.0	60
Lane Cove Tunnel off ramp (east of Pacific Highway overpass, to Gore Hill Fwy)	EB	58	4.5	60	0	0	60
Gore Hill Freeway off ramp (west of Reserve Road)	EB	274	8.7	80	99	7.8	80
Gore Hill Freeway on ramp (from Pacific Highway)	EB	959	3.7	80	294	5.9	80
Gore Hill Freeway (east of Reserve Road overpass)	EB	1728	3.4	80	653	3.7	80
Longueville Road (east of Epping Road)	WB	2243	4.9	60	760	3.5	60
	EB	1634	3.6	60	554	3.0	60
Longueville Road on ramp (from Pacific Highway)	WB	855	4.7	60	236	4.6	60
Longueville Road off ramp (to Pacific Highway)	EB	649	2.3	60	96	2.0	60
Lane Cove Tunnel on ramp, east of Pacific Highway (from Pacific Highway)	EB	431	6.4	60	57	4.4	60
Lane Cove Tunnel off ramp, east of Pacific Highway (to Pacific Highway)	WB	421	7.4	60	56	10.2	60
Pacific Highway (between Campbell Street and Dickson Avenue)	NB	1059	2.7	60	156	1.1	60
	SB	1114	1.4	60	119	0.9	60
Pacific Highway (between Dickson Avenue and Hotham Parade)	NB	1059	2.7	60	156	1.1	60
	SB	986	1.4	60	129	0.8	60
Pacific Highway (between Hotham Parade and Cobden Avenue)	NB	948	3.1	60	144	1.2	60
	SB	918	1.5	60	114	0.9	60
Pacific Highway (between Cobden Avenue and Gore Hill Freeway overpass)	NB	1088	3.1	60	161	1.3	60
	SB	918	1.5	60	114	0.9	60
Pacific Highway (between Gore Hill Freeway overpass and Gore Hill Freeway ramps)	NB	640	2.0	60	74	0.7	60
	SB	1108	4.1	60	225	4.8	60
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway NB)	NB	376	4.9	60	50	2.2	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway SB)	SB	55	16.9	60	8	18.4	60
Pacific Highway (between Gore Hill Freeway ramps to Mowbray Road)	NB	1961	3.9	60	514	5.4	60
	SB	1954	3.7	60	507	3.6	60
Hampden Road (between Palmer and Brand Street)	NB	460	4.5	50	173	5.6	50
	SB	271	1.6	50	121	3.9	50
Hampden Road (between Brand Street and Jersey Road)	NB	443	3.8	50	146	3.8	50
	SB	438	5.6	50	157	5.9	50
Hampden Road (between Jersey Road and Cleg Street)	NB	232	2.0	50	79	1.5	50
	SB	220	2.5	50	81	1.7	50
Herbert Street (between Cleg and Frederick Street)	NB	293	4.9	50	96	2.9	50
	SB	377	3.0	50	154	2.5	50
Herbert Street (between Frederick and Ella Street)	NB	470	5.4	50	136	3.0	50
	SB	538	5.2	50	185	3.7	50
Herbert Street (between Ella and Westbourne Street)	NB	273	3.4	50	97	2.4	50
	SB	302	4.7	50	120	3.6	50
Frederick Street (between Herbert Street and Reserve Road)	EB	161	10.4	50	31	9.9	50
	WB	177	6.1	50	39	3.3	50
Campbell Street (between Reserve Road and Pacific Highway)	EB	182	3.2	50	23	4.2	50
	WB	353	6.2	50	106	1.3	50
Cleg Street (between Herbert and Waltham Street)	EB	290	4.1	50	107	3.4	50
	WB	194	8.2	50	50	5.7	50
Waltham Street (between Cleg Street and Dickson Avenue)	NB	290	8.3	50	79	5.7	50
	SB	273	6.4	50	105	5.2	50
Dickson Avenue (between Waltham Street and Reserve Road)	EB	273	6.4	50	105	5.2	50
	WB	290	8.3	50	79	5.7	50
Dickson Avenue (between Reserve Road and Pacific Highway)	EB	49	0.1	50	10	0	50
	WB	177	0.9	50	0	0	50
Reserve Road (between Frederick and Campbell Street)	NB	177	6.1	50	39	3.3	50
	WB	161	10.4	50	31	9.9	50
Reserve Road (between Campbell Street and Dickson Avenue)	NB	533	16.0	50	137	16.4	50
	SB	535	18.7	50	180	16.1	50
Reserve Road (between Dickson Avenue and Gore Hill Freeway)	NB	803	13.2	50	208	12.5	50
	SB	916	12.6	50	267	12.5	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Reserve Road (between Gore Hill Freeway and Jersey Road)	NB	371	4.8	50	107	5.4	50
	SB	484	5.6	50	122	7.8	50
Jersey Road (between Reserve and Abbott Road)	EB	304	5.1	50	94	5.6	50
	WB	360	6.5	50	102	8.7	50
Jersey Road (between Abbott and Hampden Road)	EB	273	4.6	50	78	5.7	50
	WB	279	7.0	50	88	9.1	50
Connections to and from Burnt Bridge Creek Deviation							
Manly Road (between Avona Crescent and Heaton Avenue)	NB	2094	6.1	60	765	3.8	60
	SB	2160	7.3	60	684	6.3	60
Manly Road (between Heaton Avenue and Sydney Road)	NB	2094	6.1	60	765	3.8	60
	SB	2085	7.5	60	665	6.5	60
Burnt Bridge Creek Deviation (between Sydney Road and Condamine Street)	NB	1428	7.8	80	487	5.5	80
	SB	1322	8.9	80	418	7.4	80
Condamine Street (between Burnt Bridge Creek Deviation and Kenneth Road)	NB	1823	6.6	60	567	4.6	60
	SB	1690	7.6	60	504	6.6	60
Frenchs Forest Road (between Montauban Avenue and Baringa Avenue)	EB	266	3.5	60	91	1.2	60
	WB	198	0.2	60	42	0	60
Frenchs Forest Road (between Baringa Avenue and Brook Road)	EB	363	2.6	60	125	0.9	60
	WB	187	0.2	60	42	0	60
Frenchs Forest Road (between Brook and Sydney Road)	NB	311	0.2	60	96	0.0	60
	SB	428	2.2	60	138	0.8	60
Sydney Road (between Frenchs Forest Road and Manly Road)	EB	608	1.7	60	186	0.7	60
	WB	323	0.1	60	104	0.1	60
Sydney Road (between Manly Road and Wanganella Street)	EB	813	2.0	60	324	0.8	60
	WB	624	4.6	60	209	5.0	60
Sydney Road (between Wanganella and Woodland Street)	EB	838	1.9	60	278	0.9	60
	WB	664	4.4	60	220	4.8	60
Sydney Road (Woodland and Condamine Street)	EB	934	1.5	60	286	0.9	60
	WB	671	1.8	60	207	1.3	60
Wanganella Street (Sydney Road and Kitchener Street)	NB	6	0.0	50	1	0.0	50
	SB	136	0.2	50	7	0.9	50
Kitchener Street (between Wanganella and Daisy Street)	EB	309	3.8	50	50	5.6	50
	WB	254	6.3	50	52	5.1	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Daisy Street (between Kitchener and Woodbine Street)	NB	254	6.3	50	52	5.1	50
	SB	309	3.8	50	50	5.6	50
Woodbine Street (between Daisy and Bangaroo Street)	EB	309	3.8	50	50	5.6	50
	WB	254	6.3	50	52	5.1	50
Woodbine Street (between Bangaroo and Hunter Street)	EB	334	3.6	50	60	4.7	50
	WB	270	5.9	50	64	4.1	50
Maretimo Street (between Ethel and Upper Beach Street)	NB	13	0	50	0	0	50
	SB	20	0	50	8	0	50
Upper Beach Street (between Maretimo and Wanganella Street)	EB	13	0	50	0	0	50
	WB	20	0	50	8	0	50
Connections to and from Wakehurst Parkway							
Wakehurst Parkway (between Lister Avenue and Armstrong Street)	NB	485	1.3	60	122	0.3	60
	SB	429	2.2	60	144	0.8	60
Wakehurst Parkway (between Armstrong Street and Judith Street)	NB	541	1.2	60	137	0.2	60
	SB	476	2.0	60	160	0.7	60
Wakehurst Parkway (between Judith Street and Aquatic Drive)	NB	690	3.3	80	161	1.8	80
	SB	680	3.1	80	188	2.1	80
Wakehurst Parkway (between Aquatic Drive and Warringah Road)	NB	652	3.1	70	154	1.9	70
	SB	705	3.8	70	206	3.4	70
Wakehurst Parkway (between Warringah Road and Frenchs Forest Road)	NB	657	4.0	60	214	1.4	60
	SB	823	3.1	60	231	2.5	60
Wakehurst Parkway (north of Frenchs Forest Road)	NB	749	3.5	60	233	2.5	60
	SB	733	4.3	60	249	1.8	60
Warringah Road (between Forest Way and Hilmer Street)	EB	1582	5.0	70	452	5.2	70
	WB	1293	5.2	70	461	6.2	70
Warringah Road (between Hilmer Street and Wakehurst Parkway)	EB	1283	5.1	70	450	6.3	70
	WB	1566	4.9	70	445	5.2	70
Warringah Road (between Wakehurst Parkway and underpass ramps)	EB	669	6.4	70	197	9.0	70
	WB	500	5.0	70	168	12.7	70

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Warringah Road underpass (between Forest Road and underpass ramps)	EB	1061	8.9	70	335	7.0	70
	WB	1032	11.4	70	343	8.3	70
Judith Street to Manning Street (between Wakehurst Parkway and Mons Road)	EB	205	5.8	50	27	10.3	50
	WB	149	10.7	50	24	10.9	50

Notes: 1. Based on posted speeds.

2. The 2037 (design year) do minimum scenario includes the WestConnex, but without the project, Western Harbour Tunnel and Warringah Freeway Upgrade, Sydney Gateway and the M6 Motorway.

D.6 Year 2037 (design year) do something traffic volumes

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Warringah Freeway and surrounds							
Warringah Freeway (south of Merrenburn Avenue)	NB	4317	6.7	80	1335	5.0	80
	SB	4260	6.4	80	1424	5.1	80
Willoughby Road off ramp	NB	1060	10.7	60	450	8.3	60
Willoughby Road on ramp	SB	1146	8.4	60	398	6.1	60
Warringah Freeway (south of Brook Street)	NB	5377	7.5	80	1785	5.8	80
	SB	5406	6.8	80	1822	5.3	80
Brook Street off ramp	NB	957	7.4	60	275	9.2	60
Brook Street on ramp	SB	773	2.4	80	82	3.6	80
Warringah Freeway (east of Miller Street)	WB	6334	7.5	80	2059	6.3	80
	EB	6179	6.3	80	1904	5.2	80
Miller Street off ramp	WB	566	3.5	60	219	3.3	60
Miller Street on ramp	EB	764	2.4	60	164	0.3	60
Warringah Freeway (north of Ernest Street)	NB	5410	5.3	80	1755	5.0	80
Warringah Freeway (north of Ernest St, WHT exit/entry portal)	NB/exit	1490	13.8	80	523	9.4	80
	SB/entry	1080	18.4	80	204	13.0	80
Warringah Freeway (north of Ernest Street)	SB	5045	3.6	80	1623	4.0	80
Ernest Street off ramp	NB	610	3.3	50	214	1.3	50
Ernest Street on ramp	SB	643	2.0	60	30	0.0	60
Warringah Freeway (south of Falcon Street)	NB	3696	5.6	80	1253	5.1	80
Warringah Freeway (south of Falcon Street)	NB	1723	3.8	80	578	3.0	80
	SB	2112	4.8	80	702	4.9	80
Warringah Freeway (south of Falcon Street)	SB	3576	2.6	80	951	3.2	80
Falcon Street off ramp (WHT exit portal)	NB	1072	5.7	60	211	6.2	60
Falcon Street off ramp (bus lane)	NB	36	100	60	5	100	60
Military Road off ramp	NB	1083	4.2	70	483	2.4	70
Falcon Street on ramp	SB	1744	2.7	80	573	3.7	80
Falcon Street on ramp (bus lane)	SB	43	100	60	6	100	60
Berry Street on ramp	NB	379	1.5	80	141	1.4	80

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Berry Street on ramp (WHT entry portal)	NB	1180	5.1	60	253	3.0	60
Alfred Street off ramp	SB	963	1.9	60	294	1.9	60
Warringah Freeway (south of Mount Street)	NB	6123	5.1	80	2174	4.2	80
Warringah Freeway (south of Mount Street)	SB	5468	3.7	70	1809	4.4	70
Cahill Expressway (south of Mount Street)	SB	1002	2.1	70	122	1.1	70
Mount Street on ramp	SB	654	0.3	70	113	1.7	70
Mount Street on ramp (Cahill Expressway)	SB	589	0.4	70	306	0.4	70
Sydney Harbour Tunnel portals	NB/exit	2494	5.4	80	861	4.1	80
	SB/entry	2830	4.1	80	955	4.1	80
Warringah Freeway (south of High Street)	NB	2962	5.7	70	1127	4.8	70
Warringah Freeway (south of High Street)	SB	3291	2.7	70	967	4.4	70
Cahill Expressway (south of High Street)	SB	1591	1.5	70	429	0.6	70
Pacific Highway off ramp	NB	1383	1.4	60	456	2.2	60
High Street on ramp	SB	569	0.0	70	309	0.1	70
Lavender Street off ramp	NB	393	2.8	70	154	3.1	70
Bradfield Highway (south of Lavender Street)	NB	4738	4.2	70	1737	4.0	70
	SB	3291	2.7	70	967	4.4	70
Cahill Expressway (south of Lavender Street)	SB	2160	1.1	70	737	0.4	70
Ernest Street (west of Warringah Freeway)	EB	447	5.2	50	83	3.5	50
	WB	452	0.9	50	100	0.5	50
Ernest Street (between Miller and West Street)	EB	367	6.3	50	80	3.6	50
	WB	448	0.7	50	112	0.5	50
Ernest Street (between West and Sophia Street)	EB	187	0.7	50	48	0.4	50
	WB	406	1.0	50	82	0.8	50
Ernest Street (between Sophia and Alexander Street)	EB	187	0.7	50	48	0.4	50
	WB	187	0.7	50	48	0.4	50
Ernest Street (east of Warringah Freeway)	EB	1019	4.3	50	275	2.1	50
	WB	1057	1.6	50	109	0.5	50
Ernest Street (between Merlin Street and Park Avenue)	EB	1220	3.7	50	395	1.6	50
	WB	1097	1.6	50	108	0.5	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Falcon Street (west of Warringah Freeway)	EB	1409	0.7	60	342	0.6	60
	WB	1774	5.1	60	446	3.8	60
Falcon Street (between Miller and West Street)	EB	1203	0.5	60	298	0.5	60
	WB	931	4.7	60	250	2.9	60
Falcon Street (between West and Alexander Street)	EB	1200	0.5	60	312	0.5	60
	WB	719	2.3	60	205	1.4	60
Falcon Street (between Alexander Street and Pacific Highway)	EB	1186	0.7	60	306	0.6	60
	WB	800	2.0	60	247	1.1	60
Falcon Street (east of Warringah Freeway)	WB	2372	4.5	60	808	4.0	60
Falcon Street (between Watson Street and Tramway Lane)	WB	2413	4.4	60	827	3.9	60
Military Road (east of Warringah Freeway)	EB	2633	3.0	60	930	2.3	60
Military Road (between Watson Street and Ben Boyd Road)	EB	2370	3.3	60	827	2.5	60
	WB	2413	4.4	60	827	3.9	60
Military Road (between Ben Boyd Road and Young Street)	EB	2406	3.2	60	850	2.4	60
	WB	2179	4.7	60	766	4.2	60
Military Road (between Young Street and Wycombe Road)	EB	2221	3.4	60	830	2.4	60
	WB	1998	5.1	60	724	4.4	60
Willoughby Road (north of Warringah Freeway)	NB	1196	9.5	60	467	8.0	60
	SB	1357	7.3	60	463	5.6	60
Willoughby Road (south of Warringah Freeway)	NB	291	2.0	60	63	1.6	60
	SB	366	2.4	60	111	2.8	60
Willoughby Road (between Merrenburn Avenue and Dalleys Road)	NB	577	2.4	60	137	2.4	60
	SB	495	3.0	60	119	3.1	60
Willoughby Road (between Dalleys Road and Chandos Street)	NB	602	1.8	60	131	1.5	60
	SB	396	2.3	60	94	2.1	60
Willoughby Road (between Chandos and Atchison Street)	NB	407	1.3	60	102	0.9	60
	SB	435	1.4	60	112	1.7	60
Willoughby Road (between Atchison and Albany Street)	NB	284	1.4	60	36	0.7	60
	SB	206	1.1	60	40	0.3	60
Willoughby Road (between Albany and Holtermann Street)	NB	321	0.8	60	67	0.7	60
	SB	153	0.7	60	43	0.3	60
Willoughby Road (between Holtermann and Falcon Street)	SB	41	0.2	60	7	0.0	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Merrenburn Avenue (between Willoughby Road and Brook Street)	EB	337	2.8	50	83	2.9	50
	WB	180	4.6	50	17	4.2	50
Brook Street (between Merrenburn Avenue and Flat Rock Drive)	NB	1062	3.3	50	179	3.1	50
	SB	1057	8.0	50	310	8.9	50
Brook Street (between Warringah Freeway on ramp and Merrenburn Avenue)	NB	806	9.3	50	252	10.0	50
	SB	967	2.8	50	188	2.6	50
Brook Street (between Warringah Freeway on and off ramps)	NB	1166	6.6	50	301	8.6	50
	SB	124	3.6	50	38	2.3	50
Brook Street (between Warringah Freeway on ramp and Chandos Street)	NB	568	1.6	50	97	1.4	50
	SB	484	1.5	50	109	1.6	50
Chandos Street (between Alexander and Brook Street)	EB	568	1.6	50	97	1.4	50
	WB	484	1.5	50	109	1.6	50
Chandos Street (between Brook Street and Willoughby Road)	EB	419	1.6	50	54	1.1	50
	WB	324	0.8	50	81	1.5	50
Chandos Street (between Willoughby Road and Oxley Street)	EB	488	2.1	50	53	2.4	50
	WB	159	1.8	50	32	2.7	50
Chandos Street (between Oxley and Christie Street)	EB	282	2.6	50	39	2.5	50
	WB	94	0.6	50	17	2.2	50
Alexander Street (between Brook and Albany Street)	NB	217	2.0	50	63	1.6	50
	SB	227	2.8	50	49	1.9	50
Alexander Street (between Albany and Holtermann Street)	NB	269	1.6	50	61	1.3	50
	SB	228	1.9	50	56	1.3	50
Alexander Street (between Holtermann and Ernest Street)	NB	279	1.5	50	68	1.1	50
	SB	340	1.6	50	92	0.9	50
Alexander Street (between Ernest and Burlington Street)	NB	343	1.3	50	79	1.0	50
	SB	312	1.7	50	77	1.0	50
Alexander Street (between Burlington and Falcon Street)	NB	379	1.3	50	82	1.0	50
	SB	346	1.3	50	83	0.9	50
Alexander Street (between Falcon Street and Pacific Highway)	NB	385	0.8	50	89	0.6	50
	SB	257	2.1	50	42	1.9	50
Albany Street (between Alexander Street and Willoughby Road)	EB	81	0.4	50	21	0.3	50
	WB	120	1.6	50	7	0.0	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Albany Street (between Willoughby Road and Oxley Street)	EB	135	0.5	50	21	0.3	50
	WB	264	0.9	50	34	0.7	50
Albany Street (between Oxley Street and Pacific Highway)	EB	386	2.3	50	126	1.8	50
	WB	443	2.0	50	92	1.9	50
Amherst Street (west of West Street)	EB	430	1.3	60	116	1.3	60
Amherst Street (between West and Miller Street)	EB	341	1.1	50	112	2.0	50
	WB	97	0.1	50	22	0	50
West Street (between Amherst and Ernest Street)	NB	105	2.3	50	41	5.0	50
	SB	287	1.6	50	65	2.1	50
West Street (between Ernest and Falcon Street)	NB	310	8.2	50	72	6.6	50
	SB	327	1.5	50	70	1.9	50
West Street (between Falcon and Ridge Street)	NB	86	4.3	50	20	10.2	50
	SB	313	3.4	50	77	4.1	50
West Street (between Ridge and Church Street)	NB	165	2.5	50	18	3.1	50
	SB	229	1.5	50	54	1.9	50
West Street (between Church Street and Pacific Highway)	NB	165	2.5	50	18	3.1	50
	SB	229	1.5	50	54	1.9	50
Miller Street (between Pine and Amherst Street)	NB	1000	3.6	50	291	5.1	50
	SB	999	2.4	50	218	0.6	50
Miller Street (between Amherst Street and Warringah Freeway on ramp)	NB	911	3.1	50	249	4.2	50
	SB	1024	2.3	50	210	0.5	50
Miller Street (between Warringah Freeway on and off ramps)	NB	928	3.0	50	250	4.2	50
	SB	278	1.8	50	48	1.3	50
Miller Street (between Warringah Freeway off ramp and Ernest Street)	NB	434	1.9	50	45	7.2	50
	SB	349	1.5	50	62	1.0	50
Miller Street (between Ernest and Falcon Street)	NB	510	1.9	50	59	5.5	50
	SB	350	2.1	50	62	1.0	50
Miller Street (between Falcon and Ridge Street)	NB	310	2.5	50	47	1.0	50
	SB	788	6.0	50	201	3.6	50
Miller Street (between Ridge and McLaren Street)	NB	137	2.4	50	21	2.4	50
	SB	379	4.8	50	73	4.0	50
Miller Street (between McLaren and Berry Street)	NB	397	1.4	50	85	1.9	50
	SB	612	3.3	50	101	3.1	50
Miller Street (between Berry Street and Pacific Highway)	NB	333	1.6	40	72	2.2	40
	SB	151	5.9	40	40	1.7	40

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Walker Street (between Ridge and McLaren Street)	NB	188	1.1	50	32	0.8	50
	SB	582	5.5	50	153	3.2	50
Walker Street (between McLaren and Berry Street)	NB	173	0.7	50	70	1.1	50
	SB	664	4.5	50	230	1.8	50
Walker Street (between Berry and Spring Street)	NB	409	3.0	50	100	2.6	50
	SB	12	1.4	50	2	3.6	50
Ridge Street (between Walker and Miller Street)	EB	582	5.5	50	153	3.2	50
	WB	188	1.1	50	32	0.8	50
Ridge Street (between Miller and West Street)	EB	106	1.8	50	20	3.0	50
	WB	264	2.7	50	39	2.3	50
McLaren Street (between Walker and Miller Street)	EB	376	1.3	50	86	1.6	50
	WB	306	0.4	50	71	0.3	50
McLaren Street (between Miller and Angelo Street)	EB	233	1.6	50	21	1.2	50
	WB	191	0.2	50	43	0.1	50
McLaren Street (between Angelo Street and Pacific Highway)	EB	233	1.6	50	21	1.2	50
	WB	191	0.2	50	43	0.1	50
Berry Street (between Walker and Arthur Street)	EB	2134	3.2	60	659	1.6	60
Berry Street (between Little Spring and Walker Street)	EB	1246	2.1	40	400	1.2	40
Berry Street (between Denison and Little Spring Street)	EB	1391	2.0	40	431	1.2	40
Berry Street (between Miller and Denison Street)	EB	1053	2.8	40	260	2.2	40
Berry Street (between Pacific Highway and Miller Street)	EB	656	2.8	40	212	1.6	40
Spring Street (between Walker and Little Spring Street)	WB	282	1.5	50	86	2.5	50
Spring Street (between Little Spring and Denison Street)	WB	427	1.4	50	117	2.1	50
Denison Street (between Spring and Berry Street)	NB	282	1.5	50	86	2.5	50
Pacific Highway (between Arthur and Walker Street)	NB	2055	1.5	60	539	2.1	60
	SB	1360	1.0	60	404	0.9	60
Pacific Highway (between Walker and Miller Street)	NB	1393	1.1	60	383	1.3	60
	SB	619	1.6	60	110	1.1	60
Pacific Highway (between Miller and William Street)	NB	657	0.3	60	169	0.3	60
	SB	526	0.8	60	92	1.1	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Pacific Highway (between William and Berry Street)	NB	819	0.7	60	212	0.8	60
	SB	526	0.8	60	92	1.1	60
Pacific Highway (between Berry Street and Bay Road)	NB	540	0.3	60	132	0.3	60
	SB	904	2.1	60	224	1.3	60
Pacific Highway (between Bay Road and McLaren Street)	NB	669	0.3	60	156	0.3	60
	SB	897	2.4	60	178	1.9	60
Pacific Highway (between McLaren and West Street)	NB	822	0.3	60	186	0.3	60
	SB	1091	2.3	60	186	1.9	60
Pacific Highway (between West Street and Crows Nest Road)	NB	822	0.3	60	186	0.3	60
	SB	1027	2.5	60	149	2.0	60
Pacific Highway (between Crows Nest and Rocklands Road)	NB	707	0.4	60	154	0.3	60
	SB	1027	2.5	60	149	2.0	60
Pacific Highway (between Rocklands Road and Bruce Street)	NB	802	0.4	60	155	0.3	60
	SB	1073	2.4	60	148	2.1	60
Pacific Highway (between Bruce and Alexander Street)	NB	842	0.7	60	162	0.6	60
	SB	1120	2.7	60	158	2.4	60
Pacific Highway (between Alexander and Falcon Street)	NB	583	0.5	60	92	0.5	60
	SB	989	2.6	60	135	2.2	60
Pacific Highway (between Falcon and Hume Street)	NB	665	1.3	60	106	1.2	60
	SB	1373	1.7	60	197	1.6	60
Arthur Street (between Pacific Highway and Mount Street)	NB	1304	0.9	60	401	1.6	60
High Street (west of Warringah Freeway)	EB	638	1.8	70	198	0.8	70
	WB	944	1.8	70	220	2.4	70
High Street (east of Warringah Freeway)	EB	988	0.4	50	347	0.3	50
	WB	1209	0.2	50	405	0.1	50
Clark Road (between High Street and Adderstone Avenue)	NB	758	0.2	50	270	0.1	50
	SB	933	0.3	50	268	0.1	50
Clark Road (between Adderstone Avenue and Kurraba Road)	NB	627	0.2	50	230	0.1	50
	SB	815	0.4	50	223	0.1	50
Kurraba Road (between Clark Road and Holdsworth Street)	EB	740	0.2	50	234	0.1	50
	WB	811	0.4	50	219	0.1	50
Kurraba Road (between Holdsworth and Ben Boyd Road)	EB	542	0.2	50	169	0.1	50
	WB	675	0.4	50	166	0.1	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Bent Street (between Falcon Street and Alfred Street N)	SB	201	0.3	50	24	0.8	50
Alfred Street N (between Bent Street and Kurraba Road)	SB	201	0.3	50	24	0.8	50
Alfred Street N (between Kurraba Road and Mount Street)	SB	84	0.6	60	16	1.1	60
Alfred Street N (between Mount and High Street)	SB	1321	1.4	60	458	1.3	60
Gore Hill Freeway Connection							
Gore Hill Freeway (north of Willoughby Road)	NB/WB	3851	5.0	80	1306	3.5	80
	SB/EB	4229	4.1	80	1435	4.2	80
Gore Hill Freeway (to / from Longueville Road, east of Hampden Road overpass)	WB	2253	4.6	80	747	3.5	80
	EB	4229	4.1	80	1435	4.2	80
Lane Cove Tunnel (west of Hampden Road overpass)	WB	1599	5.7	80	559	3.5	80
Gore Hill Freeway (west of Hampden Road overpass)	EB	3444	3.9	80	1313	4.0	80
Gore Hill Freeway on ramp (east of Reserve Road overpass)	EB	971	6.1	60	159	8.0	60
Beaches Link off ramp (to Lane Cove Tunnel)	WB	430	21.2	80	93	19.4	80
Beaches Link on ramp (from Reserve Road)	EB	186	10.0	60	37	10.7	60
Beaches Link on ramp (from Gore Hill Freeway)	EB	658	13.9	80	186	10.8	80
Lane Cove Tunnel (west of Reserve Road overpass)	WB	2029	9.0	80	652	5.8	80
Gore Hill Freeway (west of Reserve Road overpass)	EB	2034	4.3	80	746	3.8	80
Lane Cove Tunnel on ramp (west of Reserve Road overpass)	WB	271	15.1	80	88	8.3	80
Lane Cove Tunnel (west of Reserve Road ramps)	WB	2300	9.7	80	740	6.1	80
	EB	2034	4.3	80	746	3.8	80
Gore Hill Freeway off ramp (east of Reserve Road)	WB	255	10.6	60	53	11.3	60
Gore Hill Freeway (west of Reserve Road overpass)	WB	1997	3.8	80	695	3.0	80
Gore Hill Freeway on ramp (west of Reserve Road)	WB	350	8.0	80	113	6.4	80

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Gore Hill Freeway off ramp (to Pacific Highway)	WB	990	3.5	60	334	4.0	60
Gore Hill Freeway (west of Pacific Highway overpass)	WB	1357	5.2	60	474	3.1	60
	EB	1194	5.3	60	485	3.6	60
Gore Hill Freeway (east of Pacific Highway overpass, right lane)	EB	326	2.5	60	274	1.8	60
Gore Hill Freeway (east of Pacific Highway overpass, left lane)	EB	868	6.3	60	211	5.9	60
Lane Cove Tunnel off ramp (east of Pacific Highway overpass, to Gore Hill Fwy)	EB	773	14.7	60	230	12.0	60
Gore Hill Freeway off ramp (west of Reserve Road)	EB	983	7.9	80	255	7.8	80
Gore Hill Freeway on ramp (from Pacific Highway)	EB	1084	3.4	60	293	6.3	60
Gore Hill Freeway (after Pacific Highway on ramp)	EB	1410	3.2	80	567	4.1	80
Longueville Road (east of Epping Road)	WB	2237	4.8	60	707	3.4	60
	EB	1737	4.3	60	582	3.3	60
Longueville Road on ramp (from Pacific Highway)	WB	880	4.4	60	233	4.1	60
Longueville Road off ramp (to Pacific Highway)	EB	543	2.1	60	97	1.6	60
Lane Cove Tunnel on ramp, east of Pacific Highway (from Pacific Highway)	EB	397	6.8	60	19	12.3	60
Lane Cove Tunnel off ramp, east of Pacific Highway (to Pacific Highway)	WB	284	5.0	60	47	6.0	60
Pacific Highway (between Campbell Street and Dickson Avenue)	NB	951	2.8	60	100	1.3	60
	SB	770	1.8	60	119	1.0	60
Pacific Highway (between Dickson Avenue and Hotham Parade)	NB	1126	4.1	60	138	3.8	60
	SB	810	1.5	60	127	0.8	60
Pacific Highway (between Hotham Parade and Cobden Avenue)	NB	988	4.5	60	117	4.3	60
	SB	736	1.6	60	111	0.9	60
Pacific Highway (between Cobden Avenue and Gore Hill Freeway overpass)	NB	1135	4.4	60	144	3.8	60
	SB	736	1.6	60	111	0.9	60
Pacific Highway (between Gore Hill Freeway overpass and Gore Hill Freeway ramps)	NB	573	1.6	60	76	1.4	60
	SB	908	2.8	60	198	3.5	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway NB)	NB	366	5.7	60	12	9.0	60
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway SB)	SB	31	19.2	60	7	18.1	60
Pacific Highway (between Gore Hill Freeway ramps to Mowbray Road)	NB	1767	3.1	60	453	3.7	60
	SB	1911	3.1	60	487	5.1	60
Hampden Road (between Palmer and Brand Street)	NB	308	3.1	50	123	2.9	50
	SB	461	3.5	50	174	4.3	50
Hampden Road (between Brand Street and Jersey Road)	NB	449	3.2	50	148	2.9	50
	SB	458	3.8	50	158	4.7	50
Hampden Road (between Jersey Road and Cleg Street)	NB	262	2.1	50	89	1.3	50
	SB	235	2.0	50	81	1.8	50
Herbert Street (between Cleg and Frederick Street)	NB	349	3.9	50	108	3.3	50
	SB	428	3.6	50	130	3.0	50
Herbert Street (between Frederick and Ella Street)	NB	499	4.9	50	166	2.8	50
	SB	514	5.6	50	177	4.1	50
Herbert Street (between Ella and Westbourne Street)	NB	275	2.3	50	107	2.3	50
	SB	284	3.5	50	109	3.0	50
Frederick Street (between Herbert Street and Reserve Road)	EB	250	12.2	50	95	8.3	50
	WB	314	9.0	50	106	5.3	50
Campbell Street (between Reserve Road and Pacific Highway)	EB	271	3.4	50	67	2.2	50
	WB	417	4.8	50	101	2.8	50
Cleg Street (between Herbert and Waltham Street)	EB	394	4.3	50	93	3.8	50
	WB	288	5.0	50	62	5.7	50
Waltham Street (between Cleg Street and Dickson Avenue)	NB	0	0	50	0	0	50
	SB	0	0	50	0	0	50
Beaches Link of ramp (to Dickson Avenue)	WB	256	16.7	60	49	21.7	60
Dickson Avenue (between Reserve Road and Pacific Highway)	EB	52	1.0	50	10	0.0	50
	WB	187	11.0	50	40	10.0	50
Reserve Road (between Frederick and Campbell Street)	NB	314	9.0	50	106	5.3	50
	WB	250	12.2	50	95	8.3	50
Reserve Road (between Campbell Street and Dickson Avenue)	NB	832	13.4	50	246	10.9	50
	SB	751	15.6	50	237	14.7	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Reserve Road (between Dickson Avenue and Gore Hill Freeway)	NB	869	12.9	50	256	10.5	50
	SB	667	14.2	50	229	12.4	50
Reserve Road (between Gore Hill Freeway and Jersey Road)	NB	375	4.8	50	100	4.8	50
	SB	527	4.6	50	126	6.2	50
Jersey Road (between Reserve and Abbott Road)	EB	308	4.8	50	90	4.5	50
	WB	397	4.9	50	108	6.4	50
Jersey Road (between Abbott and Hampden Road)	EB	290	3.7	50	80	4.1	50
	WB	326	4.4	50	99	6.1	50
Connections to and from Burnt Bridge Creek Deviation							
Manly Road (between Avona Crescent and Heaton Avenue)	NB	1243	2.3	60	446	1.2	60
	SB	1482	3.1	60	483	3.1	60
Manly Road (between Heaton Avenue and Sydney Road)	NB	1243	2.3	60	446	1.2	60
	SB	1448	3.1	60	475	3.1	60
Burnt Bridge Creek Deviation (between Sydney Road and Link Road)	NB	817	3.1	60	283	1.7	60
	SB	874	3.6	60	292	4.1	60
Beaches Link off ramp (to Burnt Bridge Creek Deviation)	NB	1112	11.2	80	378	9.1	80
Beaches Link on ramp (from Burnt Bridge Creek Deviation)	SB	921	13.9	80	244	16.8	80
Burnt Bridge Creek Deviation (between Link Road and Condamine Street)	NB	1702	8.7	80	613	6.4	80
	SB	1587	9.9	80	493	10.6	80
Condamine Street (between Burnt Bridge Creek Deviation and Kenneth Road)	NB	1989	7.4	60	648	5.7	60
	SB	1899	7.8	60	560	8.5	60
Frenchs Forest Road (between Montauban Avenue and Baringa Avenue)	EB	236	3.2	60	68	1.7	60
	WB	169	0.2	60	19	0.0	60
Frenchs Forest Road (between Baringa Avenue and Brook Road)	EB	333	2.3	60	99	1.2	60
	WB	158	0.2	60	19	0.0	60
Frenchs Forest Road (between Brook and Sydney Road)	NB	273	0.1	60	66	0.1	60
	SB	394	2.0	60	110	1.1	60
Sydney Road (between Frenchs Forest Road and Manly Road)	EB	555	1.5	60	148	0.9	60
	WB	290	0.1	60	77	0.1	60
Sydney Road (between Manly Road and Link Road)	EB	567	0.7	60	188	0.3	60
	WB	449	1.5	60	137	1.3	60
Sydney Road (between Link Road and Wanganella Street)	EB	660	0.6	60	204	0.3	60
	WB	523	1.5	60	147	1.5	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Sydney Road (between Wanganella and Woodland Street)	EB	734	0.5	60	210	0.3	60
	WB	524	1.4	60	149	1.4	60
Sydney Road (Woodland and Condamine Street)	EB	842	0.4	60	213	0.3	60
	WB	598	0.8	60	163	0.8	60
Wanganella Street (Sydney Road and Kitchener Street)	NB	18	0	50	7	0	50
	SB	180	0	50	46	0.3	50
Kitchener Street (between Wanganella and Daisy Street)	EB	359	2.9	50	95	2.7	50
	WB	314	4.6	50	91	2.9	50
Daisy Street (between Kitchener and Woodbine Street)	NB	314	4.6	50	91	2.9	50
	SB	359	2.9	50	95	2.7	50
Woodbine Street (between Daisy and Bangaroo Street)	EB	359	2.9	50	95	2.7	50
	WB	314	4.6	50	91	2.9	50
Woodbine Street (between Bangaroo and Hunter Street)	EB	379	2.8	50	102	2.5	50
	WB	320	4.5	50	98	2.7	50
Maretimo Street (between Ethel and Upper Beach Street)	NB	33	0	50	8	0	50
	SB	36	0	50	9	0	50
Upper Beach Street (between Maretimo and Wanganella Street)	EB	33	0	50	8	0	50
	WB	36	0	50	9	0	50
Connections to and from Wakehurst Parkway							
Wakehurst Parkway (between Lister Avenue and Armstrong Street)	NB	475	1.2	60	129	1.2	60
	SB	405	1.9	60	123	1.0	60
Wakehurst Parkway (between Armstrong Street and Judith Street)	NB	539	1.1	60	143	1.1	60
	SB	454	1.7	60	140	0.9	60
Wakehurst Parkway (between Judith Street and Beaches Link ramps)	NB	735	2.8	80	201	2.1	80
	SB	704	2.6	80	208	1.8	80
Beaches Link off ramp (to Wakehurst Parkway)	NB	853	19.7	80	229	14.8	80
Beaches Link on ramp (from Wakehurst Parkway)	SB	808	21.1	80	151	15.9	80
Wakehurst Parkway (between Beaches Link ramps and Aquatic Drive)	NB	1589	11.8	80	430	8.9	80
	SB	1512	12.5	80	359	7.8	80
Wakehurst Parkway (between Aquatic Drive and Warringah Road)	NB	1519	11.7	70	412	8.8	70
	SB	1496	12.2	70	365	7.6	70

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Wakehurst Parkway (between Warringah Road and Frenchs Forest Road)	NB	770	9.3	60	279	4.5	60
	SB	949	8.1	60	261	5.3	60
Wakehurst Parkway (north of Frenchs Forest Road)	NB	804	9.3	60	259	5.3	60
	SB	795	9.5	60	308	4.4	60
Warringah Road (between Forest Way and Hilmer Street)	EB	1386	6.6	70	437	6.5	70
	WB	1074	7.9	70	402	6.0	70
Warringah Road (between Hilmer Street and Wakehurst Parkway)	EB	1094	7.8	70	400	6.0	70
	WB	1397	6.6	70	439	6.6	70
Warringah Road (between Wakehurst Parkway and underpass ramps)	EB	752	9.7	70	222	9.4	70
	WB	650	10.1	70	212	12.1	70
Warringah Road underpass (between Forest Road and underpass ramps)	EB	844	4.8	70	231	3.6	70
	WB	897	6.6	70	282	4.7	70
Judith Street to Manning Street (between Wakehurst Parkway and Mons Road)	EB	250	4.2	50	68	3.8	50
	WB	197	7.3	50	58	4.7	50

Notes: 1. Based on posted speeds

2. The 2037 (design year) do something scenario includes the project and WestConnex, but without the Western Harbour Tunnel and Warringah Freeway Upgrade, Sydney Gateway and the M6 Motorway.

D.7 Year 2037 (design year) do something cumulative traffic volumes

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Warringah Freeway and surrounds							
Warringah Freeway (south of Merrenburn Avenue)	NB	4320	6.3	80	1248	4.7	80
	SB	4448	6.0	80	1347	5.3	80
Willoughby Road off ramp	NB	1088	5.0	60	448	5.8	60
Willoughby Road on ramp	SB	974	3.3	60	325	2.7	60
Warringah Freeway (south of Brook Street)	NB	5408	6.0	80	1697	5.0	80
	SB	5422	5.5	80	1672	4.8	80
Brook Street off ramp	NB	820	4.3	60	228	4.5	60
Brook Street on ramp	SB	703	1.3	80	86	3.7	80
Warringah Freeway (east of Miller Street)	WB	6228	5.8	80	1924	5.0	80
	EB	6125	5.0	80	1758	4.7	80
Miller Street off ramp	WB	431	1.8	60	165	3.6	60
Miller Street on ramp	EB	535	0.5	60	138	0.3	60
Warringah Freeway (north of Ernest Street)	NB	5031	4.0	80	1545	3.8	80
Warringah Freeway (north of Ernest St, WHT exit/entry portal)	NB/exit	1627	10.3	80	545	7.8	80
	SB/entry	1062	16.2	80	199	14.8	80
Warringah Freeway (north of Ernest St, WHT exit/entry portal)	NB/exit	609	14.9	80	229	10.1	80
	SB/entry	681	9.5	80	151	11.6	80
Warringah Freeway (north of Ernest Street)	SB	4854	2.6	80	1536	3.4	80
Ernest Street off ramp	NB	385	1.0	50	136	0.7	50
Ernest Street on ramp	SB	405	0.3	60	30	0.2	60
Warringah Freeway (south of Falcon Street)	NB	3673	5.8	80	1223	4.9	80
Warringah Freeway (south of Falcon Street)	NB	1836	3.7	80	597	3.4	80
	SB	1854	3.5	80	641	4.3	80
Warringah Freeway (south of Falcon Street)	SB	4086	3.1	80	1077	3.9	80
Falcon Street off ramp (WHT exit portal)	NB	945	3.8	60	214	5.0	60
Falcon Street off ramp (bus lane)	NB	36	100	60	5	100	60
Military Road off ramp	NB	906	1.1	70	418	0.6	70
Falcon Street on ramp	SB	1738	0.7	80	501	1.1	80
Falcon Street on ramp (bus lane)	SB	43	100	60	6	100	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Berry Street on ramp	NB	517	2.5	80	177	2.1	80
Berry Street on ramp (WHT entry portal)	NB	1089	3.3	60	235	2.4	60
Alfred Street off ramp	SB	1207	2.6	60	335	2.4	60
Warringah Freeway (south of Mount Street)	NB	5898	4.7	80	2061	3.9	80
Warringah Freeway (south of Mount Street)	SB	5403	2.7	70	1727	3.7	70
Cahill Expressway (south of Mount Street)	SB	1068	2.8	70	157	2.2	70
Mount Street on ramp	SB	616	0.3	70	112	1.6	70
Mount Street on ramp (Cahill Expressway)	SB	586	0.3	70	296	0.4	70
Sydney Harbour Tunnel portals	NB/exit	2081	4.0	80	708	3.1	80
	SB/entry	2674	2.7	80	863	3.4	80
Warringah Freeway (south of High Street)	NB	3050	6.0	70	1155	4.9	70
Warringah Freeway (south of High Street)	SB	3344	2.2	70	977	3.7	70
Cahill Expressway (south of High Street)	SB	1654	1.9	70	452	1.0	70
Pacific Highway off ramp	NB	1274	1.7	60	421	2.3	60
High Street on ramp	SB	493	0.0	70	273	0.0	70
Lavender Street off ramp	NB	382	3.1	70	152	3.2	70
Bradfield Highway (south of Lavender Street)	NB	4706	4.6	70	1728	4.1	70
	SB	3344	2.2	70	977	3.7	70
Cahill Expressway (south of Lavender Street)	SB	2147	1.5	70	726	0.7	70
Ernest Street (west of Warringah Freeway)	EB	407	0.3	50	74	0.2	50
	WB	424	0.7	50	93	0.4	50
Ernest Street (between Miller and West Street)	EB	337	0.3	50	72	0.3	50
	WB	431	0.5	50	108	0.4	50
Ernest Street (between West and Sophia Street)	EB	156	0.5	50	43	0.3	50
	WB	387	0.8	50	79	0.6	50
Ernest Street (between Sophia and Alexander Street)	EB	156	0.5	50	43	0.3	50
	WB	156	0.5	50	43	0.3	50
Ernest Street (east of Warringah Freeway)	EB	729	0.5	50	190	0.5	50
	WB	765	0.4	50	102	0.3	50
Ernest Street (between Merlin Street and Park Avenue)	EB	928	0.6	50	309	0.5	50
	WB	800	0.4	50	102	0.3	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Falcon Street (west of Warringah Freeway)	EB	1352	0.6	60	294	0.6	60
	WB	1604	2.5	60	409	3.0	60
Falcon Street (between Miller and West Street)	EB	1110	0.4	60	256	0.4	60
	WB	881	2.3	60	243	1.7	60
Falcon Street (between West and Alexander Street)	EB	1139	0.4	60	278	0.5	60
	WB	689	2.0	60	203	1.2	60
Falcon Street (between Alexander Street and Pacific Highway)	EB	1101	0.5	60	274	0.5	60
	WB	796	1.5	60	248	1.0	60
Falcon Street (east of Warringah Freeway)	WB	2150	1.2	60	651	1.2	60
Falcon Street (between Watson Street and Tramway Lane)	WB	2176	1.1	60	665	1.2	60
Military Road (east of Warringah Freeway)	EB	2239	1.0	60	737	0.7	60
Military Road (between Watson Street and Ben Boyd Road)	EB	1965	1.0	60	624	0.6	60
	WB	2176	1.1	60	665	1.2	60
Military Road (between Ben Boyd Road and Young Street)	EB	1957	1.0	60	645	0.6	60
	WB	1916	1.1	60	603	1.2	60
Military Road (between Young Street and Wycombe Road)	EB	1776	0.9	60	625	0.6	60
	WB	1736	1.1	60	560	1.3	60
Willoughby Road (north of Warringah Freeway)	NB	1222	4.2	60	459	5.3	60
	SB	1283	2.8	60	412	2.4	60
Willoughby Road (south of Warringah Freeway)	NB	335	1.5	60	77	1.2	60
	SB	510	2.2	60	153	2.7	60
Willoughby Road (between Merrenburn Avenue and Dalleys Road)	NB	577	2.7	60	150	2.2	60
	SB	619	2.8	60	149	2.4	60
Willoughby Road (between Dalleys Road and Chandos Street)	NB	562	1.8	60	142	1.1	60
	SB	445	1.7	60	112	1.7	60
Willoughby Road (between Chandos and Atchison Street)	NB	389	1.3	60	104	0.9	60
	SB	488	1.2	60	128	1.5	60
Willoughby Road (between Atchison and Albany Street)	NB	249	1.5	60	36	1.0	60
	SB	232	0.9	60	41	0.7	60
Willoughby Road (between Albany and Holtermann Street)	NB	306	0.7	60	64	0.8	60
	SB	150	0.5	60	45	0.7	60
Willoughby Road (between Holtermann and Falcon Street)	SB	41	0	60	6	0	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Merrenburn Avenue (between Willoughby Road and Brook Street)	EB	307	3.8	50	95	3.9	50
	WB	173	4.4	50	17	4.0	50
Brook Street (between Merrenburn Avenue and Flat Rock Drive)	NB	1006	2.2	50	165	2.6	50
	SB	905	5.4	50	268	5.1	50
Brook Street (between Warringah Freeway on ramp and Merrenburn Avenue)	NB	699	5.5	50	201	5.0	50
	SB	933	1.6	50	176	2.2	50
Brook Street (between Warringah Freeway on and off ramps)	NB	1010	4.0	50	250	4.2	50
	SB	136	2.5	50	29	1.3	50
Brook Street (between Warringah Freeway on ramp and Chandos Street)	NB	545	1.3	50	92	1.5	50
	SB	491	1.2	50	99	1.4	50
Chandos Street (between Alexander and Brook Street)	EB	545	1.3	50	92	1.5	50
	WB	491	1.2	50	99	1.4	50
Chandos Street (between Brook Street and Willoughby Road)	EB	406	1.6	50	57	2.2	50
	WB	333	1.1	50	82	1.7	50
Chandos Street (between Willoughby Road and Oxley Street)	EB	455	2.0	50	61	2.0	50
	WB	167	1.6	50	32	2.1	50
Chandos Street (between Oxley and Christie Street)	EB	248	2.6	50	39	2.5	50
	WB	98	1.0	50	17	2.2	50
Alexander Street (between Brook and Albany Street)	NB	212	1.3	50	59	1.1	50
	SB	230	2.0	50	41	1.2	50
Alexander Street (between Albany and Holtermann Street)	NB	246	1.1	50	56	0.8	50
	SB	230	1.0	50	49	0.6	50
Alexander Street (between Holtermann and Ernest Street)	NB	266	1.0	50	63	0.8	50
	SB	339	0.9	50	88	0.7	50
Alexander Street (between Ernest and Burlington Street)	NB	322	0.9	50	74	0.7	50
	SB	339	1.0	50	77	0.7	50
Alexander Street (between Burlington and Falcon Street)	NB	349	1.1	50	80	0.8	50
	SB	364	0.9	50	86	0.7	50
Alexander Street (between Falcon Street and Pacific Highway)	NB	384	0.7	50	85	0.4	50
	SB	255	1.7	50	43	1.7	50
Albany Street (between Alexander Street and Willoughby Road)	EB	81	0.5	50	22	0.3	50
	WB	101	2.1	50	7	0	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Albany Street (between Willoughby Road and Oxley Street)	EB	133	0.5	50	22	0.3	50
	WB	292	0.8	50	31	0.4	50
Albany Street (between Oxley Street and Pacific Highway)	EB	377	2.6	50	115	2.3	50
	WB	439	2.2	50	85	2.3	50
Amherst Street (west of West Street)	EB	406	1.0	60	109	0.8	60
Amherst Street (between West and Miller Street)	EB	297	0.9	50	103	1.2	50
	WB	86	0.0	50	22	0.0	50
West Street (between Amherst and Ernest Street)	NB	128	1.2	50	39	2.6	50
	SB	318	1.0	50	66	1.3	50
West Street (between Ernest and Falcon Street)	NB	299	1.1	50	66	1.8	50
	SB	327	1.1	50	70	1.3	50
West Street (between Falcon and Ridge Street)	NB	85	2.9	50	18	5.8	50
	SB	335	2.8	50	83	3.2	50
West Street (between Ridge and Church Street)	NB	157	1.9	50	15	3.2	50
	SB	240	1.0	50	56	1.0	50
West Street (between Church Street and Pacific Highway)	NB	157	1.9	50	15	3.2	50
	SB	240	1.0	50	56	1.0	50
Miller Street (between Pine and Amherst Street)	NB	806	2.5	50	217	5.6	50
	SB	857	0.6	50	181	0.5	50
Miller Street (between Amherst Street and Warringah Freeway on ramp)	NB	696	2.2	50	183	5.1	50
	SB	882	0.6	50	177	0.5	50
Miller Street (between Warringah Freeway on and off ramps)	NB	706	2.2	50	184	5.1	50
	SB	357	0.9	50	40	1.2	50
Miller Street (between Warringah Freeway off ramp and Ernest Street)	NB	325	2.3	50	33	10.4	50
	SB	407	0.7	50	54	0.9	50
Miller Street (between Ernest and Falcon Street)	NB	384	1.9	50	51	6.9	50
	SB	387	0.9	50	54	0.9	50
Miller Street (between Falcon and Ridge Street)	NB	308	1.6	50	41	1.0	50
	SB	792	2.3	50	173	2.8	50
Miller Street (between Ridge and McLaren Street)	NB	149	2.8	50	21	4.3	50
	SB	428	2.4	50	77	3.2	50
Miller Street (between McLaren and Berry Street)	NB	417	1.6	50	83	2.4	50
	SB	658	1.9	50	104	2.5	50
Miller Street (between Berry Street and Pacific Highway)	NB	353	1.9	40	70	2.8	40
	SB	202	2.2	40	45	1.0	40

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Walker Street (between Ridge and McLaren Street)	NB	186	0.9	50	27	0.9	50
	SB	553	2.4	50	126	3.4	50
Walker Street (between McLaren and Berry Street)	NB	189	0.9	50	70	1.5	50
	SB	672	2.0	50	208	1.8	50
Walker Street (between Berry and Spring Street)	NB	433	3.1	50	113	2.7	50
	SB	16	1.0	50	2	3.6	50
Ridge Street (between Walker and Miller Street)	EB	553	2.4	50	126	3.4	50
	WB	186	0.9	50	27	0.9	50
Ridge Street (between Miller and West Street)	EB	112	3.1	50	21	4.6	50
	WB	274	3.0	50	44	5.0	50
McLaren Street (between Walker and Miller Street)	EB	383	1.4	50	83	1.6	50
	WB	298	0.4	50	70	0.3	50
McLaren Street (between Miller and Angelo Street)	EB	222	1.8	50	21	1.2	50
	WB	174	0.2	50	43	0.1	50
McLaren Street (between Angelo Street and Pacific Highway)	EB	222	1.8	50	21	1.2	50
	WB	174	0.2	50	43	0.1	50
Berry Street (between Walker and Arthur Street)	EB	2148	2.3	60	666	1.6	60
Berry Street (between Little Spring and Walker Street)	EB	1248	2.0	40	418	1.2	40
Berry Street (between Denison and Little Spring Street)	EB	1401	2.0	40	448	1.2	40
Berry Street (between Miller and Denison Street)	EB	1047	2.6	40	262	2.2	40
Berry Street (between Pacific Highway and Miller Street)	EB	654	3.0	40	215	1.7	40
Spring Street (between Walker and Little Spring Street)	WB	300	1.9	50	100	2.5	50
Spring Street (between Little Spring and Denison Street)	WB	453	1.7	50	130	2.2	50
Denison Street (between Spring and Berry Street)	NB	300	1.9	50	100	2.5	50
Pacific Highway (between Arthur and Walker Street)	NB	2127	1.9	60	545	2.4	60
	SB	1401	0.9	60	401	0.8	60
Pacific Highway (between Walker and Miller Street)	NB	1431	1.6	60	380	1.6	60
	SB	657	0.9	60	114	0.6	60
Pacific Highway (between Miller and William Street)	NB	605	0.6	60	156	0.4	60
	SB	493	0.7	60	92	0.7	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Pacific Highway (between William and Berry Street)	NB	778	1.1	60	202	1.0	60
	SB	493	0.7	60	92	0.7	60
Pacific Highway (between Berry Street and Bay Road)	NB	473	0.6	60	126	0.4	60
	SB	842	2.0	60	232	1.2	60
Pacific Highway (between Bay Road and McLaren Street)	NB	577	0.5	60	148	0.4	60
	SB	796	2.2	60	180	1.6	60
Pacific Highway (between McLaren and West Street)	NB	713	0.5	60	178	0.3	60
	SB	979	2.2	60	188	1.6	60
Pacific Highway (between West Street and Crows Nest Road)	NB	713	0.5	60	178	0.3	60
	SB	895	2.5	60	148	2.0	60
Pacific Highway (between Crows Nest and Rocklands Road)	NB	607	0.5	60	147	0.4	60
	SB	895	2.5	60	148	2.0	60
Pacific Highway (between Rocklands Road and Bruce Street)	NB	711	0.5	60	146	0.4	60
	SB	956	2.2	60	151	2.0	60
Pacific Highway (between Bruce and Alexander Street)	NB	749	0.7	60	152	0.5	60
	SB	1002	2.5	60	161	2.2	60
Pacific Highway (between Alexander and Falcon Street)	NB	485	0.5	60	85	0.5	60
	SB	867	2.4	60	137	2.0	60
Pacific Highway (between Falcon and Hume Street)	NB	583	1.2	60	103	1.0	60
	SB	1165	1.5	60	182	1.4	60
Arthur Street (between Pacific Highway and Mount Street)	NB	1250	1.1	60	386	1.6	60
High Street (west of Warringah Freeway)	EB	697	1.5	70	200	0.7	70
	WB	1079	2.5	70	249	2.8	70
High Street (east of Warringah Freeway)	EB	939	0.5	50	336	0.3	50
	WB	1059	0.2	50	373	0.1	50
Clark Road (between High Street and Adderstone Avenue)	NB	654	0.2	50	255	0.2	50
	SB	765	0.1	50	233	0.1	50
Clark Road (between Adderstone Avenue and Kurraba Road)	NB	522	0.1	50	213	0.1	50
	SB	647	0.1	50	187	0.1	50
Kurraba Road (between Clark Road and Holdsworth Street)	EB	617	0.2	50	217	0.1	50
	WB	634	0.1	50	183	0.1	50
Kurraba Road (between Holdsworth and Ben Boyd Road)	EB	427	0.2	50	158	0.2	50
	WB	499	0.1	50	130	0.1	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Bent Street (between Falcon Street and Alfred Street N)	SB	191	0.2	50	23	0.3	50
Alfred Street N (between Bent Street and Kurraba Road)	SB	191	0.2	50	23	0.3	50
Alfred Street N (between Kurraba Road and Mount Street)	SB	83	0.2	60	15	0.4	60
Alfred Street N (between Mount and High Street)	SB	1521	2.1	60	483	1.7	60
Gore Hill Freeway Connection							
Gore Hill Freeway (north of Willoughby Road)	NB/WB	4320	6.3	80	1248	4.7	80
	SB/EB	4448	6.0	80	1347	5.3	80
Gore Hill Freeway (to / from Longueville Road, east of Hampden Road overpass)	WB	2596	5.4	80	777	4.3	80
	EB	4448	6.0	80	1347	5.3	80
Lane Cove Tunnel (west of Hampden Road overpass)	WB	1725	7.6	80	471	5.4	80
Gore Hill Freeway (west of Hampden Road overpass)	EB	3582	5.7	80	1278	4.8	80
Gore Hill Freeway on ramp (east of Reserve Road overpass)	EB	1056	7.7	60	106	12.4	60
Beaches Link off ramp (to Lane Cove Tunnel)	WB	336	23.4	80	86	20.3	80
Beaches Link on ramp (from Reserve Road)	EB	190	10.0	60	37	10.8	60
Beaches Link on ramp (from Gore Hill Freeway)	EB	610	13.9	80	186	10.1	80
Lane Cove Tunnel (west of Reserve Road overpass)	WB	2061	10.2	80	557	7.7	80
Gore Hill Freeway (west of Reserve Road overpass)	EB	2154	6.9	80	734	5.4	80
Lane Cove Tunnel on ramp (west of Reserve Road overpass)	WB	254	14.9	80	77	8.9	80
Lane Cove Tunnel (west of Reserve Road ramps)	WB	2316	10.7	80	634	7.9	80
	EB	2154	6.9	80	734	5.4	80
Gore Hill Freeway off ramp (east of Reserve Road)	WB	345	9.6	60	58	11.6	60
Gore Hill Freeway (west of Reserve Road overpass)	WB	2251	4.8	80	719	3.7	80
Gore Hill Freeway on ramp (west of Reserve Road)	WB	307	7.9	80	114	6.5	80

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Gore Hill Freeway off ramp (to Pacific Highway)	WB	1095	3.9	60	369	4.2	60
Gore Hill Freeway (west of Pacific Highway overpass)	WB	1463	6.0	60	464	4.1	60
	EB	1200	6.5	60	420	4.6	60
Gore Hill Freeway (east of Pacific Highway overpass, right lane)	EB	327	4.4	60	258	2.9	60
Gore Hill Freeway (east of Pacific Highway overpass, left lane)	EB	873	7.3	60	162	7.4	60
Lane Cove Tunnel off ramp (east of Pacific Highway overpass, to Gore Hill Fwy)	EB	700	15.0	60	219	11.3	60
Gore Hill Freeway off ramp (west of Reserve Road)	EB	962	8.7	80	194	9.3	80
Gore Hill Freeway on ramp (from Pacific Highway)	EB	1101	3.7	60	286	5.2	60
Gore Hill Freeway (after Pacific Highway on ramp)	EB	1428	3.9	80	544	4.1	80
Longueville Road (east of Epping Road)	WB	2263	5.3	60	689	4.1	60
	EB	1743	5.2	60	518	4.1	60
Longueville Road on ramp (from Pacific Highway)	WB	800	3.9	60	225	4.2	60
Longueville Road off ramp (to Pacific Highway)	EB	544	2.1	60	98	1.7	60
Lane Cove Tunnel on ramp, east of Pacific Highway (from Pacific Highway)	EB	301	7.2	60	17	10.7	60
Lane Cove Tunnel off ramp, east of Pacific Highway (to Pacific Highway)	WB	227	5.4	60	44	5.7	60
Pacific Highway (between Campbell Street and Dickson Avenue)	NB	866	2.5	60	99	0.8	60
	SB	805	1.9	60	121	1.0	60
Pacific Highway (between Dickson Avenue and Hotham Parade)	NB	1029	3.7	60	135	3.5	60
	SB	858	1.7	60	131	0.8	60
Pacific Highway (between Hotham Parade and Cobden Avenue)	NB	887	4.2	60	115	4.0	60
	SB	764	1.9	60	113	0.9	60
Pacific Highway (between Cobden Avenue and Gore Hill Freeway overpass)	NB	1033	3.9	60	136	3.6	60
	SB	764	1.9	60	113	0.9	60
Pacific Highway (between Gore Hill Freeway overpass and Gore Hill Freeway ramps)	NB	562	1.5	60	76	1.5	60
	SB	850	2.7	60	195	3.4	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway NB)	NB	282	6.0	60	10	4.9	60
Lane Cove Tunnel on ramp, west of Pacific Highway (from Pacific Highway SB)	SB	19	25.7	60	7	18.9	60
Pacific Highway (between Gore Hill Freeway ramps to Mowbray Road)	NB	1830	3.3	60	485	3.8	60
	SB	1897	3.3	60	477	4.4	60
Hampden Road (between Palmer and Brand Street)	NB	296	3.4	50	102	3.5	50
	SB	458	3.2	50	168	4.6	50
Hampden Road (between Brand Street and Jersey Road)	NB	446	3.5	50	133	3.2	50
	SB	461	3.7	50	153	5.0	50
Hampden Road (between Jersey Road and Cleg Street)	NB	248	2.0	50	76	1.5	50
	SB	235	1.9	50	77	1.9	50
Herbert Street (between Cleg and Frederick Street)	NB	333	4.3	50	93	3.9	50
	SB	427	3.8	50	124	3.1	50
Herbert Street (between Frederick and Ella Street)	NB	461	5.2	50	142	3.3	50
	SB	517	5.0	50	173	4.1	50
Herbert Street (between Ella and Westbourne Street)	NB	265	2.8	50	96	2.6	50
	SB	284	3.5	50	105	3.2	50
Frederick Street (between Herbert Street and Reserve Road)	EB	251	11.9	50	97	8.2	50
	WB	289	10.3	50	98	5.9	50
Campbell Street (between Reserve Road and Pacific Highway)	EB	246	4.6	50	66	3.1	50
	WB	412	4.6	50	97	2.8	50
Cleg Street (between Herbert and Waltham Street)	EB	396	4.3	50	93	3.7	50
	WB	290	5.0	50	62	5.7	50
Waltham Street (between Cleg Street and Dickson Avenue)	NB	0	0	50	0	0	50
	SB	0	0	50	0	0	50
Beaches Link of ramp (to Dickson Avenue)	WB	237	16.8	60	45	23.5	60
Dickson Avenue (between Reserve Road and Pacific Highway)	EB	68	1.4	50	12	0.5	50
	WB	178	10.1	50	38	10.9	50
Reserve Road (between Frederick and Campbell Street)	NB	289	10.3	50	98	5.9	50
	WB	251	11.9	50	97	8.2	50
Reserve Road (between Campbell Street and Dickson Avenue)	NB	801	14.4	50	238	11.7	50
	SB	764	15.2	50	238	14.7	50

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Reserve Road (between Dickson Avenue and Gore Hill Freeway)	NB	865	13.5	50	250	11.2	50
	SB	700	13.4	50	230	12.4	50
Reserve Road (between Gore Hill Freeway and Jersey Road)	NB	395	4.8	50	101	4.8	50
	SB	541	4.3	50	125	6.4	50
Jersey Road (between Reserve and Abbott Road)	EB	322	4.8	50	91	4.6	50
	WB	403	4.6	50	108	6.8	50
Jersey Road (between Abbott and Hampden Road)	EB	291	4.0	50	78	4.1	50
	WB	318	4.1	50	96	6.5	50
Connections to and from Burnt Bridge Creek Deviation							
Manly Road (between Avona Crescent and Heaton Avenue)	NB	1165	2.0	60	423	0.9	60
	SB	1434	2.8	60	460	2.9	60
Manly Road (between Heaton Avenue and Sydney Road)	NB	1165	2.0	60	423	0.9	60
	SB	1403	2.8	60	453	3.0	60
Burnt Bridge Creek Deviation (between Sydney Road and Link Road)	NB	767	2.6	60	270	1.2	60
	SB	841	3.1	60	279	3.8	60
Beaches Link off ramp (to Burnt Bridge Creek Deviation)	NB	1217	10.4	80	399	8.8	80
Beaches Link on ramp (from Burnt Bridge Creek Deviation)	SB	1036	13.1	80	267	15.7	80
Burnt Bridge Creek Deviation (between Link Road and Condamine Street)	NB	1730	8.4	80	616	6.2	80
	SB	1632	9.7	80	497	10.4	80
Condamine Street (between Burnt Bridge Creek Deviation and Kenneth Road)	NB	2006	7.2	60	649	5.6	60
	SB	1936	7.7	60	564	8.4	60
Frenchs Forest Road (between Montauban Avenue and Baringa Avenue)	EB	232	3.3	60	65	1.8	60
	WB	157	0.2	60	19	0	60
Frenchs Forest Road (between Baringa Avenue and Brook Road)	EB	329	2.4	60	97	1.2	60
	WB	146	0.2	60	19	0	60
Frenchs Forest Road (between Brook and Sydney Road)	NB	261	0.1	60	65	0.1	60
	SB	390	2.0	60	107	1.1	60
Sydney Road (between Frenchs Forest Road and Manly Road)	EB	555	1.5	60	146	1.0	60
	WB	283	0.1	60	77	0.1	60
Sydney Road (between Manly Road and Link Road)	EB	554	0.6	60	182	0.3	60
	WB	444	1.4	60	134	1.3	60
Sydney Road (between Link Road and Wanganella Street)	EB	653	0.6	60	197	0.3	60
	WB	534	1.4	60	146	1.6	60

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Sydney Road (between Wanganella and Woodland Street)	EB	722	0.5	60	202	0.3	60
	WB	525	1.3	60	147	1.5	60
Sydney Road (Woodland and Condamine Street)	EB	831	0.5	60	205	0.2	60
	WB	598	0.7	60	159	0.8	60
Wanganella Street (Sydney Road and Kitchener Street)	NB	19	0	50	8	0	50
	SB	181	0.1	50	46	0.3	50
Kitchener Street (between Wanganella and Daisy Street)	EB	359	2.9	50	95	2.7	50
	WB	314	4.5	50	91	2.8	50
Daisy Street (between Kitchener and Woodbine Street)	NB	314	4.5	50	91	2.8	50
	SB	359	2.9	50	95	2.7	50
Woodbine Street (between Daisy and Bangaroo Street)	EB	359	2.9	50	95	2.7	50
	WB	314	4.5	50	91	2.8	50
Woodbine Street (between Bangaroo and Hunter Street)	EB	378	2.8	50	101	2.5	50
	WB	320	4.5	50	97	2.7	50
Maretimo Street (between Ethel and Upper Beach Street)	NB	33	0	50	8	0	50
	SB	35	0	50	8	0	50
Upper Beach Street (between Maretimo and Wanganella Street)	EB	33	0	50	8	0	50
	WB	35	0	50	8	0	50
Connections to and from Wakehurst Parkway							
Wakehurst Parkway (between Lister Avenue and Armstrong Street)	NB	464	1.2	60	128	1.2	60
	SB	401	2.0	60	121	1.0	60
Wakehurst Parkway (between Armstrong Street and Judith Street)	NB	527	1.1	60	142	1.1	60
	SB	450	1.8	60	138	0.9	60
Wakehurst Parkway (between Judith Street and Beaches Link ramps)	NB	723	2.7	80	199	2.1	80
	SB	697	2.6	80	206	1.8	80
Beaches Link off ramp (to Wakehurst Parkway)	NB	961	18.5	80	239	14.9	80
Beaches Link on ramp (from Wakehurst Parkway)	SB	912	19.8	80	161	15.6	80
Wakehurst Parkway (between Beaches Link ramps and Aquatic Drive)	NB	1684	11.7	80	438	9.1	80
	SB	1609	12.3	80	367	7.9	80
Wakehurst Parkway (between Aquatic Drive and Warringah Road)	NB	1612	11.7	70	420	9.0	70
	SB	1584	12.2	70	373	7.7	70

Traffic monitoring location	Direction	Average hourly traffic from 7.00am – 10.00pm (15 hour)			Average hourly traffic from 10.00pm – 7.00am (9 hour)		
		Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)	Total vehicles	Percentage heavy vehicles	Speed[1] (km/h)
Wakehurst Parkway (between Warringah Road and Frenchs Forest Road)	NB	798	9.6	60	284	4.7	60
	SB	972	8.1	60	266	5.4	60
Wakehurst Parkway (north of Frenchs Forest Road)	NB	817	9.3	60	264	5.5	60
	SB	803	9.8	60	313	4.6	60
Warringah Road (between Forest Way and Hilmer Street)	EB	1388	7.0	70	439	6.7	70
	WB	1079	8.5	70	403	6.2	70
Warringah Road (between Hilmer Street and Wakehurst Parkway)	EB	1101	8.4	70	401	6.2	70
	WB	1400	7.0	70	441	6.7	70
Warringah Road (between Wakehurst Parkway and underpass ramps)	EB	757	9.8	70	223	9.4	70
	WB	660	10.1	70	213	12.4	70
Warringah Road underpass (between Forest Road and underpass ramps)	EB	855	4.7	70	239	3.6	70
	WB	898	6.5	70	288	4.7	70
Judith Street to Manning Street (between Wakehurst Parkway and Mons Road)	EB	248	4.2	50	68	3.8	50
	WB	195	7.3	50	56	4.6	50

Notes: 1. Based on posted speeds

2. The 2037 (design year) do something cumulative scenario includes the project, WestConnex, Western Harbour Tunnel and Warringah Freeway Upgrade, Sydney Gateway and the M6 Motorway.

Annexure E Construction support site assessment activities

E.1 BL1 - Cammeray Golf Course construction support site (CGC)

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst-case	OOHW - Reasonable worst-case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Site establishment	CGC_01a	Installation of enviro controls	X	-	Franna crane	1	-	98	102	-
					Bobcat	1	-	107	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
	CGC_01b	Establishment of construction facilities	X	-	Excavator with bucket	2	-	105	108	-
					Franna crane	1	-	98	102	-
					Concrete agitator	4/hr	-	108	-	-
					Concrete pump	1	-	103	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
					Water truck	1	-	98	-	-
					Bobcat	2	-	107	-	-
					Workshop hand tools	2	-	104	-	-
Access decline construction	CGC_02	Piling for access decline, shed and vent tunnels	X	-	Piling rig - bored	2	-	112	115	-
					Concrete pump	1	-	103	-	-
					Excavator with rock hammer	1	-	122[3]	126	YES
					Concrete agitator	4/hr	-	108	-	-
					Ute/light vehicle	10/hr	4/hr	89	-	-
	CGC_03	Access decline and vent tunnel excavation	X	-	Concrete agitator	4/hr	-	108	-	-
					Front end loader	1	-	110	113	-
					Roadheader	-	-	114	-	-
					Truck and dog	8/hr	-	108	117	-
					Franna crane	1	-	98	102	-
					Concrete pump	1	-	103	-	-
					Shotcrete rig - compressor	1	-	104	-	-
	CGC_4	Acoustic shed construction	X	-	Elevated work platform	2	-	102	-	-
					Rattle gun	2	-	99	-	-
					Mobile crane	2	-	110	-	-
					Site forklift	1	-	103	-	-
					Truck	4/hr	-	103	117	-
					Compressor	1	-	100	-	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst-case	OOHW - Reasonable worst-case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Cut and cover support	CGC_05a	Construction support site general activities	X	X	Workshop compressor	1	1[4]	100	-	-
					Welding equipment	1	1[4]	105	-	-
					Ute/light vehicle	10/hr	4/hr	89	-	-
					Truck	4/hr	4/hr	103	117	-
					Generator (enclosed)	1	1	94	-	-
	CGC_05b	Deliveries to site	X	-	Truck	4/hr	-.	103	117	-
					Franna Crane	1	-	98	102	-
Tunnelling	CGC_06a	General site activities	X	X	Workshop compressor	1	1[4]	100	-	-
					Welding equipment	1	1[4]	105	-	-
					Ute/light vehicle	4/hr	4/hr	89	-	-
					Franna crane	1	-	98	102	-
					Generator (enclosed)	1	1	94	-	-
	CGC_06b	Deliveries	X	-	Truck	4/hr	-	103	117	-
					Franna crane	1	-	98	102	-
	CGC_06c	Tunnelling and support	X	X	Roadheader	UG	UG	114	-	-
					Dust scrubber	UG	UG	-	-	-
					Ventilation fans (mitigated)	Note 1	Note 1	98	-	-
					Substation	1	1	90	-	-
					Water treatment pumps	2	2	98	-	-
					Concrete pump	UG	UG	103	-	-
					Tracked mobile drilling rig	-	-	120	-	YES
	CGC_06d	Tunnel lining (concreting)	X	X	Concrete pump	UG	UG	103	-	-
					Concrete agitator	Note 2	Note 2	108	-	-
					Pneumatic vibrator	UG	UG	97	-	-
	CGC_06e	Spoil handling in acoustic shed	X	X	Articulated dump truck (spoil out of tunnel)	UG	UG	108	-	-
					Front end loader	1	1[4]	110	113	-
		Spoil haulage	X	-	Dump truck	Note 2	-	108	117	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst-case	OOHW - Reasonable worst-case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Tunnel fitout and finishing	CGC_07a	Deliveries to site	X	X	Deliveries to site	4/hr	4/hr	103	117	-
	CGC_07b	Tunnel fitout – laydown areas	X	-	Workshop hand tools	1	-	-	104	-
					Ute/light vehicle	10/hr	-	89	-	-
					Elevated work platform	1	-	102	-	-
					Franna crane	1	-	98	102	-
Remove spoil shed and build motorway facilities buildings	CGC_08a	Remove spoil shed	X	-	Front end loader	1	-	110	113	-
					Franna crane	1	-	98	102	-
					Truck	4/hr	-	103	117	-
	CGC_08b	Build ventilation outlet and motorway facilities buildings	X	-	Elevated work platform	2	-	102	-	-
					Rattle gun	2	-	99	-	-
					Mobile crane	2	-	110	-	-
					Site forklift	1	-	103	-	-
					Truck	4/hr	-	103	117	-
					Compressor	1	-	100	-	-
Motorway facilities building fitout	CGC_09	Deliveries to site	X	-	Workshop hand tools	2	-	104	-	-
					Truck	4/hr	-	103	117	-
					Ute/light vehicle	4/hr	-	89	-	-
					Elevated work platform	1	-	102	-	-
					Franna crane	1	-	98	102	-
Demobilisation and rehabilitation	CGC_10	Site rehabilitation	X	-	Front end loader	1	-	110	113	-
					10t dump truck	4/hr	-	100	115	-
					Elevated work platform	2	-	102	-	-
					Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	4/hr	-	89	-	-
					Backhoe	1	-	100	104	-
					Franna crane	1	-	98	102	-

Notes:
1. The number of fans are equivalent to the number of roadheaders supported by the site.
2. Refer to the construction traffic assessment within the construction support site assessment for the number of heavy vehicles assessed during this stage.
3. In accordance with the ICNG, a 5 dBA 'penalty' is applied for activities identified as particularly annoying, such as rock hammer and concrete saw.
4. Assumed to take place within the acoustic shed. Deliveries and laydown activities would go directly into and occur within the acoustic shed.

UG = Source located underground and assumed to not contribute to airborne noise emissions.

E.2 BL2 - Flat Rock Drive construction support site (FRD)

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Early works	FRD_01	Utility works	X	-	Vacuum truck	1	-	108	-	-
					Excavator with rock hammer	1	-	122[3]	126	YES
Site establishment	FRD_02a	Installation of enviro controls	X	-	Franna crane	1	-	98	102	-
					Bobcat	1	-	107	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
	FRD_02b	Clearing and grubbing works	X	-	Excavator with bucket	2	-	102	108	-
					Elevated work platform	1	-	102	-	-
					Chainsaw (electric)	1	-	111	-	-
					Tub grinder/mulcher	1	-	114	124	-
					Dump truck	4/hr	-	108	117	-
	FRD_02c	Establishment of construction facilities	X	-	Excavator with bucket	2	-	105	108	-
					Franna crane	1	-	98	102	-
					Concrete agitator	4/hr	-	108	-	-
					Concrete pump	1	-	103	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
					Water truck	1	-	98	-	-
					Bobcat	2	-	107	-	-
					Workshop hand tools	2	-	104	-	-
	FRD_02d	Road and intersection modifications and installation of traffic controls	X	-	Truck	1	-	103	117	-
					Scissor lift	1	-	102	-	-
					Franna crane	1	-	98	102	-
					Line marking truck	1	-	108	117	-
Road works	FRD_03	Road widening	X	X	Pavement laying machine	1	1	114	117	-
					Line marking truck	1	1	108	117	-
					Truck	4/hr	4/hr	103	117	-
					Scissor lift	1	1	102	-	-
					Franna crane	1	1	98	102	-
					Road saw	1	1	121[3]	121	-
					Excavator with rock hammer	1	-	122[3]	126	YES

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Access decline construction	FRD_04	Piling for excavation shaft or spoil shed	X	-	Piling rig - bored	2	-	112	115	-
					Concrete pump	1	-	103	-	-
					Excavator with bucket	1	-	105	108	-
					Concrete agitator	4/hr	-	108	-	-
	FRD_05	Access decline excavation and construction	X	-	Concrete agitator	4/hr	-	108	-	-
					Front end loader	1	-	110	113	-
					Roadheader	-	-	114	-	-
					Tracked mobile drilling rig	-	-	120	-	YES
					Excavator with rock hammer	1	-	122	126	YES
					Truck and dog	8/hr	-	108	117	-
					Franna crane	1	-	98	102	-
					Concrete pump	1	-	103	-	-
					Shotcrete rig - compressor	1	-	104	-	-
	FRD_06	Acoustic shed construction	X	-	Elevated work platform	2	-	102	-	-
					Rattle gun	2	-	99	-	-
					Mobile crane	2	-	110	-	-
					Site forklift	1	-	103	-	-
					Truck	4/hr	-	103	117	-
					Compressor	2	-	100	-	-
Tunnel construction	FRD_07a	General site activities	X	X	Site forklift	1	1[4]	103	-	-
					Workshop hand tools	1	1[4]	104	-	-
					Franna crane	1	1[4]	98	102	-
					Ute/light vehicle	4/hr	-	89	-	-
					Workshop compressor	1	2[4]	100	-	-
					Wastewater treatment pumps	2	2	82	-	-
					Substation	1	1	75	-	-
	FRD_07b	Deliveries	X	-	Truck	4/hr	-	103	117	-
					Franna crane	1	-	98	102	-
	FRD_07c	Tunnelling and support	X	X	Roadheader	UG	UG	114	-	-
					Dust scrubber	UG	UG	-	-	-
					Ventilation fans (mitigated)	Note 1	Note 1	85	-	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Tunnel construction (*continued*)	FRD_07c	Tunnelling and support (*continued*)			Concrete pump	UG	UG	103	-	-
					Tracked mobile drilling rig	-	-	120	-	YES
	FRD_07d	Tunnel lining (concreting)	X	X	Concrete pump	UG	UG	103	-	-
					Concrete agitator	Note 2	Note 2	108	-	-
					Pneumatic vibrator	UG	UG	97	-	-
	FRD_07e	Spoil handling in acoustic shed	X	X	Articulated dump truck (spoil out of tunnel)	UG	UG	108	-	-
					Front end loader	1	1[4]	110	113	-
	FRD_07f	Spoil haulage	X	-	Dump truck	Note 2	-	108	117	-
Tunnel fitout	FRD_08a	Deliveries	X	X	Truck	4/hr	4/hr	103	117	-
					Franna crane	1	-	98	102	-
	FRD_08b	Laydown areas	X	-	Site forklift	1	-	103	-	-
					Ute/light vehicle	4/hr	-	89	-	-
					Workshop hand tools	2	-	104	-	-
Tunnel commission and site rehabilitation	FRD_09	Decommission and rehabilitate site	X	-	Front end loader	1	-	110	113	-
					10t dump truck	4/hr	-	100	115	-
					Elevated work platform	2	-	102	-	-
					Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	8/hr	-	89	-	-
					Backhoe	1	-	100	104	-
					Franna crane	1	-	98	102	-

Notes:
1. The number of fans are equivalent to the number of roadheaders supported by the site.
2. Refer to the construction traffic assessment within the construction support site assessment for the number of heavy vehicles assessed during this stage.
3. In accordance with the ICNG, a 5 dBA 'penalty' is applied for activities identified as particularly annoying, such as rock hammer and concrete saw.
4. Assumed to take place within the acoustic shed. Deliveries and laydown activities would go directly into and occur within the acoustic shed.

UG = Source located underground and assumed to not contribute to airborne noise emissions.

E.3 BL3 - Punch Street construction support site (PUN)

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Early works	PUN_01	Utility works	X	-	Vacuum truck	1	-	108	-	-
					Excavator with rock hammer	1	-	122[3]	126	YES
Site establishment	PUN_02a	Installation of enviro controls	X	-	Franna crane	1	-	98	102	-
					Bobcat	1	-	107	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
	PUN_02b	Demolition of existing structures	X	-	Excavator with bucket	1	-	105	108	-
					Excavator with rock hammer	2	-	122[3]	126	YES
					Truck and dog	8/hr	-	108	117	-
	PUN_02c	Establishment of construction facilities	X	-	Excavator with bucket	2	-	105	108	-
					Franna crane	1	-	98	102	-
					Concrete agitator	4/hr	-	108	-	-
					Concrete pump	1	-	103	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
					Water truck	1	-	98	-	-
					Workshop hand tools	2	-	104	-	-
Access decline construction	PUN_03a	Piling for excavation shaft or spoil shed	X	-	Piling rig - bored	1	-	112	115	-
					Concrete pump	1	-	103	-	-
					Excavator with bucket	1	-	105	108	-
					Concrete agitator	4/hr	-	108	-	-
	PUN_03b	Access decline excavation and construction	X	-	Concrete agitator	4/hr	-	108	-	-
					Front end loader	1	-	110	113	-
					Roadheader	-	-	114	-	-
					Tracked mobile drilling rig	-	-	120	-	YES
					Excavator with rock hammer	1	-	122	126	YES
					Truck and dog	8/hr	-	108	117	-
					Franna crane	-	-	98	102	-
					Concrete pump	1	-	103	-	-
					Shotcrete rig – compressor	1	-	104	-	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Access decline construction (*continued*)	PUN_03c	Acoustic shed construction	X	-	Elevated work platform	2	-	102	-	-
					Rattle gun	2	-	99	-	-
					Mobile crane	1	-	110	-	-
					Site forklift	1	-	103	-	-
					Truck	4/hr	-	103	117	-
					Compressor	1	-	100	-	-
Tunnel construction	PUN_04a	General site activities	X	X	Site forklift	1	1[4]	103	-	-
					Workshop hand tools	1	1[4]	104	-	-
					Franna crane	1	1[4]	98	102	-
					Ute/light vehicle	4/hr	-	89	-	-
					Workshop compressor	1	2[4]	100	-	-
					Wastewater treatment pumps	2	2	98	-	-
					Substation	1	1	90	-	-
	PUN_04b	Deliveries	X	-	Truck	4/hr	-	103	117	-
					Franna crane	1	-	98	102	-
	PUN_04c	Tunnelling and support	X	X	Roadheader	UG	UG	114	-	-
					Dust scrubber	UG	UG	-	-	-
					Ventilation fans (mitigate)	Note 1	Note 1	98	-	-
					Concrete pump	UG	UG	103	-	-
					Tracked mobile drilling rig	-	-	120	-	YES
	PUN_04d	Tunnel Lining (concreting)	X	X	Concrete pump	UG	UG	103	-	-
					Concrete agitator	Note 2	Note 2	108	-	-
					Pneumatic vibrator	UG	UG	97	-	-
	PUN_04e	Spoil handling	X	X	Articulated dump truck (spoil out of tunnel)	UG	UG	108	-	-
					Front end loader	1	1[4]	110	113	-
		Spoil haulage	X	-	Dump truck	Note 2	-	108	117	-
Tunnel fitout	PUN_05a	Deliveries	X	X	Truck	4/hr	4/hr	103	117	-
					Franna crane	1	-	98	102	-
	PUN_05b	Laydown areas	X	-	Site forklift	1	-	103	-	-
					Ute/light vehicle	4/hr	-	89	-	-
					Workshop hand tools	2	-	104	-	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Construction of operational facilities	PUN_06	Build operational motorway facilities	X	-	Concrete pump	1	-	103	-	-
					Concrete agitator	4/hr	-	108	-	-
					Pneumatic vibrator	2	-	97	-	-
					Workshop hand tools	4	-	104	-	-
					Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	8/hr	-	89	-	-
					Elevated work platform	1	-	102	-	-
					Franna crane	1	-	98	102	-
Tunnel commission and site rehabilitation	PUN_07	Site rehabilitation	X	-	Front end loader	1	-	110	113	-
					10t dump truck	4/hr	-	100	115	-
					Elevated work platform	2	-	102	-	-
					Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	8/hr	-	89	-	-
					Backhoe	1	-	100	104	-
					Franna crane	1	-	98	102	-

Notes:
1. The number of fans are equivalent to the number of roadheaders supported by the site.
2. Refer to the construction traffic assessment within the construction support site assessment for the number of heavy vehicles assessed during this stage.
3. In accordance with the ICNG, a 5 dBA 'penalty' is applied for activities identified as particularly annoying, such as rock hammer and concrete saw.
4. Assumed to take place within the acoustic shed. Deliveries and laydown activities would go directly into and occur within the acoustic shed.

UG = Source located underground and assumed to not contribute to airborne noise emissions.

E.4 BL7 and BL8 - Middle Harbour crossing construction support site (MHC)

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Build Middle Harbour north cofferdam	MHC_01	Piling for cofferdams	X	-	23 tonne hammer piling rig	1	-	129	-	YES
					Compressor	4	-	100	-	-
Build Middle Harbour south cofferdam	MHC_02				Concrete pump	1	-	103	1	-
Dewater cofferdams	MHC_03	Pumping water	X	X	Water pump on pontoon (enclosed or treated)	1	1	82	85	-
Excavate cofferdams	MHC_04	Remove soil and rock from cofferdams	X	-	Excavator with large rock hammer (north cofferdam)	2	-	124	126	YES
					Excavator with large rock hammer (south cofferdam)	2	-	124	126	YES
					Excavator with bucket	1	-	105	-	-
					Crawler crane on barge	2	-	106	-	-
					Concrete pump	1	-	103	-	-
Pile temporary mooring facility east of Clive Park	MHC_05	Pile moorings	X	-	Screw piling rig	1	-	117	-	-
Cast interface structures	MHC_06	Cast concrete interface structures	X	-	Crane on barge	1	-	106	-	-
					Concrete agitator	1	-	108	-	-
					Concrete pump	1	-	103	-	-
Remove cofferdams	MHC_07	Inundate and remove cofferdams	X	X	Water pump on pontoon (enclosed or treated)	1	1	82	85	-
Prepare foundations	MHC_08	Dredge and place gravel foundations	X	X	Backhoe dredge on barge	1	-	110	-	-
Pile foundations	MHC_09	Piling for cofferdams	X	-	23 tonne hammer piling rig	1	-	129	-	YES
					Concrete pump	1	-	103	1	-
Immerse tunnel units	MHC_10	Immerse and connect tube tunnel units	X	X	Immersion pontoon, crane/equipment/plant on barge or sea lock barge	2	2	106	120	-

Notes: 1. In accordance with the ICNG, a 5 dBA 'penalty' is applied for activities identified as particularly annoying, such as rock hammer, impact piling and concrete saw.

E.5 BL9 - Spit West Reserve construction support site (SMH)

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Early works	SMH_01	Utility works	X	-	Vacuum truck	1	-	108	-	-
					Excavator with rock hammer	1	-	122[1]	126	YES
Establish site	SMH_02	Installation of enviro controls	X	-	Franna crane	1	-	98	102	-
					Bobcat	1	-	107	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
Construct office and wharf	SMH_03a	Piling for wharves	X	-	Piling rig - vibratory	1	-	116	125	-
					Concrete pump	1	-	103	-	-
					Excavator with bucket	1	-	105	108	-
					Concrete agitator	4/hr	-	108	-	-
	SMH_03b	Establishment of construction facilities	X	-	Excavator with bucket	2	-	105	108	-
					Franna crane	1	-	98	102	-
					Concrete agitator	4/hr	-	108	-	-
					Concrete pump	1	-	103	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
					Water truck	1	-	98	-	-
					Bobcat	2	-	107	-	-
					Workshop hand tools	2	-	104	-	-
Support dredging, pile installation and cofferdam/ interface structure	SMH_04	Crane barge and truck activities	X	-	Crane and barge	1	-	106	-	-
					Franna crane	1	-	98	102	-
					Truck	4/hr	-	103	117	-
Immersed tube tunnel unit casting and fitout	SMH_05a	Concrete pour	X	-	Concrete agitator	4/hr	-	108	-	-
					Concrete pump	1	-	103	-	-
					Concrete vibrators	2	-	106	-	-
					Generator (enclosed)	1	-	94	-	-
					Workshop compressor	-	-	100	-	-
	SMH_05b	Deliveries to site	X	-	Truck	4/hr	-	103	117	-
					Franna crane	1	-	98	102	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Immersed tube tunnel fitout (*continued*)	SMH_05c	Immersed tube tunnel unit precast facility - install bulkheads/ ballast system	X	-	Elevated work platform	1	-	102	-	-
					Crane and barge	1	-	106	-	-
					Mobile crane	1	-	110	-	-
					Generator (enclosed)	1	-	94	-	-
					Compressor	1	-	100	-	-
Tube tunnel immersion construction support	SMH_06	Support tunnel unit immersion	X	X	Crane and barge	1	1	106	-	-
					Franna crane	1	1	98	102	-
					Truck	4/hr	4/hr	103	117	-
Site rehabilitation	SMH_07	Decommission site and return to existing use	X	-	Front end loader	1	-	110	113	-
					10t dump truck	4/hr	-	100	115	-
					Elevated work platform	2	-	102	-	-
					Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	8/hr	-	89	-	-
					Backhoe	1	-	100	104	-
					Franna crane	1	-	98	102	-

Notes: 1. In accordance with the ICNG, a 5 dBA 'penalty' is applied for activities identified as particularly annoying, such as rock hammer and concrete saw.

E.6 BL10 - Balgowlah Golf Course construction support site (BAL)

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Early works	BAL_01	Utility Works	X	-	Vacuum truck	1	-	108	-	-
					Excavator with rock hammer	1	-	122[3]	126	YES
Site establishment	BAL_02a	Installation of enviro controls	X	-	Franna crane	1	-	98	102	-
					Bobcat	1	-	107	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
	BAL_02b	Clearing and grubbing	X	-	Excavator with bucket	1	-	105	108	-
					Chainsaw	1	-	116	-	-
					Tub grinder/mulcher	1	-	119	124	-
					Dump truck	4/hr	-	108	117	-
	BAL_02c	Demolition of existing structures	-	-	Excavator with bucket	1	-	105	108	-
					Excavator with rock hammer	2	-	122[3]	126	YES
					Truck and dog	8/hr	-	108	117	-
	BAL_03	Road and intersection modifications and installation of traffic controls	X	-	Truck	1	1	103	117	-
					Scissor lift	1	1	102	-	-
					Franna crane	1	1	98	102	-
					Line marking truck	1	1	108	117	-
	BAL_04	Bulk earthworks	X	-	Bulldozer	1	-	116	-	YES
					Scraper	-	-	110	-	-
					Excavator with bucket	1	-	105	108	-
					Grader	-	-	113	-	-
					Dump truck	4/hr	-	108	117	-
					Truck	4/hr	-	103	117	-
					Compactor	-	-	108	-	-
					Roller	2	-	109	-	-
					Water truck	1	-	98	-	-
					Road sweeper	1	-	104	-	-
Tunnel access construction	BAL_05	Access decline excavation and construction	X	-	Concrete agitator	4/hr	-	108	-	-
					Front end loader	1	-	110	113	-
					Roadheader	-	-	114	-	-
					Tracked mobile drilling rig	-	-	120	-	YES

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Tunnel access construction (*continued*)	BAL_05	Access decline excavation and construction (*continued*)			Excavator with rock hammer	1	-	122[3]	126	YES
					Truck and dog	8/hr	-	108	117	-
					Franna crane	1	-	98	102	-
					Concrete pump	1	-	103	-	-
					Shotcrete rig - compressor	1	-	104	-	-
	BAL_06	Establishment of construction facilities	X	-	Excavator with bucket	2	-	105	108	-
					Franna crane	1	-	98	102	-
					Concrete agitator	4/hr	-	108	-	-
					Concrete pump	1	-	103	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
					Water truck	1	-	98	-	-
					Bobcat	2	-	107	-	-
					Workshop hand tools	2	-	104	-	-
	BAL_07	Piling for excavation shaft or spoil shed	X	-	Piling rig - bored	2	-	112	115	-
					Concrete pump	1	-	103	-	-
					Excavator with bucket	1	-	105	108	-
					Concrete agitator	4/hr	-	108	-	-
	BAL_08	Acoustic shed construction	X	-	Elevated work platform	2	-	102	-	-
					Rattle gun	2	-	99	-	-
					Mobile crane	2	-	110	-	-
					Site forklift	1	-	103	-	-
					Truck	4/hr	-	103	117	-
					Compressor	1	-	100	-	-
Surface road works support	BAL_09	Deliveries and laydown	X	X	Compressor	1	-	100	-	-
					Site forklift	1	-	103	-	-
					Franna crane	1	1	98	102	-
					Truck (concrete agitator)	1/hr	1/hr	108	117	-
Tunnel construction (tunnel support)	BAL_10a	General site activities	X	X	Site forklift	1	1[4]	103	-	-
					Workshop hand tools	1	1[4]	104	-	-
					Franna crane	1	1[4]	98	102	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Tunnel construction (tunnel support) (*continued*)	BAL_10a (*continued*	General site activities (*continued*			Ute/light vehicle	4/hr	-	89	-	-
					Workshop compressor	1	2[4]	100	-	-
					Wastewater treatment pumps	2	2	98	-	-
					Substation	1	1	90	-	-
	BAL_10b	Deliveries	X	-	Truck	4/hr	-	103	117	-
					Franna crane	1	-	98	102	-
	BAL_10c	Tunnelling and support			Roadheader	UG	UG	114	-	-
					Dust scrubber	UG	UG	-	-	-
			X	-	Ventilation fans (mitigated)	Note 1	Note 1	98	-	-
					Concrete pump	UG	UG	103	-	-
					Tracked mobile drilling rig	-	-	120	-	YES
	BAL_10d	Spoil handling	X	X	Articulated dump truck (spoil out of tunnel)	UG	UG	108	-	-
					Front end loader	1	1[4]	110	113	-
		Spoil haulage	X	-	Dump truck	Note 2	Note 2	108	117	-
	BAL_10e	Tunnel lining (concreting)	X	X	Concrete pump	UG	UG	103	-	-
					Concrete agitator	Note 2	Note 2	108	-	-
					Pneumatic vibrator	UG	UG	97	-	-
Tunnel fitout	BAL_11a	Laydown areas	X	-	Site forklift	1	-	103	-	-
					Ute/light vehicle	4/hr	-	89	-	-
					Workshop hand tools	2	-	104	-	-
	BAL_11b	Deliveries	X	X	Truck	4/hr	4/hr	103	117	-
					Franna crane	1	-	98	102	-
Batch plant operations	BAL_12	Concrete batch plant			Front end loader	1	-	110	113	-
					Concrete agitator	1	-	108	-	-
			X	-	Generator (enclosed)	1	-	94	-	-
					Concrete batch plant	1	-	111	123	-
					Cement delivery truck	1	-	105	117	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Golf course north works	BAL_13	Support earthworks (no rock hammer)	X	-	Excavator with bucket	3	-	105	108	-
					Grader	1	-	113	-	-
					Dump truck	8/hr	-	108	117	-
					Water truck	1	-	98	-	-
					Roller	2	-	109	-	YES
					Bulldozer	1	-	116	-	-
Operational facilities construction	BAL_14	Operational motorway facilities construction	X	-	Concrete pump	1	-	103	-	-
					Concrete agitator	4/hr	-	108	-	-
					Pneumatic vibrator	2	-	97	-	-
					Workshop hand tools	4	-	104	-	-
					Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	8/hr	-	89	-	-
					Elevated work platform	1	-	102	-	-
					Franna crane	1	-	98	102	-
Tunnel commission and site rehabilitation	BAL_15	Removal of spoil shed	X	-	Truck	4/hr	-	103	117	-
					Workshop hand tools	4	-	104	-	-
					Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	8/hr	-	89	-	-
					Elevated work platform	1	-	102	-	-
					Franna crane	1	-	98	102	-
	BAL_16	Decommission and site rehabilitation	X	-	Front end loader	1	-	110	113	-
					10t dump truck	4/hr	-	100	115	-
					Elevated work platform	2	-	102	-	-
					Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	8/hr	-	89	-	-
					Backhoe	1	-	100	104	-
					Franna crane	1	-	98	102	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Golf course south works, new oval and new field (Construct new oval)	BAL_17	Support earthworks (no rock hammer)	X	-	Excavator with bucket	3	-	105	108	-
					Grader	1	-	113	-	-
					Dump truck	8/hr	-	108	117	-
					Water truck	1	-	98	-	-
					Roller	2	-	109	-	YES
					Bulldozer	1	-	116	-	-
Golf course south works, new oval and new field (Construct new field)	BAL_18	Support earthworks (no rock hammer)	X	-	Excavator with bucket	3	-	105	108	-
					Grader	1	-	113	-	-
					Dump truck	8/hr	-	108	117	-
					Water truck	1	-	98	-	-
					Roller	2	-	109	-	YES
					Bulldozer	1	-	116	-	-

Notes:
1. The number of fans are equivalent to the number of roadheaders supported by the site.
2. Refer to the construction traffic assessment within the construction support site assessment for the number of heavy vehicles assessed during this stage.
3. In accordance with the ICNG, a 5 dBA 'penalty' is applied for activities identified as particularly annoying, such as rock hammer and concrete saw.
4. Assumed to take place within the acoustic shed. Deliveries and laydown activities would go directly into and occur within the acoustic shed.

UG = Source located underground and assumed to not contribute to airborne noise emissions.

E.7 BL12 - Wakehurst Parkway south construction support site (WPS)

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Early works	WPS_01a	Utility works	X	-	Vacuum Truck	1	-	108	-	-
					Excavator with rock hammer	1	-	122[1]	126	YES
	WPS_01b	Demolition of existing structures (non-rock hammering)	X	-	Excavator with bucket	1	-	105	108	-
					Excavator with pulveriser	2	-	108	-	-
					Truck and Dog	8/hr	-	108	117	-
Establish site	WPS_02a	Installation of environmental controls	X	-	Franna Crane	1	-	98	102	-
					Bobcat	1	-	107	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
	WPS_02b	Clearing and grubbing	X	-	Excavator with bucket	1	-	105	108	-
					Chainsaw	1	-	116	-	-
					Tub grinder/mulcher	1	-	119	124	-
					Dump truck	4/hr	-	108	117	-
	WPS_02c	Road and intersection modifications and install traffic controls.	X	-	Truck	1	-	103	117	-
					Scissor Lift	1	-	102	-	-
					Franna Crane	1	-	98	102	-
					Line marking truck	1	-	108	117	-
	WPS_02d	Establish construction facilities	X	-	Excavator with bucket	2	-	105	108	-
					Franna Crane	1	-	98	102	-
					Concrete agitator	4/hr	-	108	-	-
					Concrete Pump	1	-	103	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
					Water truck	1	-	98	-	-
					Bobcat	2	-	107	-	-
					Workshop Hand Tools	2	-	104	-	-
Support surface road works	WPS_03a	Construction support site general activities	X	-	Workshop compressor	1	-	100	-	-
					Welding equipment	1	-	105	-	-
					Ute/light vehicle	4/hr	4/hr	89	-	-
					Truck	4/hr	-	103	117	-
					Generator (enclosed)	1	-	94	-	-
					Ute/light vehicle	10/hr	-	89	-	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Support surface road works (*continued*)	WPS_03b	Deliveries to site	X	-	Truck	4/hr	-.	103	117	-
					Franna Crane	1	-	98	102	-
Support ventilation outlet and motorway facilities construction	WPS_04a	Construction support site general activities	X	-	Workshop compressor	1	-	100	-	-
					Welding equipment	1	-	105	-	-
					Ute/light vehicle	4/hr	4/hr	89	-	-
					Truck	4/hr	-	103	117	-
					Generator (enclosed)	1	-	94	-	-
					Ute/light vehicle	10/hr	-	89	-	-
	WPS_04b	Deliveries to site	X	-	Truck	4/hr	-	103	117	-
					Franna Crane	1	-	98	102	-
Site rehabilitation	WPS_05	Decommission and rehabilitate site	X	-	Front End Loader	1	-	110	113	-
					10t dump truck	4/hr	-	100	115	-
					Elevated Work Platform	2	-	102	-	-
					Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	8/hr	-	89	-	-
					Backhoe	1	-	100	104	-
					Franna Crane	1	-	98	102	-

Notes: 1. In accordance with the ICNG, a 5 dBA 'penalty' is applied for activities identified as particularly annoying, such as rock hammer and concrete saw.

E.8 BL13 - Wakehurst Parkway east construction support site (WPE)

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Early works	WPE_01	Utility works	X	-	Vacuum truck	1	-	108	-	-
					Excavator with rock hammer	1	-	122[3]	126	YES
Site establishment	WPE_02a	Installation of enviro controls	X	-	Franna crane	1	-	98	102	-
					Bobcat	1	-	107	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
	WPE_02b	Clearing and grubbing	X	-	Excavator with bucket	1	-	105	108	-
					Chainsaw	1	-	116	-	-
					Tub grinder/mulcher	1	-	119	124	-
					Dump truck	4/hr	-	108	117	-
	WPE_02c	Road and intersection modifications and installation of traffic controls.	X	X	Truck	1	1	103	117	-
					Scissor lift	1	1	102	-	-
					Franna crane	1	1	98	102	-
					Line marking truck	1	1	108	117	-
Tunnel access construction	WPE_03	Establishment of construction facilities	X	-	Excavator with bucket	2	-	105	108	-
					Franna crane	1	-	98	102	-
					Concrete agitator	4/hr	-	108	-	-
					Concrete pump	1	-	103	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
					Water truck	1	-	98	-	-
					Bobcat	2	-	107	-	-
					Workshop hand tools	2	-	104	-	-
	WPE_04	Piling for excavation shaft or spoil shed	X	-	Piling rig - bored	2	-	112	115	-
					Concrete pump	1	-	103	-	-
					Excavator with bucket	1	-	105	108	-
					Concrete agitator	4/hr	-	108	-	-
	WPE_05	Acoustic shed construction	X	-	Elevated work platform	2	-	102	-	-
					Rattle gun	2	-	99	-	-
					Mobile crane	2	-	110	-	-
					Site forklift	1	-	103	-	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Tunnel access construction (*continued*)	WPE_05 (*continue*)	Acoustic shed construction *continued*)			Truck	4/hr	-	103	117	-
					Compressor	1	-	100	-	-
Tunnel construction (tunnel support)	WPE_06a	General site activities	X	X	Site forklift	1	1[4]	103	-	-
					Workshop hand tools	1	1[4]	104	-	-
					Franna crane	1	-	98	102	-
					Ute/light vehicle	4/hr	-	89	-	-
					Workshop compressor	1	2[4]	100	-	-
					Wastewater treatment pumps	2	2	98	-	-
					Substation	1	1	90	-	-
	WPE_06b	Deliveries	X	X	Truck	4/hr	4/hr	108	117	-
					Franna crane	1	-	98	102	-
	WPE_06c	Tunnelling and support	X	-	Roadheader	UG	UG	114	-	-
					Dust scrubber	UG	UG	-	-	-
					Ventilation fans (mitigated)	Note 1	Note 1	98	-	-
					Concrete pump	UG	UG	103	-	-
					Tracked mobile drilling rig	-	-	120	-	YES
	WPE_06d	Spoil handling	X	X	Articulated dump truck (spoil out of tunnel)	UG	UG	108	-	-
					Front end loader	1	1[4]	110	113	-
		Spoil haulage	X	-	Dump truck	Note 2	Note 2	108	117	-
	WPE_06e	Tunnel lining (concreting)	X	X	Concrete pump	UG	UG	103	-	-
					Concrete agitator	Note 2	Note 2	108	-	-
					Pneumatic vibrator	UG	UG	97	-	-
Tunnel fitout	WPE_07a	Laydown areas	X	-	Site forklift	1	-	103	-	-
					Ute/light vehicle	4/hr	-	89	-	-
					Workshop hand tools	2	-	104	-	-
	WPE_07b	Deliveries	X	X	Truck	4/hr	4/hr	103	117	-
					Franna crane	1	-	98	102	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Removal of spoil shed	WPE_08	Removal of spoil shed	X	-	Truck	4/hr	-	103	117	-
					Workshop hand tools	4	-	104	-	-
					Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	8/hr	-	89	-	-
					Elevated work platform	1	-	102	-	-
					Franna crane	1	-	98	102	-
Tunnel commission and site rehabilitation	WPE_09	Decommission and rehabilitate site	X	-	Front end loader	1	-	110	113	-
					10t dump truck	4/hr	-	100	115	-
					Elevated work platform	2	-	102	-	-
					Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	8/hr	-	89	-	-
					Backhoe	1	-	100	104	-
					Franna crane	1	-	98	102	-

Notes:
1. The number of fans are equivalent to the number of roadheaders supported by the site.
2. Refer to the construction traffic assessment within the construction support site assessment for the number of heavy vehicles assessed during this stage.
3. In accordance with the ICNG, a 5 dBA 'penalty' is applied for activities identified as particularly annoying, such as rock hammer and concrete saw.
4. Assumed to take place within the acoustic shed. Deliveries and laydown activities would go directly into and occur within the acoustic shed.

UG = Source located underground and assumed to not contribute to airborne noise emissions.

E.9 BL14 - Wakehurst Parkway north construction support site (WPN)

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Early works	WPN_01	Utility works	X	-	Vacuum truck	1	-	108	-	-
					Excavator with rock hammer	1	-	122[1]	126	YES
Site establishment	WPN_02	Establishment of construction facilities	X	-	Excavator with bucket	2	-	105	108	-
					Franna crane	1	-	98	102	-
					Concrete agitator	4/hr	-	108	-	-
					Concrete pump	1	-	103	-	-
					Truck (medium rigid)	4/hr	-	103	117	-
					Water truck	1	-	98	-	-
					Bobcat	2	-	107	-	-
					Workshop hand tools	2	-	104	-	-
Concrete batch plant operations	WPN_03a	Concrete batch plant	X	-	Front end loader	1	-	110	113	-
					Concrete agitator	1	-	108	-	-
					Generator (enclosed)	1	-	94	-	-
					Concrete batch plant	1	-	111	123	-
					Cement delivery truck	1	-	105	117	-
Surface road works	WPN_03b	Construction support site general activities	X	-	Workshop compressor	1	-	100	-	-
					Welding equipment	1	-	105	-	-
					Ute/light vehicle	4/hr	-	89	-	-
					Truck	4/hr	-	103	117	-
					Generator (enclosed)	1	-	94	-	-
					Ute/light vehicle	10/hr	-	89	-	-
	WPN_03c	Support and deliveries	X	X	Truck	4/hr	4/hr	103	117	-
					Franna crane	1	1	98	102	-
Permanent tunnel support facilities construction	WPN_04	Construct the permanent tunnel support facilities	X	-	Ute/light vehicle	8/hr	-	89	-	-
					Concrete agitator	4/hr	-	108	-	-
					Concrete pump	1	-	103	-	-
					Franna crane	1	1	98	102	-
					Workshop hand tools	2	-	104	-	-
					Pneumatic vibrator	2	-	97	-	-

Site activity	Works ID	Activity/modelled works	Standard construction hours	OOHW	Plant item	Standard - Reasonable worst case	OOHW - Reasonable worst case	Individual plant item SWL (L_{Aeq})[3]	Individual plant item SWL (L_{Amax})	Vibration intensive plant
Site rehabilitation	WPN_05	Decommission and site rehabilitation			Front end loader	1	-	110	113	-
					10t dump truck	4/hr	-	100	115	-
					Elevated work platform	2	-	102	-	-
			X	-	Generator (enclosed)	2	-	94	-	-
					Ute/light vehicle	8/hr	-	89	-	-
					Backhoe	1	-	100	104	-
					Franna crane	1	-	98	102	-

Notes: 1. In accordance with the ICNG, a 5 dBA 'penalty' is applied for activities identified as particularly annoying, such as rock hammer and concrete saw.

Annexure F Surface road works assessment activities

Assumed activity noise level SWL, dB(A)			Plant/equipment item	No. Units operating during noise intensive 15 minute period		Individual item sound power level, dB(A)	Usage factor[5]	$L_{Aeq\ 15\ minute}$ SWL, dB(A)	L_{Amax} SWL[4], dB(A)
Typical activity[1]	Worst case activity[2]	Maximum instantaneous[3]		Typical activity	Worst case activity				
Mobilisation/demobilisation and site setup (ie Installing construction boundary hoardings/fences and traffic barriers)									
108	110	117	Truck	1	1	103	15	103	117
			Power hand tools	2	4	101	15	101	116
			Generator (enclosed)	1	2	94	15	94	-
			Elevated work platform	1	1	102	15	102	-
			Franna crane	1	1	98	15	98	102
Support site general activities (ie General site activities)									
100	105	102	Site Forklift	1	1	103	7.5	100	-
			Workshop hand tools	-	1	104	7.5	101	-
			Franna crane	-	1	98	15	98	102
			Ute/light vehicle	4/hr	4/hr	89	15	89	-
Deliveries (ie Work site delivery and unloading operation)									
98	104	117	Truck	1	1	103	15	103	117
			Franna crane	1	1	98	15	98	102
Deliveries (oversized) (ie Work site delivery and unloading operation)									
110	111	117	Articulated truck	1	1	108	15	108	117
			Mobile crane	1	1	110	15	110	-
Utilities modification works (ie Relocation of utilities and services)									
110	120	126	Vacuum truck	1	1	108	15	108	-
			Ute/light vehicle	1	1	89	15	89	-
			Excavator with bucket	1	1	105	7.5	102	108
			Excavator with medium rock hammer	-	1	118	7.5	120*	126
			Dump truck	1/hr	1	108	15	103	117
			Road saw	-	-	121	5	121*	-
			Generator/Daymaker	1	1	94	15	94	-

Assumed activity noise level SWL, dB(A)			Plant/equipment item	No. Units operating during noise intensive 15 minute period		Individual item sound power level, dB(A)	Usage factor[5]	$L_{Aeq\ 15\ minute}$ SWL, dB(A)	L_{Amax} SWL[4], dB(A)
Typical activity[1]	Worst case activity[2]	Maximum instantaneous[3]		Typical activity	Worst case activity				
Pavement/road modification works (ie Remove/construct kerbing/pavement works)									
110	120	126	Vacuum truck	1	1	108	15	108	-
			Ute/light vehicle	1	1	89	15	89	-
			Excavator with bucket	1	-	105	7.5	102	108
			Excavator with medium rock hammer	-	1	118	7.5	120*	126
			Concrete pump	1	-	103	15	103	-
Clearing and grubbing works (ie General land clearing, tree and stump removal, topsoil stripping, loading)									
112	116	124	Excavator with bucket	-	1	105	7.5	102	108
			Elevated work platform	1	1	102	15	102	-
			Chainsaw (electric)	1	1	106	7.5	111*	-
			Tub grinder/mulcher	-	1	119	5	114	124
			Dump truck	4/hr	4/hr	108	15	108	117
Piling - Bored									
108	117	117	Crane	1	1	98	15	98	102
			Piling rig - bored	1	2	112	15	115*	115
			Excavator with bucket	-	1	105	7.5	102	108
			Bobcat	1	1	107	15	107	-
			Concrete agitator	1/hr	4/hr	108	15	108	-
			Concrete pump	-	1	103	15	103	-
			Welding equipment	-	1	105	15	105	-
			Truck	-	1	103	15	103	117
Pile breaking									
113	122	126	Excavator with medium rock hammer	-	1	118	7.5	120*	126
			Bobcat	-	1	107	15	107	-
			Truck	-	1	103	15	103	117
			Compressor	1	2	90	15	90	-
			Jackhammer	1	4	113	5	113*	-

Assumed activity noise level SWL, dB(A)			Plant/equipment item	No. Units operating during noise intensive 15 minute period		Individual item sound power level, dB(A)	Usage factor[5]	$L_{Aeq\ 15\ minute}$ SWL, dB(A)	L_{Amax} SWL[4], dB(A)
Typical activity[1]	Worst case activity[2]	Maximum instantaneous[3]		Typical activity	Worst case activity				
Concrete formwork and reinforcement									
104	113	116	Power hand tools	2	5	101	15	101	116
			Generator (enclosed)	1	1	94	15	94	-
			Compressor	-	1	100	15	100	-
			Mobile crane	-	1	110	15	110	-
			Truck	-	1	103	15	103	117
Concrete pours									
112	116	117	Concrete agitator	4/hr	10/hr	108	15	108	117
			Concrete pump	1	2	103	15	103	-
			Concrete vibrators	2	5	106	15	106	-
			Generator (enclosed)	1	2	94	15	94	-
			Compressor	-	1	100	15	100	-
Shotcrete									
109	112	117	Concrete agitator	1/hr	2/hr	108	15	108	117
			Shotcrete rig - compressor	1	1	104	15	104	-
Rock drilling									
95	117	124	Tracked mobile drilling rig	1	1	120	7.5	117	124
			Generator (enclosed)	1	1	94	15	94	-
			Compressor	1	1	100	15	100	-
Road furniture installation/modification									
107	114	117	Truck	1	1	103	15	103	117
			Power hand tools	1	2	101	15	101	116
			Elevated work platform	1	1	102	15	102	-
			Concrete core drill	-	1	113	7.5	110	-
			Franna crane	-	1	98	15	98	102
			Line marking truck	-	1	108	15	108	117

Assumed activity noise level SWL, dB(A)			Plant/equipment item	No. Units operating during noise intensive 15 minute period		Individual item sound power level, dB(A)	Usage factor[5]	$L_{Aeq\ 15\ minute}$ SWL, dB(A)	L_{Amax} SWL[4], dB(A)
Typical activity[1]	Worst case activity[2]	Maximum instantaneous[3]		Typical activity	Worst case activity				
Rock trimming									
116	121	126	Excavator with twin header attachment	1	-	112	7.5	109	-
			Excavator with medium rock hammer	-	1	118	7.5	120*	126
			Bobcat	1	1	107	15	107	-
Rock crushing									
116	116	120	Rock crusher	1	1	118	7.5	115	120
			Excavator with bucket	1	1	105	7.5	102	108
			Tipper truck	4/hr	4/hr	104	15	104	117
Spoil handling									
104	106	117	Tipper truck	4/hr	4/hr	104	15	104	117
			Excavator with bucket	0	1	105	7.5	102	108
Bulk earthwork									
116	119	117	Bulldozer	1	1	116	10	114	-
			Scraper	-	-	110	15	110	-
			Excavator with bucket	1	2	105	7.5	102	108
			Grader	-	1	113	15	113	-
			Dump truck	4/hr	8/hr	108	15	108	117
			Truck	4/hr	4/hr	103	15	103	117
			Roller	1	1	109	7.5	106	-
			Compactor	-	1	108	15	108	-
			Water truck	1	1	98	15	98	-
Drainage infrastructure									
109	121	126	Backhoe	-	1	100	15	100	104
			Road saw	-	-	121	5	121*	-
			Excavator with medium rock hammer	-	1	118	7.5	120*	126
			Franna crane	1	1	98	15	98	102
			Excavator with bucket	-	1	105	7.5	102	108
			Tracked mobile drilling rig	-	-	120	7.5	117	-
			Compactor	-	1	108	15	108	-
			Concrete agitator	1	1	108	15	108	-
			Truck	4/hr	4/hr	103	15	103	117

Assumed activity noise level SWL, dB(A)			Plant/equipment item	No. Units operating during noise intensive 15 minute period		Individual item sound power level, dB(A)	Usage factor[5]	$L_{Aeq\ 15\ minute}$ SWL, dB(A)	L_{Amax} SWL[4], dB(A)
Typical activity[1]	Worst case activity[2]	Maximum instantaneous[3]		Typical activity	Worst case activity				
Noise barrier installations									
111	118	117	Piling rig - bored	-	2	112	15	115	115
			Generator (enclosed)	1	1	94	15	94	-
			Mobile crane	1	2	110	15	110	-
			Concrete vibrators	-	1	106	15	106	-
			Concrete pump	-	1	103	15	103	-
			Welding equipment	-	1	105	15	105	-
			Excavator with bucket	1	1	105	7.5	102	108
			Truck	-	4/hr	103	15	103	117
Resurfacing works									
112	118	117	Daymaker	4	4	93	15	93	-
			Pavement profiler	-	-	110	15	110	-
			Dump truck	4/hr	12/hr	108	15	108	117
			Bobcat	1	2	107	15	107	113
			Pavement laying machine	1	1	114	15	114	-
			Asphalt truck and sprayer	-	-	103	15	103	-
			Roller	-	-	109	7.5	106	-
Paving/asphalting/road surface road works (including concrete sawing)									
109	120	126	Pavement laying machine	-	-	114	15	114	-
			Truck	4/hr	4/hr	103	15	103	103
			Asphalt truck and sprayer	1	-	103	15	103	117
			Roller	1	-	109	7.5	106	-
			Concrete saw	-	1	119	5	119*	126
Paving/asphalting/road surface road works									
109	114	117	Pavement laying machine	-	1	114	15	114	114
			Truck	1	1	103	15	103	103
			Asphalt truck and sprayer	1	-	103	15	103	103
			Roller	1	-	109	7.5	106	106

Assumed activity noise level SWL, dB(A)			Plant/equipment item	No. Units operating during noise intensive 15 minute period		Individual item sound power level, dB(A)	Usage factor[5]	$L_{Aeq\ 15\ minute}$ SWL, dB(A)	L_{Amax} SWL[4], dB(A)
Typical activity[1]	Worst case activity[2]	Maximum instantaneous[3]		Typical activity	Worst case activity				
Concrete barriers and traffic controls									
99	105	117	Truck	4/hr	4/hr	103	15	103	117
			Franna crane	-	1	98	15	98	102
			Ute/light vehicle	1	3	89	15	89	-
Erection of structural steelwork									
111	117	117	Truck	4/hr	12/hr	103	15	103	117
			Mobile crane	1	2	110	15	110	-
			Percussion drill	-	1	110	7.5	112*	-
			Compressor	-	1	100	15	100	-
			Generator (enclosed)	-	1	94	15	94	-
			Daymaker	1	2	93	15	93	-
			Elevated work platform	1	3	102	15	102	-
Erection/removal of precast concrete/large items									
110	111	117	Truck	-	-	103	15	103	117
			Mobile crane	1	1	110	15	110	-
			Daymaker	1	1	93	15	93	-
			Elevated work platform	-	1	102	15	102	-
Demolition (non-rock hammering)									
109	112	120	Excavator with bucket (loading hard materials)	1	1	113	5	108	120
			Franna crane	-	2	98	15	98	-
			Truck and dog	4/hr	8/hr	108	15	108	117

Assumed activity noise level SWL, dB(A)			Plant/equipment item	No. Units operating during noise intensive 15 minute period		Individual item sound power level, dB(A)	Usage factor[5]	$L_{Aeq\ 15\ minute}$ SWL, dB(A)	L_{Amax} SWL[4], dB(A)
Typical activity[1]	Worst case activity[2]	Maximum instantaneous[3]		Typical activity	Worst case activity				
Demolition (rock hammering)									
109	121	126	Truck	4/hr	4/hr	103	15	103	117
			Excavator with medium rock hammer	-	1	118	7.5	120*	126
			Excavator with bucket (loading hard materials)	1	2	113	5	108	120
			Concrete saw	-	-	121	5	120*	-
			General power tools (drill, etc.)	-	1	105	7.5	102	-
			Generator (enclosed)	1	1	94	15	94	-
			Jackhammer	-	1	113	5	113*	-
			Compressor	-	1	100	15	100	-

Notes:
1. Typical activity - (eg when the concrete saw/rock hammer are NOT operating)
2. Worst case (Noise intensive) - (eg when the concrete saw/rock hammer are operating)
3. Maximum instantaneous noise level (eg maximum level an object bangs when it is dropped)
4. L_{Amax} levels only noted for equipment potentially used during the night period
5. Usage factor is number of minutes in use during typical 15 minute period

* = 5 dB(A) annoyance penalty incorporated.

Annexure G Construction Noise and Vibration Guideline (CNVG) (Roads and Maritime Services, 2016a) standard mitigation measures

G.1 CNVG standard mitigation measures

Action required	Applies to	Details
Management measures		
Implementation of any project specific mitigation measures required	Airborne noise	Implementation of any project specific mitigation measures required.
Implement community consultation or notification measures	Airborne noise Ground-borne noise Vibration	Notification detailing work activities, dates and hours, impacts and mitigation measures, indication of work schedule over the night time period, any operational noise benefits from the works (where applicable) and contact telephone number. Notification should be a minimum of seven (7) calendar days prior to the start of works. For projects other than maintenance works more advanced consultation or notification may be required.
Site inductions	Airborne noise Ground-borne noise Vibration	All employees, contractors and subcontractors are to receive an environmental induction. The induction must at least include: • All project specific and relevant standard noise and vibration mitigation measures • Relevant licence and approval conditions • Permissible hours of work • Any limitations on high noise generating activities • Location of nearest sensitive receivers • Construction employee parking areas • Designated loading/unloading areas and procedures • Site opening/closing times (including deliveries • Environment incident procedures.
Behavioural practices	Airborne noise	No swearing or unnecessary shouting or loud stereos/radios on site. No dropping of materials from height, throwing of metal items and slamming of doors.
Verification	Airborne noise Ground-borne noise Vibration	Where specified, a noise verification program is to be carried out for the duration of the works in accordance with the construction noise and vibration management Plan and any approval and licence conditions.
Attended vibration measurements	Vibration	Where required, attended vibration measurements should be carried out at the commencement of vibration generating activities to confirm that vibration levels are within the acceptable range to prevent cosmetic building damage.
Update Construction Environmental Management Plans (CEMP)	Airborne noise Ground-borne noise Vibration	The CEMP must be regularly updated to account for changes in noise and vibration management issues and strategies.
Building condition surveys	Vibration Blasting	Undertake building dilapidation surveys on all buildings located within the buffer zone prior to commencement of activities with the potential to cause property damage.

Action required	Applies to	Details
Source controls		
Construction hours and scheduling	Airborne noise Ground-borne noise Vibration	Where feasible and reasonable, construction should be carried out during the standard construction hours. Work generating high noise and/or vibration levels should be scheduled during less sensitive time periods if practicable.
Construction respite period during normal hours and out of hours work	Airborne noise Ground-borne noise Vibration	As a guide, high noise and vibration generating activities near receivers should be carried out in continuous blocks that do not exceed 3 hours each, with a minimum respite period of one hours between each block. The duration of each block of work and respite should be flexible to accommodate the usage and amenity at nearby receivers. Unless negotiated with the community with consultation documented and approved by the Transport for NSW project manager or permitted under the licence there should be no more than: • Two consecutive evenings or nights per week • Three evenings or nights per week • Six evenings or nights per month. For night works, these periods of work should be separated by not less than one week.
Equipment selection	Airborne noise Ground-borne noise Vibration	Use quieter and less noise/ vibration emitting construction methods where feasible and reasonable. Ensure plant, including silencers, is well maintained.
Plant noise levels	Airborne noise	The noise levels of plant and equipment must have operating Sound Power or Sound Pressure Levels compliant with the criteria in CNVG. Implement a noise monitoring audit program to ensure equipment remains within the more stringent of the manufacturer's specifications or CNVG
Rental plant and equipment	Airborne noise	The noise levels of plant and equipment items are to be considered in rental decisions and in any case, cannot be used on site unless compliant with the applicable criteria.
Use and siting of plant	Airborne noise Vibration	The offset distance between noisy plant and adjacent sensitive receivers is to be maximised, where feasible and reasonable. Plant used intermittently to be throttled down or shut down when not in use, where feasible and reasonable. Noise-emitting plant to be directed away from sensitive receivers, where feasible and reasonable. Only have necessary equipment on site.
Plan work sites and activities to minimise noise and vibration	Airborne noise Vibration	Locate construction support sites away from sensitive receivers and discourage access from local roads. Plan traffic flow, parking and loading/unloading areas to minimise reversing movements within the site. Where additional activities or plant may only result in a marginal noise increase and speed up works, consider limiting duration of impact by concentrating noisy activities at one location and move to another as quickly as possible. Very noisy activities should be scheduled for normal working hours. If the work cannot be carried out during the day, it should be completed before 11.00pm. Where practicable, work should be scheduled to avoid major student examination periods when students are studying for examinations such as before or during Higher School Certificate and at the end of higher education semesters. If programmed night work is postponed, the work should be re-programmed and the approaches it the CNVG should apply.

Action required	Applies to	Details
Reduced equipment power	Airborne noise Vibration	Use only the necessary size and power.
Non-tonal reversing alarms.	Airborne noise	Non-tonal reversing beepers (or an equivalent mechanism) must be fitted and used on all construction vehicles and mobile plant regularly used on site and for any out of hours work. Consider the use of ambient sensitive alarms that adjust output relative to the ambient noise level.
Minimise disturbance arising from delivery of goods to construction support sites.	Airborne noise	Loading and unloading of materials/deliveries is to occur as far as possible from sensitive receivers. Select site access points and roads as far as possible away from sensitive receivers. Dedicated loading/unloading areas to be shielded if close to sensitive receivers. Delivery vehicles to be fitted with straps rather than chains for unloading, wherever possible. Avoid or minimise out of hours movement, where feasible and reasonable.
Blasting regime	Airborne noise Vibration	The noise and vibration impact of blasting operations can be minimised by: • Choosing the appropriate blast charge configurations • Ensuring appropriate blast-hole preparation • Optimising blast design, location, orientation and spacing. • Selecting appropriate blast times • Utilising knowledge of prevailing metrological conditions • AS 2187.1 Explosive-Storage, transport and use, Part 2: Use of explosives, provides more detailed advice on ground vibration and airblast overpressure impact minimisation options.
Engine compression brakes	Construction vehicles	Limit the use of engine compression brakes at night and in residential areas. Ensure vehicles are fitted with a maintained Original Equipment Manufacturer exhaust silencer or a silencer that complies with the National Transport Commission's 'In-service test procedure' and standard.
Path controls		
Shield stationary noise sources such as pumps, compressors, fans, etc.	Airborne noise	Stationary noise sources should be enclosed or shielded where feasible and reasonable while ensuring that the occupational health and safety of workers is maintained. Appendix D of AS 2436:2010 lists materials suitable for shielding.
Shield sensitive receivers from noisy activities.	Airborne noise	Use structures to shield residential receivers from noise such as site shed placement; earth bunds; fencing; erection of operational stage noise barriers (where feasible and reasonable) and consideration of site topography when situating plant.
Receptor controls		
Structural surveys and vibration monitoring	Vibration	Pre-construction surveys of the structural integrity of vibration sensitive buildings may be warranted. At locations where there are high risk receptors, vibration monitoring should be conducted during the activities causing the vibration.