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2

NOISE AND VIBRATION

REPORT 10-8859-R1

Revision 0

Sydney Light Rail Extension
Stage 1 Lilyfield to Dulwich Hill
Noise and Vibration Assessment

PREPARED FOR

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7 OCTOBER 2010

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Sydney Light Rail Extension

Stage 1 Lilyfield to Dulwich Hill

Noise and Vibration Assessment

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EXECUTIVE SUMMARY

Background

In February 2010, the NSW Government announced, as part of the Metropolitan Transport Plan, a commitment to extend the existing Sydney light rail system in the Inner West from Lilyfield to Dulwich Hill and in the CBD from Haymarket to Circular Quay via Barangaroo. These extensions comprise two stages:

- Stage 1 – an Inner West extension of 5.6 km along the Rozelle Goods Line from Lilyfield to Dulwich Hill
- Stage 2 – a CBD extension from Haymarket to Circular Quay via Barangaroo with consideration of a future light rail option from Circular Quay to Central via George Street.

Collectively these two extensions are known as the Sydney Light Rail Extensions (SLRE). The SLRE would be provided in conjunction with a shared pedestrian and cycle path integrated in an enhanced and managed environmental corridor, known as the GreenWay. The proposed GreenWay would be a 3 m wide pedestrian and cycle shared path from Cooks River to Sydney Harbour (Iron Cove) at Dobroyd Point. The GreenWay would be located on the western side of the light rail corridor, separated from light rail operations but providing access to light rail stops.

Scope of this Report

Heggies Pty Ltd (Heggies) has been engaged by Parsons Brinckerhoff (PB) to assess the noise and vibration impacts of the construction and operation of the SLRE Stage 1.

The objectives of this report are to comply with the requirements of the Director-General of the Department of Planning for the Environmental Assessment (EA), to inform the EA for the SLRE Stage 1 and to be included in the EA as a technical paper.

Ambient noise surveys have been carried out along the proposed alignment to determine the existing noise environment. Sensitive noise and vibration receivers have been identified, and appropriate criteria have been determined for different receiver types for both the construction and operational phases of the project. Noise and vibration levels have been predicted and potential exceedances of the project criteria have been identified, for both construction and operational activities. The noise and vibration assessment covers the following aspects of the project:

- Construction noise at locations near proposed stops
- Construction noise where bridge and underpass works are required
- Indicative construction noise along the length of the GreenWay
- Construction noise at the Pyrmont Stabling Facility
- Construction traffic noise impacts
- Construction vibration impacts on structures
- Construction vibration impacts on human comfort
- A strategy for construction noise and vibration mitigation and management
- Noise from operation of the light rail extension
- Operational noise mitigation and compliance monitoring requirements
- Vibration from operation of the light rail extension
- Operational vibration compliance monitoring requirements

- Noise from operation of the proposed new substations

Conclusions

The predicted noise and vibration impacts of the project may be summarised as follows:

Construction Noise

Construction Noise Management Levels (NMLs) have been set in accordance with the DECCW's Interim Construction Noise Guideline. At the key construction sites, predicted construction noise levels indicate minor to significant exceedances of the NMLs for daytime activities at sensitive receivers. These are a direct result of the relative close proximity of some receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. Where works are required out of normal construction hours, higher exceedances are predicted as a result of the lower NMLs. Night-time works will require careful management of all noise-producing equipment and activities.

Site-specific Construction Noise and Vibration Management Plans (CNVMPs) should be developed in the detailed design phase when more information is available on the schedule for the works and the equipment to be used. The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, and contact details to obtain further information. Where night works are required, the proponent should apply all feasible and reasonable work practices identified in the CNVMP. Where all feasible and reasonable practices have been applied and night-time noise would be more than 5 dBA above the noise affected level, the proponent should negotiate with the community to determine a schedule for the works.

Construction Vibration

The potential impacts of vibration caused by construction activities have been assessed, considering both the risk of damage to structures and potential exceedances of the human comfort criteria. To minimise the risk of structural damage, safe working distances have been identified for vibration intensive plant. At any locations where vibration intensive plant is proposed to be used within the identified safe working distances, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure is recommended to determine the applicable safe vibration level.

Some items of equipment proposed to be used in the construction of the project have the potential to result in exceedances of the human comfort criteria at distances of up to around 40 m from the works, depending on the duration and nature of the construction activity. Any exceedances would be expected to be of short duration only. Where vibration intensive activities are proposed close to sensitive receivers, these works should be scheduled during the day where possible. Potential vibration impacts should be considered in the site-specific CNVMPs, to be developed in the detailed design phase when more information is available on the schedule for the works and the equipment to be used.

Operational Noise

Operational noise criteria for the project have been determined in consultation with the DECCW. For airborne noise created by operation of the light rail, the criteria for the day, evening and night-time periods are 60 dBA L_{Aeq}(day), 55 dBA L_{Aeq}(evening) and 50 dBA L_{Aeq}(night). A L_{Amax} criterion of 82 dBA also applies at the facade of residential receivers.

Modelling of operational noise impacts from the project has identified compliance with the operational noise criteria along most of the alignment, although potential exceedances have been identified at seven locations. The identified exceedances are between 1 dB and 4 dB.

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Attended monitoring of operational noise is recommended at the locations where potential exceedances have been identified to confirm the need for noise mitigation. The potential mitigation measures (if required) could include rail dampers, noise barriers, upgraded fences or building treatments. Measurements would also be undertaken at other representative locations across the project area for the purpose of validating the noise level predictions and determine if any additional feasible and reasonable mitigation measures are required.

Operational Vibration

Operational vibration criteria for the project have been determined in consultation with the DECCW. Vibration levels have also been assessed against the Vibration Dose Value (VDV) criteria described in Assessing Vibration: A Technical Guideline.

The assessment of operational vibration indicates that vibration levels are predicted to comply with the VDV criteria at all locations. Exceedances (of up to 2 dB) of the more stringent facade vibration design goal of 103 dB have been predicted at two residences, however as vibration levels may be variable, the actual levels could be up to 10 dB lower than the maximum predictions. Attended monitoring of operational vibration is recommended at these locations after commissioning.

Substation Noise

The analysis of substation noise levels in accordance with the NSW Industrial Noise Policy (INP) indicates compliance with the intrusiveness, amenity and sleep disturbance criteria is likely at all existing residences. Mitigation of the substation noise (other than the proposed enclosures) is not likely to be required.

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1 INTRODUCTION

1.1 Background

In February 2010, the New South Wales (NSW) Government announced, as part of the Metropolitan Transport Plan, a $500 million commitment to extend the existing Sydney Light Rail system in the Inner West along the disused Rozelle Goods Line corridor from Lilyfield to Dulwich Hill and in the central business district (CBD) from Haymarket to Circular Quay via Barangaroo. This comprised:

- Stage 1 — an Inner West extension of 5.6 km along the disused Rozelle Goods Line corridor from Lilyfield to Dulwich Hill
- Stage 2 — a CBD western corridor extension from Haymarket to Circular Quay via Barangaroo with consideration of a future light rail option from Circular Quay to Central via George St

Collectively these two stages are known as the Sydney Light Rail Extensions (SLRE).

In the 2010-11 NSW Budget, funding has been allocated to start construction on the SLRE Stage 1 (the Inner West extension) following the Environmental Assessment process, as well as to undertake pre-construction work on Stage 2.

In finalising the scope of work for the SLRE Stage 1 (the Inner West extension), the NSW Government took into account the many practical suggestions received from the community following the public release of the Sydney Light Rail - Inner West Extension Study (GHD 2010).

The community strongly favoured the inclusion of a walking and cycling shared path in the corridor, along with a number of bushcare sites – termed a "GreenWay" - from the Cooks River to Iron Cove. On 19 July 2010 the NSW Government announced that the GreenWay would be included in the SLRE Stage 1 (the Inner West extension) project.

SLRE Stage 1 (the Inner West extension) including the GreenWay forms the project and is the subject of this noise and vibration impact assessment.

1.2 Objectives

Heggies Pty Ltd (Heggies) has been engaged by Parsons Brinckerhoff (PB) to assess the noise and vibration impacts of the construction and operation of the SLRE Stage 1. This report forms part of the project Environmental Assessment (EA). The project proponent is Transport NSW.

Transport NSW has lodged a Project Application with the Department of Planning for the SLRE Stage 1, supported by a Preliminary Environmental Assessment (PEA). In response to the Project Application and PEA, the Director General of the Department of Planning has issued requirements outlining the key points to be addressed by the proponent in the detailed EA. The issues relating to noise and vibration are as follows:

> ***"General Construction Impacts** - The EA must assess the impacts of, and present a management framework for:*
>
> ** noise and vibration, with consideration given to:*
>
> > *the intensity and duration of noise and vibration impacts from all construction activities and sources on and off site;*
> >
> > *the nature, sensitivity and impact to potentially affected receivers and structures (including heritage items);*

scheduling construction works having regard to the nature of construction activities;

a strategy for managing construction noise and vibration, with a particular focus paced on those activities identified as having the greatest potential for adverse noise or vibration impacts, and a broader, more generic approach developed for lower-risk activities; and

the Interim Construction Noise Guidelines (DECC, 2009) and Assessing Vibration: A Technical Guideline (DEC, 2006)

Operational Noise and Vibration *– including but not limited to:*

** noise and vibration impacts along the corridor associated with light rail operations, including specific consideration of impacts to sensitive receivers;*

** establishing applicable noise criteria for the project, with the objective of achieving a reduction of past rail freight noise levels and best practice in Australia for light rail, and*

** taking into account the Inner West Light Rail Extension Project Approval dated March 1999, NSW Industrial Noise Policy, and Assessing Vibration: A Technical Guideline (DEC, 2006)"*

The objectives of this report are:

- To comply with the requirements of the Director-General of the Department of Planning for the EA
- To inform the EA for the SLRE Stage 1 and to be included in the EA as a technical paper

1.3 Relevant Guidelines

Operational noise has been assessed consistent with the criteria adopted for the existing light rail in consultation with the NSW Department of Environment, Climate Change and Water (DECCW). Noise from the operation of the substations has been assessed in accordance with the DECCW's *Industrial Noise Policy* (INP) with guidance on sleep disturbance criteria taken from the online Application Notes to the INP and the DECCW's *Environmental Criteria for Road Traffic Noise* (ECRTN).

Construction Noise has been assessed in accordance with the DECCW's *Interim Construction Noise Guideline*.

Vibration has been assessed in accordance with the DECCW's *Assessing Vibration: A Technical Guideline* and with specific criteria for light rail determined in consultation with the DECCW.

1.4 Terminology

Specific acoustic terminology is used within this assessment. An explanation of common terms is included as **Appendix A**.

Consistent with normal rail terminology, the Down and Up directions refer to trains travelling from Central Station and to Central Station, respectively. The Down and Up sides of the corridor are the left-hand and right-hand sides, respectively, when facing away from Central Station (ie facing in the direction of increasing chainage).

2 PROJECT DESCRIPTION

2.1 Project Overview

Overviews of the project are shown in **Figure 1** to **Figure 5** and comprise the following key features:

- A 5.6 km extension of the light rail between the existing Lilyfield light rail stop and the proposed Dulwich Hill Interchange stop. The extension would be located within the existing disused Rozelle Goods Line corridor.
- Nine new light rail stops — Leichhardt North, Hawthorne, Marion, Taverners Hill, Lewisham West, Waratah Mills, Arlington, Dulwich Grove and Dulwich Hill Interchange.
- Minor modifications to the existing Lilyfield stop and surrounding track to tie-in new track and overhead wiring infrastructure with the existing light rail.
- Modifications to the existing northern car park at Bedford Cr to accommodate the Dulwich Hill Interchange stop.
- Raising of the existing bridge over Parramatta Rd which will carry the light rail.
- Provision of the GreenWay, a shared pedestrian and cycle path from Iron Cove at Dobroyd Point to the northern bank of the Cooks River.
- Provision of pedestrian linkages (access pathways) to surrounding neighbourhoods to enable access to the GreenWay shared path and light rail stops.
- Modification of the existing road bridge structures to accommodate the GreenWay shared path – namely at Hercules St, Old Canterbury Rd, Constitution Rd, Davis St and Longport St.
- New pedestrian/cycle bridge at Parramatta Rd adjacent to the light rail overbridge.
- New pedestrian/cycle bridge across the Hawthorne Canal near Hawthorne stop.
- New infrastructure to ensure accessibility and connectivity between the shared path, local streets and light rail stops.
- Provision of sites for bushcare and vegetation remediation areas in order to provide for existing, and an increase in, local habitat for fauna.
- Appropriate safety fencing or separation of shared path and light rail operations, and the light rail operations and the heavy passenger rail operations at Dulwich Hill.
- Provision of overhead wiring, substation and utilities infrastructure.

2.2 New Light Rail Stops

The distance between the proposed stops ranges from 350 m to 980 m, with an average spacing of around 640 m. The platforms would be a mix of staggered and aligned, with each platform being 30 m long and 3 m wide, and a 4 m wide passenger rail crossing point at each stop.

2.3 Service Operation

The existing fleet of seven Light Rail Vehicles (LRVs) would be supplemented by an additional three vehicles to allow a similar service frequency to the existing line of one LRV each way every 10-15 minutes. This frequency could potentially increase in the future to cater for growing demand and to minimise crowding.

The existing light rail operates between 6:00 am and 11:00 pm on weeknights and until 12:30 am on Friday and Saturday nights. The average speed is approximately 25 km/h (including stopping time) with a maximum theoretical speed of 80 km/h.

Figure 1 Project Overview Lilyfield to Leichhardt North

Figure 2 Project Overview Leichhardt North to Marion

Figure 3 Project Overview Marion to Lewisham West

Light rail alignment
Proposed light rail stops
Local government area boundary
Watercourse
Existing GreenWay shared path (upgraded)
New GreenWay shared path (at-grade)
New GreenWay shared path (elevated)
Existing bushcare site
Potential bushcare/landscaping
Potential substation location
Sensitive receivers (non residential)
Monitoring location

Note: Indicitive only, subject to detail design.

Figure 4 Project Overview Lewisham West to Arlington

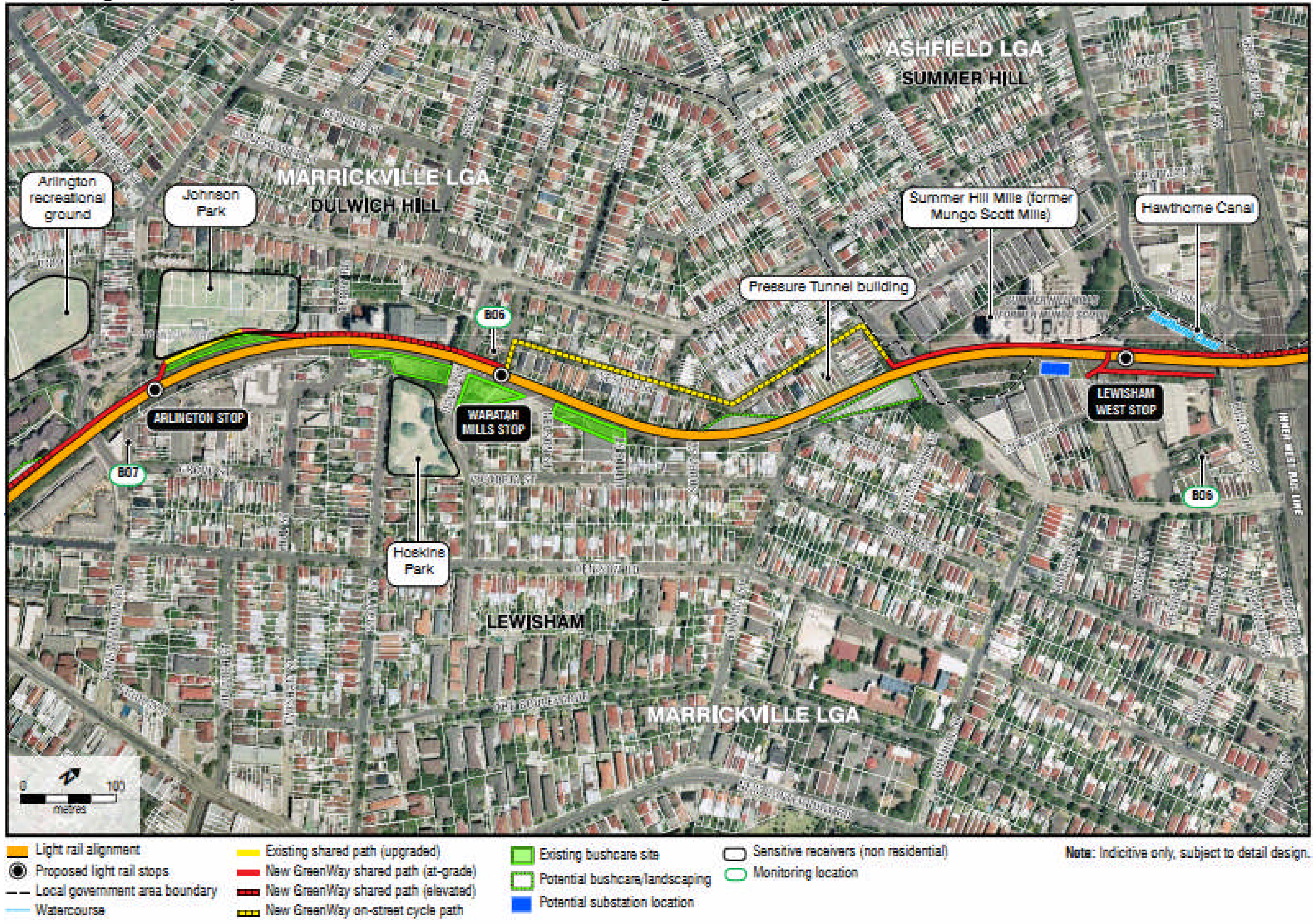


Figure 5 Project Overview Arlington to Dulwich Hill Interchange

2.4 Rail Infrastructure

The SLRE would be contained within the existing rail corridor, apart for at the terminus at the Dulwich Hill Interchange stop, where the proposed light rail fringes the existing informal northern car park at Bedford Cr. The route would be double track, with a standard gauge of 1.435 m.

Maintenance and reconstruction of the existing track is being carried out by RailCorp. The impact of this work has been assessed in a separate Review of Environmental Factors (REF) and therefore is not considered in this report.

Power would be supplied to the LRVs from a single 750V DC overhead catenary to a pantograph mounted on the vehicle roof. The supply of traction power would require the construction of two new substations. Three potential locations for these substations have been identified and are considered in this report; near Catherine St, the Marion Stop and the Lewisham West Stop. Two preferred locations will be confirmed in the detailed design phase.

2.5 Associated Infrastructure

The proposed GreenWay would be a 3 m wide pedestrian and cycle shared path from Cooks River to Sydney Harbour (Iron Cove) at Dobroyd Point. The GreenWay would be located on the western side of the light rail corridor, separated from light rail operations but providing access to light rail stops. Subject to local topography and access requirements, the shared path would be grade separated.

The GreenWay is proposed to pass under a number of roads. At these locations the existing overbridges do not have sufficient lateral clearances to accommodate the GreenWay, so new underpasses would need to be constructed.

Away from the overbridges, the GreenWay would also require either cutting or embankment widening at some locations, or elevated support structures.

This report includes an assessment of the noise and vibration impacts of construction of the GreenWay. There is no requirement to assess operational noise impacts from users of the GreenWay and operational noise impacts of the GreenWay are not expected to be significant.

3 EXISTING NOISE ENVIRONMENT

3.1 Existing Environment

The SLRE would be located in an established urban corridor and involve the conversion of a disused freight line into commuter transport. The project would pass through Leichhardt, Ashfield and Marrickville Local Government Areas. Much of the corridor has residential zoning consisting of a mix of single and multiple dwellings. Other existing land uses in the study area include industrial areas, schools and child-care centres, active recreation areas, retail areas, existing CityRail lines, and open space.

The ambient noise environment of the area is variable. In many areas it is controlled by road traffic noise. Some areas already experience rail traffic noise from the existing Inner West and Bankstown Lines. Due to the close proximity to Sydney's Kingsford Smith Airport, noise from aircraft is at times clearly audible. Some locations are also subject to noise from industrial sources.

3.2 Future Residential Developments

In addition to the existing residential areas along the proposed SLRE, a number of sites have been identified as potential future development sites. These include the Summer Hill Mills site on the western side of the line near the proposed Lewisham West stop, and the McGill St precinct on the eastern side of the line in the same area. A further future development site has been identified at Grove St near the proposed Arlington stop.

Noise and vibration impacts on these future developments have not been assessed in this report as development applications have not yet been made. Any future developments in the vicinity of the proposed SLRE should be planned in accordance with the *State Environmental Planning Policy (Infrastructure) 2007* (the 'Infrastructure SEPP') as supported by the NSW Department of Planning's *Development Near Rail Corridors and Busy Roads – Interim Guideline*. However, it is noted that the future development of these sites would be comparable to the completed development of the Waratah Mills site, and that noise and vibration impacts from the light rail would not be expected to limit or constrain future development.

3.3 Ambient Noise Surveys

3.3.1 Monitoring Locations

In order to characterise the existing ambient noise environment across the project area (in relation to both construction and operation) and to establish present ambient noise levels upon which to base the noise emission targets, environmental noise monitoring was performed at a number of representative locations during August 2010.

These locations were selected based on an inspection of the potentially affected areas, giving consideration to other noise sources which may influence the recordings, security issues for the noise monitoring devices and gaining permission for access to the location from the resident or landowner.

Table 1 lists the monitoring locations, which are also shown in the overview pictures of **Figure 1** to **Figure 5**. Both attended and unattended measurements were taken at each monitoring location.

Table 1 Noise Monitoring Locations

Location	Address	Light Rail Stop Area
B01	121 Francis St	Leichhardt North
B02	23 Lyall St	Hawthorne
B03	122 Hawthorne Pde	Marion
B04	14 Hathern St	Taverners Hill
B05	4 William St	Lewisham West
B06	77 Weston St	Waratah Mills
B07	66 Constitution Rd	Arlington
B08	8/14 Hercules St	Dulwich Grove
B09	9 Bedford Cr	Dulwich Hill Interchange

3.3.2 Methodology for Unattended Noise Monitoring

The purpose of the unattended noise monitoring was to determine the existing L_{Aeq}, L_{A90} and other relevant statistical noise levels during the daytime, evening and night-time periods. These are required to determine the appropriate noise design goals and as a basis for assessing the potential noise impacts during construction.

Unattended noise loggers were deployed adjacent to sensitive receivers over a minimum period of one week in order to measure the prevailing levels of background and ambient noise. The measurements were generally conducted at a height of 1.5 m above the ground level and 1 m from the facade of the subject building, where possible.

All noise measurement instrumentation used in the surveys was designed to comply with the requirements of AS 1259.2-1990 *"Acoustics - Sound Level Meters. Part 2: Integrating - Averaging"* and carried appropriate and current NATA calibration certificates.

The equipment utilised for the continuous unattended noise surveys comprised of Acoustic Research Laboratories Type EL215 and Type EL316 Environmental Noise Loggers, and SVANTEK 957 Noise Loggers. All microphones were fitted with wind shields.

The calibration of the loggers was checked both before and after each measurement survey, and the variation in calibration at all locations was found to be within acceptable limits at all times.

All noise loggers were set to record statistical noise descriptors in continuous 15 minute sampling periods for the duration of their deployment.

The results of the noise monitoring have been processed in accordance with the procedures contained in the INP so as to establish representative noise levels at the residences. Rain and wind affected results were excluded.

3.3.3 Unattended Noise Monitoring Results

The results of the unattended ambient noise surveys are presented in **Table 2**, with the 24 hour average noise level plots for each monitoring location shown graphically in **Appendix B**.

Representative Rating Background Levels (RBL) and L_{Aeq} (energy averaged) noise levels during DECCW's standard daytime, evening and night-time hours are shown in **Table 2**.

It is noted that RailCorp was carrying out work to renew the existing line throughout the duration of the unattended noise monitoring, as observed both when deploying and retrieving the loggers and during the attended noise measurements. This trackwork was restricted to standard construction daytime working hours, and the resulting noise was observed to be generally intermittent throughout the week of logging. Therefore, it is considered unlikely that the RBLs determined from the unattended noise logging in **Table 2** have been affected by noise from trackwork.

Table 2 Summary of Unattended Noise Logging

Location	Noise Level (dBA)[1]					
	Daytime 7.00 am - 6.00 pm		Evening 6.00 pm - 10.00 pm		Night 10.00 pm - 7.00 am	
	RBL	LAeq	RBL	LAeq	RBL	LAeq
B01	53	65	49	63	42	59
B02	41	59	41	55	37	51
B03	48	62	46	58	36	53
B04	52	65	48	63	42	61
B05	50	61	47	60	42	59
B06[2]	39	61	39	54	31	48
B07	44	60	42	54	36	52
B08	44	60	42	58	35	51
B09	44	58	42	56	36	54

Note 1: The Rating Background Level (RBL) and LAeq noise levels have been obtained using the calculation procedures documented in the DECCW's Industrial Noise Policy.

Note 2: Daytime LAeq noise levels at B06 (77 Weston St) were affected by noise from trackwork throughout the week of logging, in particular by equipment accessing the rail corridor through the nearby access gate.

3.3.4 Attended Noise Measurements

Attended noise measurements were undertaken at the locations listed in **Table 1** in order to quantify the noise levels from the various noise sources in the vicinity of the unattended noise monitoring locations.

At each location the attended measurements were performed using a Brüel & Kjær Type 2231 or a SVAN 957 sound level meter for a minimum period of 30 minutes in two 15 minute intervals. Wind speeds were below 5 m/s at all times, and all measurements were performed at a height of 1.5 m above ground level.

Calibration of the sound level meter was checked before and after each measurement and the variation in calibration at all locations was found to be within acceptable limits at all times. During each of the attended noise measurements the observer noted the various noise sources and levels influencing the ambient noise environment. The acoustic environment at the attended locations is described in **Table 3**.

Trackwork was being undertaken in the rail corridor at a number of locations during the attended measurements. Where this was the case, the typical noise levels due to trackwork are stated in **Table 3.** In particular, trackwork was observed during the attended measurements at locations B01 (121 Francis St), B02 (23 Lyall St), B03 (122 Hawthorne Pde) and B06 (77 Weston St). In general, trackwork was observed to be intermittent rather than sustained, with machinery and workers moving steadily along the corridor.

Table 3 Attended Noise Monitoring Results

Location	Date	Time of Day	Noise Levels (dBA)					Description and Typical LAmax Levels (dBA)
			LAmax	LA1	LA10	LAeq	LA90	
B01	13/8/2010	11:03	83	74	68	65	58	Trackwork (hammering) 72-74
		11:23	84	76	69	66	58	Trackwork (mowing) 58, 62, 71
								Traffic Darley Rd 63-71
								Trucks 70, 76
								Aircraft 80, 82, 74, 83,79, 77
B02	13/8/2010	11:46	71	66	59	56	51	Trackwork 56, 60, 64, 68
		12:02	71	64	58	55	49	Traffic Darley Rd 53, 56, 61
								Truck 67, 70
								Aircraft 60, 62, 64, 71
B03	13/8/2010	12:25	86	73	66	63	55	Trackwork 60, 56, 79, 75, 83
		12:41	82	73	66	63	55	Local traffic 69, 73, 76, 69, 71
								Trucks 80, 72
								Aircraft 60, 58, 62, 66, 63
								Motorbike 67, 76
B04	13/8/2010	13:47	86	79	72	69	62	Traffic 68, 72, 70, 77, 80
		14:02	88	78	72	69	59	Trucks 79, 81, 85, 88
								Motorbikes 81, 86, 73
								Distant trains 54
B05	13/8/2010	14:23	81	69	60	59	53	Local traffic 71, 72, 62, 73
		14:38	86	69	61	60	53	Distant traffic 67, 60, 58, 65
								Distant industrial 50, 51
								Distant trains 56, 58, 57
B06	5/8/2010	14:45	84	62	56	56	44	Construction (trackwork) 46-66
		15:00	73	68	63	58	44	Local traffic 50, 59, 64
								Aircraft 60, 64, 67
								Dogs 72
B07	5/8/2010	12:20	72	68	63	59	48	Local traffic 56, 60, 62
		12:35	76	73	65	61	47	Local industry 67, 70
								Aircraft 72, 51, 73
								Distant industrial 48
B08	5/8/2010	14:05	83	79	68	66	48	Local traffic 74, 68, 78
		14:20	82	76	68	64	49	Truck 83
								Distant traffic 46
								Children at school 48
								Aircraft 55, 79
B09	5/8/2010	11:20	80	71	63	60	47	Freight train 63, 70, 66
		11:35	73	67	60	57	45	Passenger train 61, 60, 55
								Distant traffic 43-46
								Aircraft 60, 68, 73
								Breeze in trees 55, 60

3.4 Identification of Noise and Vibration Sensitive Receivers

The sensitivity of occupants to noise and vibration varies according to the nature of the occupancy and the activities performed within the affected premises. For example, recording studios are more sensitive to noise and vibration than residential premises, which in turn are more sensitive than typical commercial premises. The sensitivity may also depend on the existing environment. For example, the DECCW's *"Industrial Noise Policy"* and AS/NZS 2107:2000 *"Recommended Design Sound Levels and Reverberation Times for Building Interiors"* recommend higher acceptable noise levels in urban areas compared with suburban areas. Receivers may be classified into the following categories:

1. Residential
2. Educational
3. Hospitals
4. Places of worship
5. Commercial
6. Industrial
7. Other (for example museums, heritage items, recreation areas)

In the assessment presented in this report, all residential receivers are considered to be sensitive. Most commercial and industrial receivers are less sensitive to noise and vibration. **Table 4** lists sensitive receivers, excluding those of a residential nature, that are situated along the alignment (see also **Figures 1 to 5**).

Commercial or industrial receivers are included only where they are in close proximity to the alignment or a proposed stop and where the business is considered potentially sensitive to noise or vibration impacts. The relevant construction and operational noise goals for these receivers are identified in **Section 4.3** and **Section 6.3** respectively.

Heritage items are listed only where there is a potential noise or vibration impact on the item. Note that heritage listed residential dwellings have been assessed as residential receivers, and are therefore not included in this list.

Table 4 Identified Noise and/or Vibration Sensitive Receivers (Non-Residential)

Receiver	Light Rail Stop Area	Receiver Type
Catherine St Bridge*	Lilyfield	Heritage Item
Charles St Bridge*	Leichhardt North	Heritage Item
Blackmore Park	Leichhardt North	Active Recreation
Canal Rd Film Centre	Leichhardt North, Hawthorne	Film Industry
Hawthorne Canal Reserve	Hawthorne	Active Recreation
Café Bones	Hawthorne	Commercial
Richard Murden Reserve	Hawthorne	Active Recreation
Netball Courts	Hawthorne	Active Recreation
Tennis Courts	Hawthorne	Active Recreation
Lambert Park	Marion	Active Recreation
The Marion Nursing Home	Marion	Other (Residential)
Marion St Bridge*	Marion	Heritage Item
Hawthorne Canal*	Marion, Taverners Hill, Lewisham West	Heritage Item
Battle Bridge*	Taverners Hill	Heritage Item

Receiver	Light Rail Stop Area	Receiver Type
Parramatta Road Bridge*	Taverners Hill	Heritage Item
Lewisham Railway Substation*	Lewisham West	Heritage Item
Lewisham Railway Viaduct*	Lewisham West	Heritage Item
Lewisham Sewage Viaduct*	Lewisham West	Heritage Item
Summer Hill Mills (former Mungo Scott Mills) *	Lewisham West	Heritage Item
Pressure Tunnel Building*	Lewisham West / Waratah Mills	Heritage Item
Hoskins Park	Waratah Mills	Active Recreation
Johnson Park	Arlington	Active Recreation
Arlington Recreation Ground	Arlington	Active Recreation
Dulwich Hill Public School	Dulwich Grove	Educational
Jack Shanahan Park	Dulwich Hill Interchange	Active Recreation

Note: Receivers marked with an asterisk are vibration-sensitive only.

4 CONSTRUCTION NOISE ASSESSMENT

4.1 Introduction

The following sections contain an assessment of the airborne construction noise and construction vibration impacts associated with the project. Construction noise and vibration goals have been determined based on the relevant government guidelines and industry standards. Noise and vibration emission levels have been determined based on expected activities and where exceedances are predicted, feasible and reasonable impact mitigation measures are considered.

The Director-General's Requirements (DGRs) (see **Section 1.2**) state that the EA is to include consideration of the potential impacts associated with, and a management framework for construction works to ensure potential noise and vibration impacts are controlled.

The EA must include a considered approach for the scheduling of works having regard to the nature of construction activities, and a strategy managing noise and vibration impacts (with focus on the activities identified as having the greatest impact, and a generic approach for lower risk activities).

It is noted that ground-borne construction noise has not been assessed, as the nature of the project means that ground-borne noise impacts are expected to be negligible.

4.2 Construction Noise Metrics

The three primary noise metrics used to describe construction noise emissions in the modelling and assessments are:

$L_{A1(1minute)}$ the "typical maximum noise level" for an event, used in the assessment of potential sleep disturbance during night-time periods. Alternatively, assessment may be conducted using the L_{Amax} or maximum noise level

$L_{Aeq(15minute)}$ the "energy average noise level" evaluated over a 15-minute period. This parameter is used to assess the potential construction noise impacts.

L_{A90} the "background noise level" in the absence of construction activities. This parameter represents the average minimum noise level during the daytime, evening and night-time periods respectively. The $L_{Aeq(15\ minute)}$ construction noise management levels are based on the L_{A90} background noise levels.

The subscript "A" indicates that the noise levels are filtered to match normal human hearing characteristics (ie A-weighted).

4.3 Project Specific Construction Noise Management Levels

The project would be constructed over approximately 12 months. Although it is anticipated that most works will be completed during standard daytime construction hours, at some locations night works would also be required.

The Director General's Requirements specify that the construction noise assessment must take into account the DECCW's "*Interim Construction Noise Guideline".* Heggies has adopted the following approach for the project construction, consistent with the DECCW Guideline:

- Determine project specific **Noise Management Levels** (NMLs) for noise affected receivers consistent with current practices to deal with construction noise in a transparent and consistent way.
- Where the construction noise levels are predicted to exceed the NMLs, all **feasible** and **reasonable** work practices will be investigated to minimise noise emissions.

- Having investigated all **feasible** and **reasonable** work practices, if construction noise levels are still predicted to exceed the NMLs then the potential noise impacts would be managed via site specific construction noise management plans, to be prepared in the detailed design phase.

4.3.1 Residential Receivers

The existing noise environment varies along the alignment. Location specific $L_{Aeq(15minute)}$ NMLs for sensitive residential receivers are determined along the alignment based on the background noise monitoring as described in **Table 5.** The resulting construction NMLs derived from the noise monitoring locations are listed in **Table 6**.

Table 5 Determination of NMLs for Residential Receivers

Time of Day	NML
Daytime (7.00 am to 6.00 pm)	RBL or L_{A90} Background +10 dBA
Evening (6.00 pm to 10.00 pm)	RBL or L_{A90} Background +5 dBA
Night-time (10.00 pm to 7.00 am)	RBL or L_{A90} Background +5 dBA

Table 6 Residential NMLs

Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
	Daytime	Evening	Night-time
B01	63	54	47
B02	51	46	42
B03	58	51	41
B04	62	53	47
B05	60	52	47
B06	49	44	36
B07	54	47	41
B08	54	47	40
B09	54	47	41

In additional to the NMLs, where construction would be required during the night-time period the potential for sleep disturbance should be assessed. The DECCW's current approach to assessing potential sleep disturbance is to apply an initial screening criterion of background plus 15 dBA (as described in the online Application Notes to the INP), and to undertake further detailed analysis if the screening criterion cannot be achieved. The sleep disturbance screening criterion applies outside bedroom windows during the night-time period.

Where the screening criterion cannot be met, the additional analysis should consider the number of potential sleep disturbance events during the night, the level of exceedance and noise from other events. It may also be appropriate to consider other guidelines including the DECCW's ECRTN which contains additional guidance relating to the potential sleep disturbance impacts.

4.3.2 Other Sensitive Land Uses

The project specific $L_{Aeq(15minute)}$ NMLs for other sensitive receivers are listed in **Table 7**.

Table 7 Noise Management Levels for Other Sensitive Receivers

Land Use	NML $L_{Aeq(15minute)}$[1]
Classrooms at schools and other educational institutions	Internal noise level 45 dBA
Hospital wards and operating theatres	Internal noise level 45 dBA
Places of worship	Internal noise level 45 dBA
Active recreation areas	External noise level 65 dBA
Passive recreation areas	External noise level 60 dBA

Note 1 NML applies when properties are being used.

As described in DECCW's Interim Construction Noise Guideline, internal noise levels are to be assessed at the centre of the occupied room. External noise levels are to be assessed at the most affected point within 50 m of the area boundary. Where internal noise levels cannot be measured, external noise levels may be used. A conservative estimate of the difference between internal and external noise levels is 10 dB with windows open.

4.3.3 Commercial and Industrial Premises

For commercial premises, which include offices, retail outlets and small commercial premises an external NML of $L_{Aeq(15minute)}$ 70 dBA has been adopted. For industrial premises, an external NML of $L_{Aeq(15minute)}$ 75 dBA is appropriate. In both cases the external noise levels should be assessed at the most affected occupied point of the premises.

4.4 Construction Sites and Activities

Construction works will be undertaken along the full length of the light rail and the GreenWay shared path alignment as shown in the following overviews **Figure 6** through to **Figure 12**. It is anticipated that a number of construction compound areas of varying size would be required for the construction of the project. These construction compounds would be located close to key construction activities, for example near the proposed stop locations or underpass excavation sites. At each of these sites, the establishment of the compound would involve vegetation clearing and ground levelling, setting up security fencing and site offices and works site facilities as required. Some loading and unloading of materials and equipment would also be expected. These establishment activities are not considered to be noise intensive.

Figure 6 Construction Overview Lilyfield

Figure 7 Construction Overview Lilyfield to Leichhardt North

Figure 8 Construction Overview Leichhardt North to Marion

Figure 9 Construction Overview Marion to Lewisham West

Figure 10 Construction Overview Lewisham West to Arlington

Figure 11 Construction Overview Arlington to Dulwich Hill Interchange

- Proposed light rail stops
- Watercourse
- Local government area boundary
- Existing shared path (upgraded)
- New GreenWay shared path (at-grade)
- New GreenWay shared path (elevated)
- New GreenWay on-street cycle path
- Existing bushcare site
- Potential bushcare/landscaping
- Construction compound area
- Construction footprint
- Vehicle access point

Note: Indicitive only, subject to detail design.

Figure 12 Construction Overview Stabling and Maintenance Facility

Construction footprint

Note: Indicitive only, subject to detail design.

Table 8 lists the construction sites and activities assessed in this report, with details of access to the site and the potentially noisy activities proposed at each site. 'Worst case' noise impacts at nearby sensitive receivers have been assessed at each of these locations.

Table 8 Construction Sites and Noise Intensive Activities

Location	Description	Construction Access	Equipment and Activities
Lilyfield	Within the Rozelle Goods Yard	Lilyfield Rd, City West Link	Overhead wiring and track tie in works
Leichhardt North Stop	At grade, but with lift and stair access to City West Link intersection as well as graded paths.	Darley Rd, near Francis St	Earthworks, stop construction, stair and lift construction
Hawthorne Stop	Reclaimed land - platform suspended on piles. Access via paths and graded ramps. New pedestrian bridge over Hawthorne Canal	Lyall St ,potentially Allen St	Earthworks, piling, stop construction, ramps and pedestrian bridge construction
Marion Stop	Platform elevated, suspended on piles. Access via stair and lift from Marion St, and Stair and path	Marion St	Earthworks, piling, stop construction, stair and lift construction
Taverners Hill Stop	Elevated platform on steep embankment, suspended on piles. Lifts either side of Parramatta Rd, stair access from Brown St	Brown St, Parramatta Rd	Earthworks, piling, stop construction, stair and lift construction
Lewisham West Stop	Platform at grade	Hudson St, Alfred St, Smith St.	Earthworks, stop construction, access pathway
Waratah Mills Stop	Platform at grade	Weston St, Davis St	Earthworks, stop construction, stairs, pathway
Arlington Stop	The platforms will require widening of the existing cutting and excavation for stair access.	Constitution Rd, and potentially Johnston Park	Earthworks, cutting widening, stop construction, stair and pathway construction
Dulwich Grove Stop	The platforms will require widening of the existing cutting and excavation for stair access.	Hercules Rd	Earthworks, stop construction, stair and lift construction.
Dulwich Hill Interchange Stop	Excavation will be required including some through rock to provide interchange at grade. 4 m central platform at this location.	Bedford Cr	Excavation, earthworks, stop construction, stair and lift construction
Parramatta Rd Overbridge	Upgraded bridge over Parramatta Rd	Brown St, Parramatta Rd	Structure upgrades including raising of the bridge, construction of retaining walls and backfill compaction
Hercules St Underpass	New underpass for GreenWay under existing road	New Canterbury Rd	Earthworks, piling, concreting and tunnel excavation
Old Canterbury Rd Underpass	New underpass for GreenWay under existing road	Hudson St, Alfred St, Smith St.	Earthworks, piling, concreting and tunnel excavation
Constitution Rd Underpass	New underpass for GreenWay under existing road	Constitution Rd	Earthworks, piling, concreting and tunnel excavation

Location	Description	Construction Access	Equipment and Activities
Davis St Underpass	New underpass for GreenWay under existing road	Weston and Davis St	Earthworks, piling, concreting and tunnel excavation
Longport St Underpass	New underpass for GreenWay under existing road	Longport St	Earthworks, piling, concreting and tunnel excavation
GreenWay	Along route, particularly where path would be elevated	Location dependent	Earthworks, piling, concreting
Pyrmont	Stabling and Maintenance Facility	Pyrmont Rd	Extension of siding into car park

4.5 Construction Noise Modelling

In order to quantify noise emissions from the key construction sites, computer noise models were developed based on geometric noise propagation. The model for these sites includes source noise emission levels, location of sources and receivers, acoustic shielding provided by intervening ground topography and ground effects. Maximum sound power levels for equipment assumed in the modelling (prior to mitigation) are presented in **Table 9**.

Table 9 Summary of Sound Power Levels used for Construction Equipment

Plant Item	L_{Amax} Sound Power Level (dBA)
Excavator Hammer	122
Dump Truck	108
Excavator (approx 20T)	105
Excavator (approx 30T)	110
Excavator (approx 40T)	115
Front End Loader	111
Compactor	105
Water Cart	108
Concrete Saw	118
Jackhammer	113
Mobile Crane	110
Generator	104
Bored Piling Rig	110
Concrete Truck	112
Concrete Pump	109
Compressor	105
Vibratory Roller	114

Note 1: In accordance with the DECCW Interim Construction Noise guideline for activities identified as particularly annoying (such as jackhammering, rock breaking and power saw operation), a 5 dBA “penalty” is added to the source sound power level when predicting noise using the quantitative method.

The sound power levels given in **Table 9** are maximum noise emission levels of plant that will or may be used on this project in typical operation. In order to apply the construction noise goals for the project, it is necessary to convert these levels to equivalent $L_{Aeq(15minute)}$ noise emissions. From numerous field studies on large construction projects, the measured difference between the L_{Amax} and $L_{Aeq(15minute)}$ noise levels have been found to be up to 10 dBA depending on the mixture of the plant, intensity of operation and location of the plant relative to the receiver.

In the present study, where the equipment is generally confined to the key construction areas and the receivers are relatively close, adjustments of between 2 dBA to 5 dBA have been applied to convert the L_{Amax} noise levels shown in **Table 9** to L_{Aeq} noise levels for comparison with the construction NMLs.

The proposed equipment to be used at each key construction site is a subset of that presented in **Table 9** Key construction activities representative of the typical noise emissions expected to occur during the project are:

- Excavation using excavators, rockbreakers and other construction plant – noting this occurs at some construction sites, not all;
- Earthworks which may involve piling at some locations;
- Installation of stairs, lifts and at some locations platform support using piling;
- Stop construction, fitout and commissioning.

The assessment of airborne noise impacts at the key construction sites has been divided into three sections: the construction sites near stops; the sites associated with bridge or underpass works; and the work at the Pyrmont stabling and maintenance facility.

4.6 Airborne Construction Noise - Locations Near Stops

Construction at the stop sites would occur during the daytime only and scenarios were developed representative of the activities having potentially the greatest noise impact on the surrounding receivers. The predicted noise levels presented in the following tables are representative of the 'noisiest' construction periods. Generally, noise levels would be expected to be lower than those presented for a majority of the 12 month construction period.

The typical $L_{Aeq(15minute)}$ noise levels without noise controls implemented on site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in the following tables. A range of predicted noise levels is shown as the distance between the noise sources and receivers will vary as the work progresses.

Also shown are the predicted noise levels with 3 m hoarding/noise wall at the perimeter between the site and receivers, to provide an indication of potential noise reduction. It is noted that noise intensive works such as concreting, piling etc will occur over a relatively short portion of the nominal 12 month construction period, and specific noise control measures such as noise barriers may not be reasonable. Furthermore where a stop site is in a cutting there will be negligible attenuation of noise as a result of the hoarding/noise wall. This situation is presented as 'n/a' in the following tables.

4.6.1 Lilyfield Construction Site

At Lilyfield, where there is an existing light rail stop, construction works are required to tie in overhead wiring and track to the existing light rail. Ambient noise monitoring was not carried out at this site, instead background noise levels been determined from measurements conducted in the vicinity for the CBD Metro project. Site specific construction NMLs are presented in **Table 10**.

Table 10 Lilyfield Residential Construction NMLs

Location	LAeq(15minute) Construction NMLs (dBA)		
	Daytime	Evening	Night-time
Lilyfield Rd	66	60	52
Brennan St	59	54	47

Note The Lilyfield Rd and Brennan St receiver NMLs are based on the noise surveys conducted at Lamb St and Starling St respectively as part of the CBD Metro Study.

The nearest noise sensitive receivers to the Lilyfiled construction site (**Figure 6**) are listed in **Table 11**, along with the predicted noise levels and exceedances of the NMLs with and without mitigation in the form of 3 m hoardings.

Table 11 Lilyfield Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Lilyfield Rd Residential - North	160	Daytime	66	48-54	0	n/a
Lilyfield Rd Commercial - North	78	Daytime	70	53-62	0	-
Brenan St Residential - South	29	Daytime	59	57-69	10	2

4.6.2 Leichhardt North Stop Construction Site

At Leichhardt North, the key noise impacts would be due to the stop construction, including earthworks, platform construction, and stair and lift construction. The nearest noise sensitive receivers to this site (shown in **Figure 8**) are identified in **Table 12**. The NMLs at this site are based on the ambient noise survey conducted at location B01 - 121 Francis St. Also shown in **Table 12** are the predicted noise levels and exceedances of the NMLs with and without mitigation in the form of 3 m hoardings.

Table 12 Leichhardt North Stop Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Wragg St Residential - North	38	Daytime	63	60-64	0	n/a
Darley Rd Residential - South	26	Daytime	63	69-73	10	2
Darley Rd Commercial - South	28	Daytime	70	69-73	3	-

Note Wragg St residences are shielded by City West Link traffic noise walls.

4.6.3 Hawthorne Stop Construction Site

At the Hawthorne stop construction site shown in **Figure 8**, the key noise impacts would be due to earthworks, piling, stop construction, and construction of ramps and pedestrian bridges. The nearest noise sensitive receivers to the Hawthorne Stop site are identified in **Table 13**. The NMLs at this site are based on the ambient noise survey conducted at location B02 - 23 Lyall St. Also shown in **Table 13** are the predicted noise levels and exceedances of the NMLs with and without mitigation in the form of 3 m hoardings.

Table 13   Hawthorne Stop Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	**3 m Hoarding**
Hawthorne Pde Residential - West	60	Daytime	51	61-62	11	3
Darley Rd Residential - East	30	Daytime	51	69-72	21	13
Hawthorne Canal Reserve	30	Daytime	65	69-72	7	-

4.6.4 Marion Stop Construction Site

At the Marion stop construction site (**Figure 9**), the key noise impacts would be due to earthworks, piling, stop construction, and construction of stairs and lifts. The nearest noise sensitive receivers to this site are identified in **Table 14**. The NMLs at this site are based on the ambient noise survey conducted at location B03 - 122 Hawthorne Pde. Also shown in **Table 14** are the predicted noise levels and exceedances of the NMLs with and without mitigation in the form of 3 m hoardings.

Table 14   Marion Stop Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	**3 m Hoarding**
Hawthorne Pde Residential - West	89	Daytime	58	61-63	5	-
Marion St Commercial - East	6	Daytime	70	69-84	14	6
Richard Murden Reserve	38	Daytime	65	65-70	5	-
Lambert Park	36	Daytime	65	64-67	2	-

4.6.5 Taverners Hill Stop Construction Site

At the Taverners Hill stop construction site (**Figure 9**), the key noise impacts would be due to earthworks, piling, stop construction, and construction of stairs and lifts. The nearest noise sensitive receivers to this site are identified in **Table 15**. The NMLs at this site are based on the ambient noise survey conducted at location B04 - 14 Hathern St. Also shown in **Table 15** are the predicted noise levels and exceedances of the NMLs with and without mitigation in the form of 3 m hoardings.

Table 15 Taverners Hill Stop Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Hawthorne Pd Residential - West	39	Daytime	62	67-71	9	1
Hawthorne Pd Commercial - West	26	Daytime	70	69-74	4	-
Hathern St Residential - East	20	Daytime	62	70-77	15	7
Hathern St Commercial - East	25	Daytime	70	68-74	4	-

4.6.6 Lewisham West Stop Construction Site

At the Lewisham West stop construction site (**Figure 10**), the key noise impacts would be due to earthworks, stop construction, and construction of access pathways. The nearest noise sensitive receivers to this site are identified in **Table 16**. The NMLs at this site are based on the ambient noise survey conducted at location B05 - 4 William St. Also shown in **Table 16** are the predicted noise levels and exceedances of the NMLs with and without mitigation in the form of 3 m hoardings.

Table 16 Lewisham West Stop Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Smith St Commercial - West	39	Daytime	70	62-66	0	-
Brown St Commercial - East	26	Daytime	70	72-81	11	3
William St Residential - East	20	Daytime	60	63-65	5	-

4.6.7 Waratah Mills Stop Construction Site

At the Waratah Mills stop construction site (**Figure 10**), the key noise impacts would be due to earthworks, stop construction, and construction of stairs and access pathways. The nearest noise sensitive receivers to this site are identified in **Table 17**. The NMLs at this site are based on the ambient noise survey conducted at location B06 - 77 Weston St. Also shown in **Table 17** are the predicted noise levels and exceedances of the NMLs with and without mitigation in the form of 3 m hoardings.

Table 17 Waratah Mills Stop Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Weston St Residential - West	12	Daytime	49	75-81	32	24
Davis St Residential - East	18	Daytime	49	72-77	28	20
Nelson St Commercial - East	5	Daytime	70	70-88	18	10
Hoskins Park	18	Daytime	65	72-77	12	4

4.6.8 Arlington Stop Construction Site

At the Arlington stop construction site (**Figure 10**), the key noise impacts would be due to earthworks, cutting widening, stop construction, and stair and pathway construction. The nearest noise sensitive receivers to this site are identified in **Table 18**. The NMLs at this site are based on the ambient noise survey conducted at location B07 - 66 Constitution Rd. Also shown in **Table 18** are the predicted noise levels and exceedances of the NMLs with and without mitigation in the form of 3 m hoardings.

Table 18 Arlington Stop Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Constitution Rd Residential West	50	Daytime	54	65-68	14	6
Constitution Rd Residential East	16	Daytime	54	70-77	23	15
Constitution Rd Commercial East	14	Daytime	70	72-79	9	1
Johnson Park	14	Daytime	65	72-79	14	6

4.6.9 Dulwich Grove Stop Construction Site

At the Dulwich Grove stop construction site (**Figure 11**), the key noise impacts would be due to earthworks, stop construction, and stair and lift construction. The nearest noise sensitive receivers to this site are identified in **Table 19**. The NMLs at this site are based on the ambient noise survey conducted at location B08 - 8/14 Hercules St. Also shown in **Table 19** are the predicted noise levels and exceedances of the NMLs with and without mitigation in the form of 3 m hoardings.

Table 19 Dulwich Grove Stop Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Consett St Residential - West	20	Daytime	54	67-77	23	n/a
Dulwich Hill Public School	32	Daytime	55[1]	59-68	13	5
Hercules St Commercial - East	22	Daytime	70	64-75	5	n/a

Note 1: On the assumption that the schools operate with openable windows, and that typically a 10 dBA reduction from outside to inside is applicable for openable windows, a resulting external LAeq noise level of 55 dBA is required to comply with the internal NML.

4.6.10 Dulwich Hill Interchange Stop Construction Site

At the Dulwich Hill Interchange stop construction site (**Figure 11**), the key noise impacts would be due to excavation, earthworks, stop construction, and stair and lift construction. At this site, two scenarios have been modelled representing the initial site establishment including excavation, and the subsequent stop construction activities. The excavation scenario noise predictions are shown in **Table 20**. The stop construction scenario noise predictions are shown in **Table 21**. The NMLs at this site are based on the ambient noise survey conducted at location B09 - 9 Bedford Cr. Also shown in **Table 20** and **Table 21** are the predicted noise levels and exceedances of the NMLs with and without mitigation in the form of 3 m hoardings.

Table 20 Dulwich Hill Interchange Excavation and Site Establishment Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Bedford Cr Residential	22	Daytime	54	79-87	33	25
Wardell Rd Residential North	30	Daytime	54	72-84	30	22
Ewart Ln Residential	68	Daytime	54	71-76	22	n/a
Wardell Rd Residential South	66	Daytime	54	71-76	22	n/a
Wardell Rd Commercial North	23	Daytime	70	75-86	16	n/a
Wadell Rd Commercial South	50	Daytime	70	74-79	9	n/a

Table 21 Dulwich Hill Interchange Stop Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Bedford Cr Residential	22	Daytime	54	71-77	23	15
Wardell Rd Residential North	30	Daytime	54	62-72	18	10
Ewart Ln Residential	68	Daytime	54	62-66	12	4
Wardell Rd Residential South	66	Daytime	54	63-66	12	4
Wardell Rd Commercial North	23	Daytime	70	64-76	6	-
Wadell Rd Commercial South	50	Daytime	70	66-68	0	-

4.6.11 Summary of Construction Noise Near Stop Sites

The impacts of noise at the construction sites near stops may be summarised as follows:

- Construction works at the Lilyfield site consist of activities in the compound area. Due to the relatively large distances to receivers and high NML's as a result of traffic and other sources there is no impact to residential and commercial receivers to the north. At residences to the south on Brenan St there is an exceedance of up to 10 dBA. This is a moderate exceedance.
- At the Leichhardt North Stop residences to the north are shielded by existing road traffic barriers, and compliance with the NML is predicted. To the south on Darley Rd the NMLs are exceeded by up to 10 dBA at residences and 3 dBA at commercial receivers. This is a moderate exceedance.
- At the Hawthorne Stop residences to the west and east have a clear view to the stop location, which is elevated with respect to the residences. The NMLs are predicted to be exceeded by up to 11 dBA to the west, and 21 dBA to the east. These exceedances are considered moderate to significant.
- At the Marion Stop residences to the west and commercial receivers to the east have a clear view to the stop location, which is elevated with respect to these receivers. The NMLs are predicted to be exceeded by up to 5 dBA to the west, and 14 dBA to the east. These exceedances are considered minor to moderate.
- At the Taverners Hill Stop residences and commercial receivers to the west and residences and commercial receivers to the east have a relatively clear view to the stop location (noting that eastern receivers may receive shielding from Brown St) which is elevated with respect to these receivers. The NMLs are predicted to be exceeded by up to 15 dBA for residences and 4 dBA for commercial receivers. These exceedances are considered moderate to minor respectively.
- At the Lewisham West residences and commercial receivers are generally on grade with the stop. The NMLs are predicted to be exceeded by up to 5 dBA for residences and up to 11 dBA for commercial. These exceedances are considered minor to moderate respectively.
- At the Waratah Mills site residences and commercial receivers are generally on grade with the stop. The NMLs are predicted to be exceeded by up to 32 dBA and 28 dBA for residences to the west and east respectively. These are significant exceedances being a direct result of the close proximity of receivers and relatively lower ambient noise levels in the area. At commercial receivers the NML is exceeded by up to 18 dBA.
- At the Arlington site residences and commercial are generally on grade with the stop. The NMLs are predicted to be exceeded by up to 14 dBA and 23 dBA for residences to the west and east respectively. These are moderate to significant exceedances being a direct result of the close proximity of receivers and relatively lower ambient noise levels in the area. At commercial receivers the NML is exceeded by up to 25 dBA.
- At the Dulwich Grove site residences and commercial receivers are generally overlooking the stop which is in cut. The NMLs are predicted to be exceeded by up to 20 dBA at residences to the west, up to 22 dBA at commercial receivers to the east and up to 32 dBA at the school. These are significant exceedances being a direct result of the close proximity of receivers. School exceedances assume open windows, and further investigation on the noise reduction from outside to inside is required during the construction planning and site establishment phases of the project, together with liaison with the school.
- At the Dulwich Hill Interchange site residences and commercial to the north are generally partially shielded whilst those to the south overlook the stop which is in cut. At this site as well as stop construction, an excavation scenario using rockbreakers has been modelled. During construction the NMLs are predicted to be exceeded by up to 12 dBA to 23 dBA at residences and up to 6 dBA at commercial receivers. During excavation higher exceedances of up to 22 dBA to 33 dBA at residences and up to 9 dBA to 16 dBA at commercial receivers are predicted.

4.7 Airborne Construction Noise - Bridge and Underpass Sites

Construction at the bridge and underpass sites would occur during the daytime and night-time to maintain daytime bridge operations. Scenarios were developed for the operations, to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Excavation and site establishment.
- Earthworks and construction.

The predicted noise levels presented in the following tables are representative of the 'noisiest' construction periods, however generally noise levels would be expected to be lower than those presented for a majority of the construction period.

4.7.1 Structure Upgrades to Parramatta Rd Rail Overbridge

The existing rail bridge over Parramatta Rd has insufficient clearance and is required to be raised by approximately 500 mm. The two most noise-intensive scenarios have been identified as the bridge works, to be carried out at night, and the construction of retaining walls to be completed during the daytime. The site specific NMLs are based on the ambient noise survey conducted at location B04 – 14 Hathern St. Predicted noise levels and exceedances for the bridge works are shown in **Table 22** and for the retaining wall construction in **Table 23**.

Table 22 Parramatta Rd Bridge Works Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Hathern St Residential	46	Night-time	47	65-69	22	n/a
Cook St Residential	40	Night-time	47	65-71	24	n/a
Haig Avenue Residential	76	Night-time	47	61-65	18	n/a
Hawthorne Pde Residential	57	Night-time	47	63-68	21	n/a
Parramatta Rd Commercial	18	Night-time	70	72-79	-	-

Table 23 Parramatta Rd Retaining Wall Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Hathern St Residential	46	Daytime	62	75-80	18	10
Cook St Residential	40	Daytime	62	72-77	15	7
Haig Avenue Residential	76	Daytime	62	69-74	12	4
Hawthorne Pde Residential	57	Daytime	62	71-76	14	6
Parramatta Rd Commercial	18	Daytime	70	72-79	9	1

4.7.2 Longport St Underpass

At this location, there is insufficient room to accommodate both the GreenWay shared path and the proposed light rail under the existing bridge structure. It is proposed to construct an underpass tunnel for the GreenWay shared path through the existing bridge abutments. The construction would take between four and six months, and would potentially require night works and road closures for around two weeks, with other work being carried out during the daytime.

The site specific NMLs are based on the ambient noise survey conducted at location B05 – 4 William St. Predicted noise levels and exceedances for typical construction activities are shown in **Table 24** and for night-time works in **Table 25**.

Table 24 Longport St Underpass Typical Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Longport St Residential	19	Daytime	60	77-79	19	11
William St Residential	75	Daytime	60	66-67	7	-
Alfred St Residential	115	Daytime	60	60-62	2	-
Old Canterbury Rd Commercial	43	Daytime	70	69-72	2	-
Edward St Commercial	126	Daytime	70	59-61	0	-
Smith St Commercial	62	Daytime	70	66-68	0	-

Table 25 Longport St Underpass Night-time Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Longport St Residential	19	Night-time	47	69-71	24	16
William St Residential	75	Night-time	47	59-60	13	5
Alfred St Residential	115	Night-time	47	53-55	8	-
Old Canterbury Rd Commercial	43	Night-time	n/a	63-66	-	-
Edward St Commercial	126	Night-time	n/a	53-55	-	-
Smith St Commercial	62	Night-time	n/a	59-61	-	-

4.7.3 Old Canterbury Rd Underpass

At this location, there is insufficient room to accommodate both the GreenWay shared path and the proposed light rail under the existing bridge structure. It is proposed to construct an underpass tunnel for the GreenWay shared path through the existing bridge abutments. The construction would take between four and six months, and would potentially require night works and road closures for around two weeks, with other work being carried out during the daytime.

The site specific NMLs are based on the ambient noise survey conducted at location B06 – 77 Weston St. Predicted noise levels and exceedances for typical construction activities are shown in **Table 26** and for night-time works in **Table 27**.

Table 26 Old Canterbury Rd Underpass Typical Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Old Canterbury Rd Residential	8	Daytime	49	72-85	36	28
Fred St Residential	50	Daytime	49	68-71	22	14
Edward St Commercial	8	Daytime	70	74-86	16	8
McGill St Commercial	70	Daytime	70	65-67	0	-

Table 27 Old Canterbury Rd Underpass Night-time Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Old Canterbury Rd Residential	8	Night-time	36	65-73	37	29
Fred St Residential	50	Night-time	36	62-65	29	21
Edward St Commercial	8	Night-time	n/a	n/a	n/a	n/a
McGill St Commercial	70	Night-time	n/a	n/a	n/a	n/a

4.7.4 Davis St Underpass

At this location, there is insufficient room to accommodate both the GreenWay shared path and the proposed light rail under the existing bridge structure. It is proposed to construct an underpass tunnel for the GreenWay shared path through the existing bridge abutments. The construction would take between four and six months, and would potentially require night works and road closures for around two weeks, with other work being carried out during the daytime.

The site specific NMLs are based on the ambient noise survey conducted at location B06 – 77 Weston St. Predicted noise levels and exceedances for typical construction activities are shown in **Table 28** and for night-time works in **Table 29**

Table 28 Davis St Underpass Typical Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Terry Rd Residential	8	Daytime	49	73-83	34	26
Weston St Residential	7	Daytime	49	75-87	38	30
Davis St Residential	55	Daytime	49	67-69	20	12
Pigott St Residential	75	Daytime	49	64-67	18	10
Davis St Commercial	37	Daytime	70	70-73	3	-

Table 29 Davis St Underpass Night-time Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Terry Rd Residential	8	Night-time	36	66-73	37	29
Weston St Residential	7	Night-time	36	68-78	42	34
Davis St Residential	55	Night-time	36	60-63	27	19
Pigott St Residential	75	Night-time	36	57-60	24	16
Davis St Commercial	37	Night-time	n/a	n/a	-	-

4.7.5 Constitution Rd Underpass

At this location, there is insufficient room to accommodate both the GreenWay shared path and the proposed light rail under the existing bridge structure. It is proposed to construct an underpass tunnel for the GreenWay shared path through the existing bridge abutments. The construction would take between four and six months, and would potentially require night works and road closures for around two weeks, with other work being carried out during the daytime.

The site specific NMLs are based on the ambient noise survey conducted at location B07 – 66 Constitution Rd. Predicted noise levels and exceedances for typical construction activities are shown in **Table 30** and for night-time works in **Table 31**.

Table 30 Constitution Rd Underpass Typical Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Williams Pde Residential	10	Daytime	54	77-85	31	23
Constitution Rd Residential (North West)	70	Daytime	54	65-67	13	5
Constitution Rd Residential (North East)	45	Daytime	54	69-72	18	10
Constitution Rd Residential (South East)	20	Daytime	54	76-79	25	17
Constitution Rd Commercial	20	Daytime	70	76-79	9	1

Table 31 Constitution Rd Underpass Night-time Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Williams Pde Residential	10	Night-time	41	70-78	37	29
Constitution Rd Residential (North West)	70	Night-time	41	58-60	19	11

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Constitution Rd Residential (North East)	45	Night-time	41	62-65	24	16
Constitution Rd Residential (South East)	20	Night-time	41	68-71	30	22
Constitution Rd Commercial	20	Night-time	n/a	n/a	n/a	n/a

4.7.6 Hercules St Underpass

At this location, there is insufficient room to accommodate both the GreenWay shared path and the proposed light rail under the existing bridge structure. It is proposed to construct an underpass tunnel for the GreenWay shared path through the existing bridge abutments. The construction would take between four and six months, and would potentially require night works and road closures for around two weeks, with other work being carried out during the daytime.

The site specific NMLs are based on the ambient noise survey conducted at location B08 – 8/14 Hercules St. Predicted noise levels and exceedances for typical construction activities are shown in **Table 32** and for night-time works in **Table 33**.

Table 32 Hercules St Underpass Typical Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Hercules St Residential	7	Daytime	54	73-87	33	25
Terrace Rd Residential	12	Daytime	54	76-84	30	22
Dulwich Hill Public School	25	Daytime	55	73-77	22	14
Hercules St Commercial	30	Daytime	70	70-74	4	-

Table 33 Hercules St Underpass Night-time Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Hercules St Residential	7	Night-time	40	67-78	38	30
Terrace Rd Residential	12	Night-time	40	70-77	37	29
Dulwich Hill Public School	25	Night-time	n/a	n/a	n/a	n/a
Hercules St Commercial	30	Night-time	n/a	n/a	n/a	n/a

4.7.7 Summary of Bridge and Underpass Construction Noise

The impacts of noise to upgrade bridge structures or to excavate underpasses to accommodate the GreenWay may be summarised as follows:

- The Parramatta Rd rail overbridge is elevated with respect to the surrounding residences and commercial receivers. For general bridge works which are likely to occur through the night-time during lower traffic periods, the NMLs are predicted to be exceeded by up to 22 dBA at the surrounding residences, if works were to occur during the daytime or evening lower exceedances are predicted as a result of the higher NMLs. During daytime retaining wall construction NMLs are predicted to be exceeded by up to 18 dBA at the surrounding residential receivers and up to 9 dBA at the surrounding commercial receivers.

- The Longport St underpass works are generally on grade with the surrounding receivers. At the residential receivers to the east, NMLs are predicted to be exceeded by up to 19 dBA during the daytime and 24 dBA during night-time piling activities. At the remaining surrounding residential receivers NMLs are predicted to be exceeded by up to 7 dBA during daytime construction and by up to 13 dBA during night-time piling activities.

- At the residences surrounding the Old Canterbury Rd underpass works residences and commercial receivers are generally on grade with the work site. The NMLs are predicted to be exceeded by up to 37 during both daytime construction works and night-time piling works. The high exceedances are a result of lower ambient noise levels in the area and residential receivers located in close proximity to the works.

- At the Davis St underpass site residences and commercial receivers are generally on grade with the works. The NMLs are predicted to be exceeded by up to 38 dBA and 34 dBA for residences to the northeast and northwest respectively. These are significant exceedances being a direct result of the close proximity of receivers and relatively lower ambient noise levels in the area. During night-time piling works residential receivers to the northeast and northwest will exceed the NMLs by up to 42 dBA and 37 dBA, respectively.

- At the Constitution Rd underpass site residences and commercial receivers are generally on grade with the works. The NMLs are predicted to be exceeded by up to 31 dBA and 18 dBA for residences to the west and east respectively. During night-time piling activities NMLs are predicted to be exceeded by up to 37 dBA and 30 dBA for residences to the west and east respectively.

- At the Hercules St underpass residences and commercial receivers are generally overlooking the site which is in cut. The NMLs are predicted to be exceeded by up to 33 dBA at residences to the west, and up to 22 dBA at the school. During potential night-time piling activities the NMLs are predicted to be exceeded by up to 38 dBA. School exceedances assume open windows, and further investigation on the noise reduction from outside to inside is required during the construction planning and site establishment phases of the project, together with liaison with the school.

4.8 Airborne Construction Noise Along GreenWay

Construction of the GreenWay would require works along the length of the alignment. The intensity of work required at each location would depend on the topography and whether the path is at grade or elevated. Construction of the GreenWay path would occur during the daytime only. Two scenarios representative of the activities having potentially the greatest noise impact on nearby receivers have been considered, general earthworks (utilising and excavator and a truck) and piling. The predicted noise levels presented in the following table are therefore representative of the 'noisiest' construction periods at locations where the GreenWay would be elevated. Generally, noise levels would be expected to be lower than those presented for a majority of the 12 month construction period.

The $L_{Aeq(15minute)}$ noise levels without noise controls implemented on site have been predicted for a range of indicative receiver distances from the works for these two scenarios (see **Table 34**). It is noted that as the work progresses along the alignment, the distance between the noise sources and each receiver will change.

Table 34 Indicative Worst Case Construction Noise Along GreenWay

Receiver Distance (m)	Earthworks LAeq Noise Level (dBA)	Piling LAeq Noise Level (dBA)
10	83	80
20	77	74
30	73	70
40	71	68
50	69	66

4.9 Airborne Construction Noise - Pyrmont Stabling Facility

The existing Pyrmont Stabling Facility serves the light rail rolling stock currently operating between Central and Lilyfield. As part of the project the stabling facility is proposed to be upgraded, which will include the extension of one siding (rail track) into the existing car park by about 30 m and additional fencing, lighting, CCTV and intruder alarms (see **Figure 12**). The works would be conducted during standard daytime construction hours. The construction noise impact of the stabling facility upgrade is assessed in this section.

4.9.1 Ambient Noise Survey

An ambient noise survey was conducted at 190 Pyrmont St, being representative of the nearest residences to the west. This survey was conducted on the morning of 31 August 2010 to establish representative background noise levels for the purpose of determining NMLs. The results of the survey are presented in **Table 35**.

Table 35 Pyrmont Attended Noise Monitoring Results

Location	Time of Day	Noise Levels (dBA)					Description and Typical LAmax Levels (dBA)
		LAmax	LA1	LA10	LAeq	LA90	
190 Pyrmont St	8:28	84	73	68	66	61	Local traffic on Pyrmont St 60-72
	8:43	78	73	68	66	61	Motor bikes on Pyrmont St 78, 78
							Traffic on Western Distributor Ramps 60-72

4.9.2 Construction Noise Impacts

At the Pyrmont Stabling construction site, the key noise impacts would be due to rail track construction in the existing carpark. The nearest noise sensitive receivers to this site are identified in **Table 36**. Also shown in **Table 36** are the predicted noise levels and exceedances of the NMLs with and without mitigation in the form of 3 m hoardings.

Table 36 Pyrmont Stabling Upgrade Construction Noise Levels

Receiver Area	Distance (m)	Period	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)	
					None	3 m Hoarding
Novotel Hotel - North	55	Daytime	70 [1]	56-66	0	-
Pymont St Residential - West	42	Daytime	70 [1]	65-69	0	-
Commercial - East	50	Daytime	70	63-67	0	-

Note 1 The RBL + 10 dBA NML exceeds the 70 dBA "commercial" NML, hence an NML of 70 dBA has been adopted.

4.9.3 Summary of Construction Noise at Pyrmont Stabling Facility

The residences and commercial receivers surrounding the Pyrmont Stabling site are generally on grade or overlooking the worksite. Predicted noise levels for construction activities comply with the NMLs at all receivers even without hoarding.

4.10 Construction Traffic Noise Assessment

4.10.1 Construction Traffic Noise Assessment Goals

For traffic operating on public roads to and from the subject sites the DECCW's "*Environmental Criteria for Road Traffic Noise*" (ECRTN) are appropriate for assessing potential road traffic noise impacts. The DECCW's recommended noise goals for the three most common road categories are set out in **Table 37**.

Table 37 DECCW Road Traffic Noise Goals

Development	Day (7.00 am to 10.00 pm)	Night (10.00 pm to 7.00 am)
Land use developments with potential to create additional traffic on existing FREEWAYS/ARTERIAL roads	$L_{Aeq(15hour)}$ 60 dBA	$L_{Aeq(9hour)}$ 55 dBA
Land use developments with potential to create additional traffic on COLLECTOR roads	$L_{Aeq(1hour)}$ 60 dBA	$L_{Aeq(1hour)}$ 55 dBA
Land use developments with potential to create additional traffic on LOCAL roads	$L_{Aeq(1hour)}$ 55 dBA	$L_{Aeq(1hour)}$ 50 dBA

Where the L_{Aeq} traffic noise levels already exceed the above noise goals, a 2 dBA increase in the overall traffic noise levels is normally regarded as an alternative target (having investigated the application of all feasible and reasonable noise mitigation) in order to maintain the general acoustic amenity of the area.

It is possible that on local roads immediately adjacent to the various subject work sites, the community may associate heavy vehicle movements with the project. Once the heavy vehicles move further from each of the sites onto major collector or arterial roads however, the noise would be perceived as part of the general road traffic.

Sleep Disturbance and Maximum Noise Level Events

The DECCW's ECRTN and the Road and Traffic Authority's (RTA's) *"Environmental Noise Management Manual"* (ENMM) provide guidance as to the likelihood of sleep disturbance resulting from maximum noise level events (mainly associated with heavy vehicle movements). The ECRTN points out the following:

> *"There are no universally accepted criteria governing the likelihood of sleep disturbance. In other words, at the current level of understanding, it is not possible to establish absolute noise levels that correlate to levels of sleep disturbance (for all or even a majority of people)."*

Notwithstanding the ECRTN and ENMM suggests that:

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

Furthermore in assessing potential sleep disturbance impacts from road traffic noise the ENMM suggests:

- At locations where road traffic is continuous rather than intermittent, the $L_{Aeq(9hour)}$ target noise level should sufficiently account for sleep disturbance impacts.
- However, where the emergence of L_{Amax} noise levels over the ambient L_{Aeq} noise level is greater than 15 dBA, the L_{Aeq} criterion may not sufficiently account for sleep disturbance impacts.

The ENMM defines a "maximum noise event" as a vehicle passby for which the difference in the L_{Amax} and $L_{Aeq(1hour)}$ noise levels is greater than 15 dBA. Assessment of sleep disturbance should include consideration of the number of maximum noise level events occurring during the night-time period.

4.10.2 Construction Noise Traffic Assessment

Daytime Impacts

Heggies has been provided with indicative vehicle movements and estimates of heavy vehicle percentage for typical arterial, collector and local roads in the residential areas surrounding the worksites. Of these the local roads will be the most sensitive to construction traffic associated with the project.

A typical local road is Weston St, Lewisham, which will serve the Waratah Mills stop construction site. The 5 day Annual Average Daily Traffic (AADT) for Weston St is 238, and daytime hourly flows range from 10 to 20 vehicles per hour with an estimated 5 percent of heavy vehicles. Heggies has been advised construction traffic associated with the project at any construction site is likely to be a typical maximum of two to three trucks per hour, and may peak at five trucks per hour during concrete pouring.

For a typical receiver on Weston St the baseline $L_{Aeq(1hour)}$ noise level is predicted to comply with the 55 dBA ECRTN criterion. Further more the addition of the construction traffic is predicted to increase the daytime traffic noise levels by typically 2 dBA, with a $L_{Aeq(1hour)}$ noise level of 53 dBA which complies with the 55 dBA criterion. In summary the project is not anticipated to generate any significant daytime traffic noise impacts as a result of traffic associated with construction.

Night-time Impacts

Night-time works are proposed for the Parramatta Rd bridge overpass and piling associated with the Bridge Works to accommodate the GreenWay.

For sensitive receivers with openable windows, (which would apply to residences on the access routes other than Parramatta Rd) the 55 dBA based external sleep disturbance screening criterion is expected to be exceeded in the range of 4 dBA to 12 dBA. On this basis, it would be recommended that further investigation be conducted during the construction planning and site establishment phases of the project to confirm the number of existing sleep disturbing events that occur as well as the external to internal noise reduction achieved at these locations.

4.11 Construction Noise Mitigation Strategy

The DECCW's *Interim Construction Noise Guideline* describes strategies for construction noise mitigation and control that are applicable for this project. The approach to construction noise control involves time restrictions, level restrictions and feasible and reasonable mitigation measures.

4.11.1 Time Restrictions

Recommended standard hours for normal construction work on the project are as follows:

- Monday to Friday 7:00 am to 6:00 pm
- Saturday 8:00 am to 1:00 pm
- No work on Sundays or public holidays

It is expected that the majority of construction work on the project will be undertaken during standard hours. The raising of the rail bridge over Parramatta Rd and the construction of underpasses to accommodate the GreenWay have been identified by the proponent as potentially requiring night works to minimise disruption to the road network. Where night works are proposed, site-specific Construction Noise and Vibration Management Plans (CNVMPs) should be developed in the detailed design phase when more information is available on the schedule for the works and the equipment to be used.

4.11.2 Level Restrictions

The NMLs at potentially affected sensitive receivers have been identified in this report. Where exceedances of the NMLs have been predicted during the daytime (standard construction hours), receivers are considered to be noise affected. The proponent should apply all feasible and reasonable work practices to meet the NMLs. The proponent should also inform all potentially impacted residents of the the nature of works to be carried out, the expected noise levels and duration, and contact details.

Receivers are considered to be highly noise affected if noise levels exceed 75 dBA during the standard construction hours. The assessment indicates that the worst case noise scenarios may lead to noise levels exceeding 75 dBA during the daytime at two of the stop locations (Dulwich Grove and Dulwich Hill Interchange), during construction of the GreenWay and at the locations where bridge and underpass works are required. At these locations, site-specific Construction Noise and Vibration Management Plans (CNVMPs) should be developed in the detailed design phase when more information is available on the schedule for the works and the equipment to be used. The proponent should schedule work to provide respite periods from the noisiest activities, and communicate with the impacted residents by clearly explaining the duration and noise level of the works.

The proposed night works to construct underpasses to accommodate the GreenWay are predicted to result in significant exceedances of the NMLs. The proponent should identify all feasible and reasonable work practices in the CNVMPs. Where all feasible and reasonable practices have been applied and noise would be more than 5 dBA above the noise affected level, the proponent should negotiate with the community to determine the schedule for the works.

4.11.3 Feasible and Reasonable Mitigation Measures

Excavation, piling, earthworks and bridgeworks (particularly those that are required to be conducted during the evening and night-time) will require careful management of all noise-producing equipment and activities. The reasonableness of the identified feasible mitigation measures would be considered during the construction planning and site establishment phases of the project, and in the development of CNVMPs. In general, mitigation measures that should be considered are summarised as follows:

- For construction of the stops and at the bridge and underpass sites, 3 m high perimeter noise walls should be considered, noting that noise walls are effective for receivers at or near ground level and not effective for receivers overlooking the sites.
- Given the potentially high noise levels at residential receivers, adherence to recommended DECCW daytime construction hours is critical for excavation or rockbreaking activities.
- When working adjacent to schools, particularly noisy activities should be scheduled outside normal school hours, where possible.
- Avoiding the coincidence of noisy plant working simultaneously close together and adjacent to sensitive receivers will result in reduced noise emissions.
- Where possible, the offset distance between noisy plant items and nearby noise sensitive receivers should be as great as possible.
- Where possible, equipment with directional noise emissions should be oriented away from sensitive receivers.
- Regular compliance checks on the noise emissions of all plant and machinery used for the project would indicate whether noise emissions from plant items were higher than predicted. This also identifies defective silencing equipment on the items of plant.
- Ongoing noise monitoring during construction at sensitive receivers during critical periods to identify and assist in managing high risk noise events.
- Where possible heavy vehicle movements should be limited to daytime hours.
- Reversing of equipment should be minimised so as to prevent nuisance caused by reversing alarms.
- Loading and unloading should be carried out away from sensitive receivers, where practicable.

5 CONSTRUCTION VIBRATION ASSESSMENT

5.1 Vibration Damage Goals - Surface Structures

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

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

Sources of vibration that are considered in the standard include demolition, blasting (carried out during mineral extraction or construction excavation), piling, ground treatments (eg compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

The recommended limits (guide values) for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented numerically in **Table 38** and graphically in **Figure 13**.

Table 38 Transient Vibration Guide Values - Minimal Risk of Cosmetic Damage

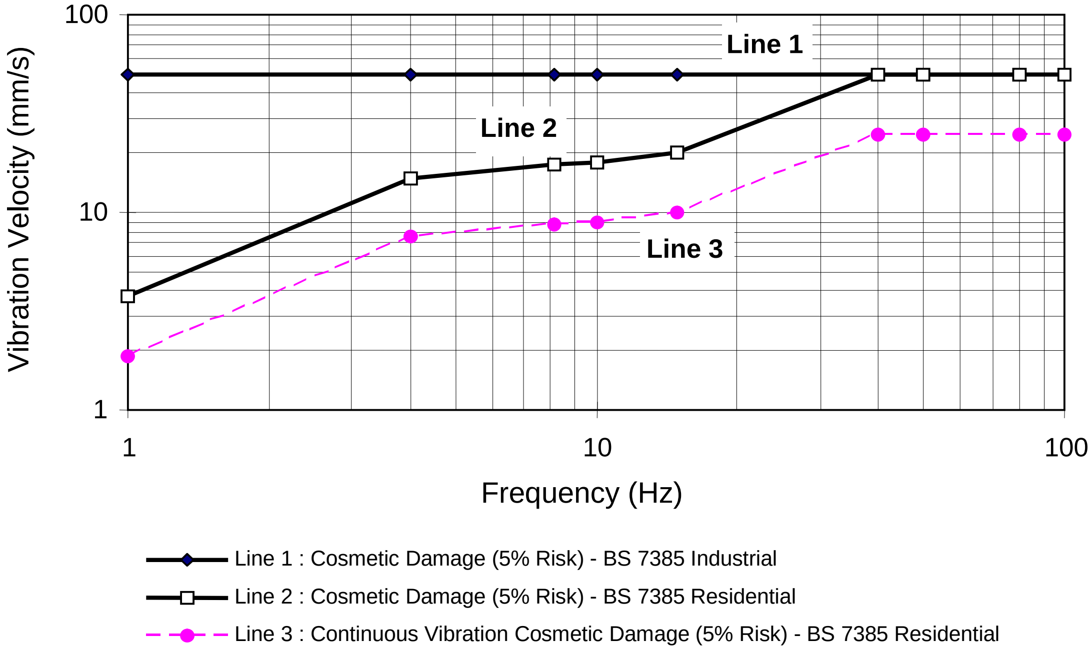
Line	Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	**15 Hz and Above**
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial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

The Standard states that the guide values in **Table 38** relate predominantly to transient vibration which does not give rise to resonant responses in structures and low-rise buildings.

Where the dynamic loading caused by continuous vibration may give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in **Table 38** may need to be reduced by up to 50%.

Note: rockbreaking/hammering and sheet piling activities are considered to have the potential to cause dynamic loading in some structures (eg residences) and it may therefore be appropriate to reduce the transient values by 50%.

Figure 13 Transient Vibration Guide Values for Cosmetic Damage



In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for building types corresponding to "Line 2" are reduced. Below a frequency of 4 Hz where a high displacement is associated with the relatively low peak component particle velocity value, a maximum displacement of 0.6 mm (zero to peak) is recommended. This displacement is equivalent to a vibration velocity of 3.7 mm/s at 1 Hz.

The Standard goes on to state that minor damage is possible at vibration magnitudes which are greater than twice those given in **Table 38**, and major damage to a building structure may occur at values greater than four times the tabulated values.

Fatigue considerations are also addressed in the Standard and it is concluded that unless calculation indicates that the magnitude and number of load reversals is significant (in respect of the fatigue life of building materials) then the guide values in **Table 38** should not be reduced for fatigue considerations.

It is noteworthy that extra to the guide values nominated in **Table 38**, the standard states that:

> *"Some data suggests that the probability of damage tends towards zero at 12.5 mm/s peak component particle velocity. This is not inconsistent with an extensive review of the case history information available in the UK."*

Also that:

> *"A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive."*

For most construction activities involving intermittent vibration sources such as impact hammers or rockbreakers, 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, a conservative vibration damage screening level of 7.5 mm/s has been adopted for preliminary assessment purposes.

5.2 Safe Working Distances for Vibration Intensive Plant

For the purpose of this assessment a "safe distance" would correspond to the nearest distance at which the maximum vibration level generated by the operation of a subject plant item is predicted not to exceed the 7.5 mm/s cosmetic damage threshold (noting that higher vibration levels may be permitted for typical building constructions - refer **Section 5.1**).

Table 39 presents indicative "safe distances" for the plant items likely to be used in the construction of the project. It is noted that these safe working distances apply to all structures, including residences and the sensitive receivers identified in **Table 4**.

Table 39 Safe Working Distances - Cosmetic Damage

Plant Items	Safe Working Distance (m)
Hydraulic Impact Hammer - Small	1
Hydraulic Impact Hammer - Medium	4
Hydraulic Impact Hammer - Large	15
Vibratory Roller - 10 Tonne	6
Vibratory Trench Roller - 3 Tonne	1

At any locations where vibration intensive plant is proposed to be used within the identified safe working distances in **Table 39**, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure is recommended to determine the applicable safe vibration level.

5.3 Human Comfort Vibration Goals

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

The actual perception of motion or vibration may not, in itself, be disturbing or annoying. An individual's response to that perception, and whether the vibration is "normal" or "abnormal", depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling.

Human tactile perception of random motion, as distinct from human comfort considerations, was investigated by Diekmann and subsequently updated in German Standard DIN 4150 Part 2-1975. On this basis, the resulting degrees of perception for humans are suggested by the vibration level categories given in **Table 40**.

Table 40 Peak Vibration Levels and Human Perception of Motion

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

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

Table 40 suggests that people will just be able to feel floor vibration at levels of about 0.1 mm/s (RMS) and that the motion becomes "noticeable" at a level of approximately 0.7 mm/s (RMS).

Construction activities typically generate building vibrations that are intermittent or impulsive in nature, however vibration levels may sometimes be constant from sources such as generators or ventilation fans. Examples of intermittent vibration events include the vibration generated by rockbreakers, vibratory rollers, drilling/piling and excavators. Examples of impulsive vibration events include the vibration generated by demolition activities, blasting or the dropping of heavy equipment.

Where vibration is intermittent or impulsive in character, DECCW's "*Assessing Vibration: a technical guideline*" recognises that higher vibration levels are tolerable to building occupants than for continuous vibration. As such, higher vibration goals are usually applicable for short term, intermittent and impulsive vibration activities than for continuous vibration sources.

The following sections describe the applicable continuous and intermittent vibration goals for the project construction activities.

5.3.1 Human Comfort Goals for Continuous and Impulsive Vibration

The DECCW's "*Assessing Vibration: a technical guideline*" is applicable to human comfort considerations and nominates preferred and maximum vibration goals for critical areas, residences and other sensitive receivers. The applicable human comfort vibration goals for continuous and impulsive vibration sources are provided in **Table 41** and **Table 42** respectively. In all cases, the vibration goals are expressed in terms of the RMS vibration velocity level in mm/s, measured in the most sensitive direction (z-axis).

The DECCW vibration guideline notes the following in relation to the preferred and maximum vibration levels:

> *"There is a low probability of adverse comment or disturbance to building occupants at vibration values below the preferred values. Activities should be designed to meet the preferred values where an area is not already exposed to vibration. Where all feasible and reasonable measures have been applied, values up to the maximum value may be used if they can be justified. For values beyond the maximum value, the operator should negotiate directly with the affected community. Situations exist where vibration above the preferred values can be acceptable, particularly for temporary disturbances and infrequent events of short term duration. An example is a construction or excavation project.*

In circumstances where work is short term, feasible and reasonable mitigation measures have been applied, and the project has a demonstrated high level of social worth and broad community benefits, then higher vibration values (above the maximum) may apply. In such cases, best management practices should be used to reduce values as far as practicable, and a comprehensive community consultation program should be instituted."

Table 41 Preferred and Maximum Vibration Levels for Continuous Vibration

Building Type	Preferred Vibration Level RMS Velocity (mm/s)	Maximum Vibration Level RMS Velocity (mm/s)
Critical Working Areas (eg hospital operating theatres, precision laboratories)	0.10	0.20
Residential Daytime	0.20	0.40
Residential Night-time	0.14	0.28
Offices, schools, educational institutions and places of worship	0.40	0.80
Workshops	0.80	1.60

Note: Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

Table 42 Preferred and Maximum Vibration Levels for Impulsive Vibration

Building Type	Preferred Vibration Level RMS Velocity (mm/s)	Maximum Vibration Level RMS Velocity (mm/s)
Critical Working Areas (eg hospital operating theatres, precision laboratories)	0.1	0.2
Residential Daytime	6.0	12.0
Residential Night-time	2.0	4.0
Offices, schools, educational institutions and places of worship	13.0	26.0
Workshops	13.0	26.0

Note: Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

5.3.2 Human Comfort Goals for Intermittent Vibration

For most construction activities that generate perceptible vibration in nearby buildings, the character of the vibration emissions is intermittent. This includes equipment such as rockbreakers, excavators, piling rigs, rock drills, vibratory rollers and heavy vehicle movements.

The applicable human comfort vibration goal for intermittent vibration sources is defined in terms of Vibration Dose Values (VDVs) as provided in **Table 43**. A definition of the VDV parameter is provided in the DECCW vibration guideline. The permissible vibration level corresponding to the VDV varies according to the duration of exposure. For example, higher vibration levels are permitted if the total duration of the vibration event(s) is small and lower vibration levels are permitted with if the total duration of the vibration event(s) is large.

Table 43 Preferred and Maximum Vibration Dose Values for Intermittent Vibration

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

Note: Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

5.4 Project Specific Human Comfort Vibration Comments

Some items of equipment proposed to be used to construct the project have the potential to result in exceedances of the human comfort criteria at distances of up to around 40 m, depending on the duration and nature of the construction activity. Any exceedances would be expected to be of short duration. Where vibration intensive activities are proposed close to sensitive receivers, these works should be scheduled during the day where possible. Potential vibration impacts should be considered in the site-specific CNVMPs, to be developed in the detailed design phase when more information is available on the schedule for the works and the equipment to be used.

6 OPERATIONAL NOISE ASSESSMENT

6.1 Introduction

The main sources of airborne noise from LRVs originate at the wheel-rail interface as a result of surface irregularities on the wheel and/or rail running surfaces and interaction forces. During a LRV passby, the wheel, bogies, rail and rail support system vibrate and hence radiate airborne noise. The key parameters influencing the level of airborne noise are therefore the vehicle speed, wheel condition, rail condition, vehicle length, number of vehicles, and track design. Receiver distance and the presence of natural or man-made barriers located between the railway line and receivers (to break line-of-sight noise propagation) will also influence noise levels at receivers.

The existing light rail system has shown that noise generated from equipment mounted to the light rail vehicles is typically minimal. The exception is the warning bell used to signal impending departure of the LRVs from stops. It is noted that the current operating procedure during the night-time period is for warning bells to be used only when in the opinion of the driver there is considered to be a danger to public safety. Noise from warning bells has therefore not been included in the noise modelling.

Impact noise from rail discontinuities such as turnouts and mechanical joints or uneven welded joints also has an effect on the level of wheel-rail noise emission, as impulsive noise is emitted as each wheel of the LRV impacts the discontinuity. Other factors that can affect the levels of noise emission include bridges and tight radius curves. The relevancy of these factors has been considered as part of the noise assessment.

6.2 Operational Noise Metrics

The primary noise metrics used to describe light rail noise emissions in the modelling and assessments are:

L_{Amax} The "Maximum Noise Level" occurring during a LRV passby noise event.

L_{Aeq} The "Equivalent Continuous Noise Level", sometimes also described as the "energy-averaged noise level". The L_{Aeq} may be likened to a "noise dose", representing the cumulative effects of all the noise events occurring in the relevant time period.

L_{AE} The "Sound Exposure Level", which is used to indicate the total acoustic energy of an individual noise event. This parameter is used in the calculation of L_{Aeq} values from individual noise events.

The subscript "A" indicates that the noise levels are filtered to match normal human hearing characteristics (ie A-weighted).

6.3 Operational Noise Goals

The noise goals relating to airborne noise emissions from LRVs are the same as those specified in the *Inner West Light Rail Extension Approval* dated 3 March 1999. The applicability of these operational noise goals has been confirmed in consultation with the DECCW and are summarised in **Table 44**.

Table 44 Operational Noise Goals

Parameter	Criterion	Application
L_{Amax}	82 dBA at 7.5 m	General requirement at 60 km/h on typical track
L_{Amax}	82 dBA	At existing residential facades
L_{Aeq} Day	60 dBA	7.00 am to 7.00 pm at existing residential facades
L_{Aeq} Evening	55 dBA	7.00 pm to 11.00 pm at existing residential facades
L_{Aeq} Night	50 dBA	11.00 pm to 7.00 am at existing residential facades

6.4 Operational Noise Modelling

SoundPLAN Version 6.5 has been used to calculate airborne noise emission levels for this part of the study. Of the train noise prediction models available within SoundPLAN, the Nordic Rail Traffic Noise Prediction Method (Kilde 1984) has been used, since it is capable of efficiently and reliably calculating both the L_{Amax} and L_{Aeq} noise levels.

The calculation procedure takes into account the direct noise, the noise diffracting over obstacles or barriers and the noise reflected off buildings. The calculation was carried out using a fixed calculation grid with a spacing of 10 m to produce noise contours. The resulting contours were interpolated between the grid points.

6.4.1 Rolling Stock Noise Levels

Noise emission limits from rail vehicles are normally specified in terms of the L_{AE} and L_{Amax} (fast) noise levels at a particular speed, measured at a particular distance from the track centreline.

Heggies has undertaken a review of the yearly noise compliance measurements taken of the existing light rail system (between 2004 and 2010) to determine the following reference noise levels for the airborne noise modelling. The reference speed is 60 km/h and measurement distance is 7.5 m from the track centreline.

- L_{Amax} 82 dBA (at 60 km/h and 7.5 m distance)
- L_{AE} 83 dBA (at 60 km/h and 7.5 m distance)

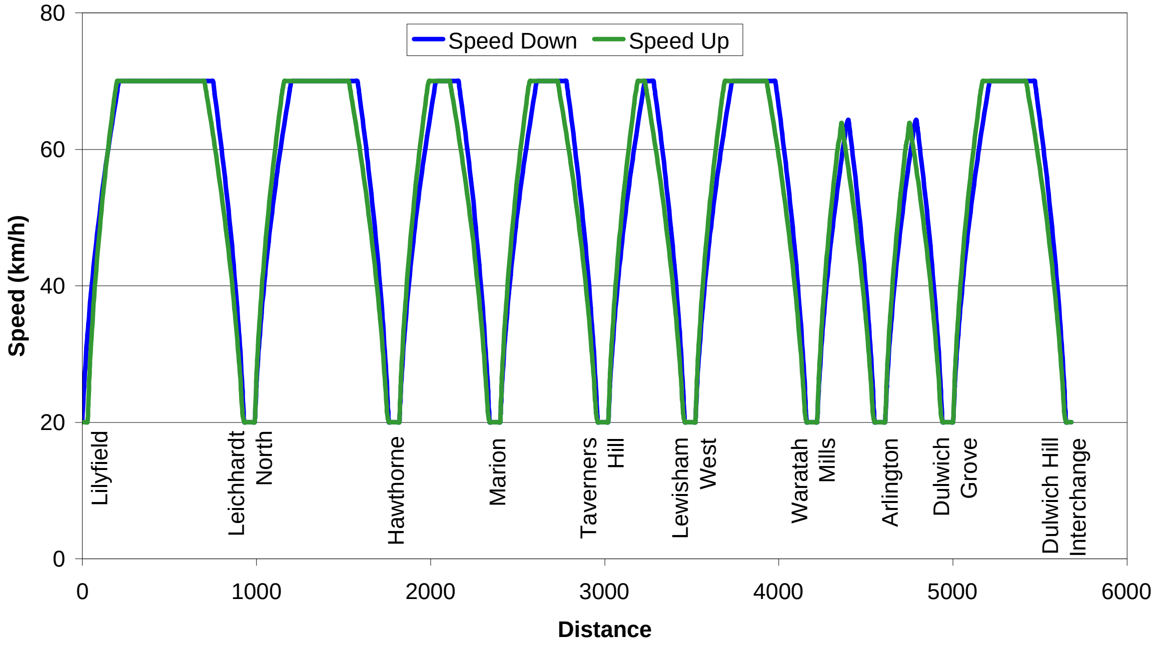
6.4.2 Vehicle Speeds

A maximum speed of 70 km/h has been assumed for the LRVs, with a speed restriction of 20 km/h through the stops (if not stopping to pick up or set down passengers). In practice, the existing LRVs rarely operate at faster than 60 km/h although they have a theoretical top speed of 80 km/h.

Between the stops, a speed profile has been assumed based on a typical sustained acceleration of 0.8 m/s^2 and a typical deceleration of 1 m/s^2. It is noted that faster braking is achievable, but would only occur in an emergency situation. The resulting assumed speed profile along the alignment in both directions is shown in **Figure 14**.

The Nordic Rail Traffic Noise Prediction Method as used in SoundPLAN has a minimum vehicle speed of 30 km/h. Therefore the minimum modelled speed through the stops is 30 km/h, leading to a conservative assessment of noise at the stop locations.

Figure 14 Assumed Speed Profile



6.4.3 LRV Numbers

The project will operate a similar frequency of service to the existing light rail. The first service in each direction is at 6:00 am. The last service currently departs Central at 11:00 pm and Lilyfield at 11:20 pm on weekdays, and Central at 12:10 am then Lilyfield at 12:30 am on Friday and Saturday nights. In the mornings, the service frequency is approximately every half hour before 6:30 am on weekdays and before 8:00 am on weekends. The operating frequency during the day (until 9:00 pm) is typically every 12 minutes then every 15 minutes until the last service.

This operating frequency has been used to estimate the number of passby events for the day, evening and night-time periods to use in the noise modelling for the SLRE as shown in **Table 45**. The LRV numbers assumed represent the current operating practice, with the night-time numbers being the worst case as occurring on the weekend. It is noted that the first morning services will travel out to Dulwich Hill Interchange from their stabling facility prior to entering service, while in the evening all services will terminate at Central and then return to the stabling facility without further travel on the extended section of the alignment.

Table 45 LRV Numbers

Time of Day	Assumed Frequency	LRV Numbers (Up)	LRV Numbers (Down)	LRV Numbers (Total)
Day (7am to 7pm)	12 minutes	60	60	120
Evening (7pm to 11pm)	12/15 minutes	18	18	36
Night (11pm to 7am)	15 minutes	10	12	22

6.4.4 Rail Surface Discontinuities

The trackform in the existing rail corridor was jointed rail, which has source noise levels 5 dB to 10 dB higher than continuously welded rail. As discussed in the *Rozelle Goods Line – Rail Track Maintenance and Reconstruction Review of Environmental Factors*, the renewed track will be converted to continuously welded rail, where joints are welded and finished to provide a smooth running surface. As a result of the track renewal works, the airborne noise associated with the wheel/rail interaction will be reduced significantly compared with the previous freight operations in the existing corridor.

Assuming track would be maintained in good condition without defects, the only significant rail surface discontinuities would be at crossovers and turnbacks. The probable locations of crossovers and turnbacks would be at Lilyfield and/or Leichhardt North, at Dulwich Hill Interchange, and possibly at Lewisham West to allow for out-of-course operations. As the locations are not confirmed at the time of this assessment, crossovers have not been included in the SoundPLAN model.

Crossovers would typically add less than 6 dB to the L_{AE} rolling noise source levels at a distance of 15 m. Since noise levels from a point source decrease 6 dB with each doubling of distance, noise impacts from crossovers are unlikely to be significant at distances greater than 30 m. To minimise noise impacts from the crossovers, they should be located either close to the proposed stops where LRV speeds are at their lowest, or at a distance of at least 30 m from the nearest sensitive receiver.

6.4.5 Bridge Noise

There are three open transom, non-ballasted steel bridges along the proposed alignment, over Charles St, Marion St and Parramatta Rd. The first two of these bridges have metal side screens, while the bridge over Parramatta Rd has no side screens. Open transom steel bridges are lightly damped structures and an increase in noise levels is expected as LRVs pass over these structures. A correction of 8 dB has been applied in the SoundPLAN model for the Charles St and Marion St bridges. A correction of 10 dB has been applied for the Parramatta Rd Bridge.

6.4.6 Flanging Noise

Flanging noise is a high frequency, broadband or multi-tonal (tissh-tissh) noise which sometimes occurs on tight curves (less than 500 m radius). Flanging noise has been observed in the past on some sections of the existing light rail route, and is controlled by the use of friction modifiers applied to the running surface using rolling stock based applicators. On the basis that there are already mitigation measures for flanging noise in place, no corrections for flanging on curves have been applied in the noise modelling.

6.4.7 Miscellaneous Noise Modelling Inputs

The following data and inputs have also been used in the modelling of airborne noise from the project:

- Ground terrain, track alignment strings and proposed stop locations - these were supplied to Heggies in AutoCAD format.
- Buildings and receiver locations - the location of buildings and their representation within the noise model has been derived from aerial photography. The various uses of the nearby buildings were determined by site inspection.

6.4.8 Noise Modelling Scenarios

Noise contours have been predicted at calculation heights of 2.0 m and 5.0 m above ground level, representing first and second floor receivers respectively. The 2.0 m contours are shown in **Appendix C.** Separate noise contour plots have been provided for the $L_{Aeq(day)}$, $L_{Aeq(evening)}$, $L_{Aeq(night)}$ and L_{Amax} noise parameters.

6.5 Predicted Operational Noise Levels

In addition to the noise contour plots in **Appendix C**, the noise levels at residential receivers predicted to experience the highest noise levels along the alignment are summarised in **Table 46.** This table is intended to indicate noise levels at different times of day at the facades of the residences closest to the route. The noise catchment areas indicated are divided by the stop locations – this is because between stops the LRV's reach their maximum speeds, so noise levels are predicted to be higher between stops than adjacent to the stops. Where the closest receiver is a multi-storey building, the levels shown are for the worst-affected storey.

Table 46 Predicted Operational Noise Levels at Residential Receivers with Highest Noise Levels

Noise Catchment Area	Maximum Predicted Noise Levels at Residential Receivers (dBA)			
	$L_{Aeq(day)}$	**$L_{Aeq(evening)}$**	**$L_{Aeq(night)}$**	**L_{Amax}**
Residential Noise Goal	**60**	**55**	**50**	**82**
Lilyfield – Leichhardt North	56	55	50	80
Leichhardt North - Hawthorne	53	52	47	75
Hawthorne - Marion	52	52	46	74
Marion – Taverners Hill	51	50	45	74
Taverners Hill – Lewisham West	53	53	48	77
Lewisham West – Waratah Mills	59	59*	54*	86*
Waratah Mills - Arlington	58	57*	52*	83*
Arlington – Dulwich Grove	55	54	49	78
Dulwich Grove – Dulwich Hill Interchange	56	55	50	81

Note: Asterisks indicate exceedances of operational noise goals

No exceedances of the noise goals have been identified for sensitive non-residential receivers.

Exceedances of the operational noise goals have been predicted at seven residential locations between the Lewisham West and Arlington stops as summarised in **Table 47**. These noise levels have been calculated for a receiver location 1 m from the worst affected level of the worst affected facade. In all cases these are locations where the LRV's are expected to reach their top speed. No exceedances have been identified of the daytime noise goals.

Table 47 Exceedances of Residential Operational Noise Goals

Address	Evening		Night		LAMax	
	L_{Aeq} (dBA)	**Exceedance (dB)**	**L_{Aeq} (dBA)**	**Exceedance (dB)**	**L_{Amax} (dBA)**	**Exceedance (dB)**
Residential Noise Goal	**55**		**50**		**82**	
115 Old Canterbury Rd	56	1	51	1	82	-
29 Eltham St	57	2	52	2	83	1
108 Victoria Rd	57	2	52	2	83	1

1 Short St	58	3	53	3	85	3
4 Short St	59	4	54	4	86	4
10 Terry Rd (former Waratah Mills)	57	2	52	2	84	2
5 Terry Rd	56	1	51	1	83	1

6.6 Noise Mitigation Options

Based on the assumptions detailed above, the assessment of airborne operational noise indicates that noise levels are predicted to comply with the noise goals at most locations. However, some potential exceedances of the noise goals have been identified. The predicted exceedances are relatively low, between 1 dB and 4 dB.

The potential mitigation options include:

- **Source control measures** such as optimised track design, rail dampers.
- **Operational measures** such as reduced speeds or reducing the number of LRV movements.
- **Path control measures** such as acoustic shielding between the railway line and the receiver locations.
- **Receiver controls** at existing developments such as building facade treatments or property noise barriers (fences).

The hierarchy of noise control is to give first preference to source control measures, then to physical mitigation measures between the source/receiver and as a final measure, receiver controls.

Of the above mitigation options, the suggested *operational measures* are not considered feasible as they would restrict the efficiency and frequency of the service. The remaining control measures (source, path and receiver) are discussed in the following sections.

6.6.1 Source Control Measures

As the proposed extension will utilise the existing disused freight line, changing the track design is not a feasible option.

Rail dampers are a potential source control measure for the light rail. Rail dampers are effective in situations where the rail is a significant contributor to rolling noise. This can occur where track decay rates are low (for example on track with soft rail pads). If the rail pads are relatively stiff, rail dampers may also be effective if the rolling stock has relatively low wheel noise emissions. LRVs have smaller wheels than traditional rail rolling stock, and the wheels are resilient and partially shielded by the vehicle side skirts. These factors might mean rail dampers would be more effective for light rail than for heavy rail, even if the rail pads used are stiff. The reduction achievable through rail dampers would be up to 3 dB, depending on the dynamic interaction between the track and wheels.

6.6.2 Path Control Measures

Noise barriers are a path control measure and are effective when they break the line of sight from the source to the receiver. Noise barriers placed at the corridor boundary typically provide a noise reduction of 5 dBA to 10 dBA at the ground floor of nearby receiver locations. For elevated receiver locations, the noise barrier attenuation reduces significantly and noise barriers are usually ineffective at levels two and above. Low profile noise barriers located close to the track could provide a similar benefit.

Earth mounds are sometimes proposed as an alternative to noise barriers, but are not feasible in this case due to space limitations.

Noise barriers are normally only cost-effective in situations where three or more locations are similarly impacted by the noise source and the noise barrier will provide a noticeable benefit. For this project, the only location where noise barriers might be considered is on the Down side of the track in the vicinity of Short St.

6.6.3 Receiver Controls

Treatments to buildings usually involve higher performance windows, doors and seals to keep noise out. Building treatments effectively require occupants to keep their windows and doors closed and hence alternative ventilation is usually required to maintain adequate air flow. An obvious disadvantage is that building treatments would not have any effect on the noise levels outside the dwelling in their front or back yards. Upgrading property fences is also an option.

The acoustic treatment of individual dwellings is generally not favoured for reasons including:

- It may not be effective for lightweight buildings.
- It provides no protection to outdoor areas.
- Mechanical ventilation and/or air-conditioning is required, resulting in higher energy consumption.

6.7 Noise Mitigation Recommendations

Measurements of the ambient L_{Aeq} noise levels along the alignment (see **Table 2**) show that at eight out of nine locations the existing night-time L_{Aeq} values are already higher than the night-time noise criterion set for the light rail, and existing levels at the other location (near the Waratah Mills Stop) are within 2 dB of the night-time noise criterion. The existing evening noise levels are similarly already generally close to or higher than the evening L_{Aeq} criterion for the light rail.

Despite this, the receivers between Waratah Mills and Lewisham West with predicted exceedances of the noise goals are located in the area along the alignment with the lowest existing noise levels so noise mitigation may be required. The following sections discuss the likely mitigation requirements at each of the locations where potential exceedances have been identified.

6.7.1 155 Canterbury Road, 29 Eltham Street

The potential exceedances at these locations are minor (1 dB to 2 dB). These properties are isolated from other potentially affected properties and mitigation options other than individual dwelling treatments are unlikely to be cost effective. Noting that the noise modelling does not take into account any shielding provided by existing boundary fences, at these locations the need for mitigation should be determined on the basis of attended measurements after the commencement of operations.

6.7.2 1 and 4 Short Street and 108 Victoria Road

This area is predicted to be most affected by noise from the project. At this location, the rail corridor is at its narrowest, and the houses at 1 and 4 Short St and at the adjacent 108 Victoria Rd are closer to the tracks than other residences along the alignment.

At this location, potential mitigation measures include rail dampers, low profile noise barriers close to the track, noise barriers or fences at the corridor boundary, or individual dwelling treatments. Any one of these mitigation measures would be expected to meet the noise criteria at these locations.

On the basis that the predicted exceedance of the noise criteria is relatively low and because there are a number of potential mitigation options, the appropriate mitigation should be determined on the basis of attended measurements after the commencement of operations. It is noted however that in corridor noise barriers are unlikely to be cost effective to install after the commencement of operations.

6.7.3 5 and 10 Terry Road

The properties on Terry Rd (including the former Waratah Mills site) were developed while the Rozelle Goods Line was operational and the designs were required to take into account the noise impacts associated with rail operations.

On the basis that the potential noise exceedances at these locations is only minor and rail related noise levels from the light rail would be less than the rail noise levels when the developments were approved, no mitigation measures are proposed for these locations.

6.8 Compliance Monitoring

Attended measurements of operational noise are recommended after commencement of operations at the locations listed in **Table 47** to confirm if mitigation measures are required.

Attended measurements will also be undertaken at other representative locations in consultation with the proponent across the project area to validate the noise predictions and to determine if any additional feasible and reasonable mitigation measures are required.

6.9 Other General Mitigation Measures

During operations, careful attention will need to be taken to ensure that curve flanging and curve squeal are managed in accordance with the current operating procedure. It is anticipated that top of rail friction modification may be required at some locations, for example at the southern end of the alignment where there are a number of curved sections, but that the existing application of lubricant is likely to be sufficient. Regular attended measurements are also recommended to monitor curving noise.

Between the hours of 10:00 pm and 7:00 am, warning bells should only be used where in the opinion of the driver, it is considered to be a danger to public safety. This is consistent with the current operating procedure for the existing light rail.

The locations of crossovers should be determined to take their noise impacts into account. Where possible, to minimise noise emissions crossovers should be located close to stops (where speeds are at their lowest) and at a distance of at least 30 m from existing sensitve receivers.

7 OPERATIONAL VIBRATION ASSESSMENT

7.1 Introduction

Vibration from rail vehicles is generated by dynamic forces at the wheel-rail interface. It will occur, to some degree, even with continuously welded rail and smooth wheel and rail surfaces (due to the moving loads, finite roughness of the surfaces and elastic deformation). Significantly higher vibration levels can occur due to rail and wheel surface irregularities, including some irregularities that do not cause significant levels of airborne noise.

This vibration passes via the sleepers or rail mounts into the ground or track support structure. It then propagates through the ground and may sometimes be felt or perceived as tactile or visible vibration by the occupants of buildings.

The effects of vibration in buildings can be divided into three (3) main categories; those in which the occupants or users of the building are inconvenienced or possibly disturbed, those where the building contents may be affected and those in which the building or the structure may be damaged.

7.1.1 Human Perception of Vibration

The actual perception of motion or vibration may not, in itself, be disturbing or annoying. An individual's response to that perception, and whether the vibration is "normal" or "abnormal", depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling. Industrial environments are clearly less sensitive than say, commercial buildings, where the usual expectation is that there should be little perceptible vibration.

Although people are able to perceive relatively low vibration levels, it is not appropriate to set vibration emission limits requiring "no vibration", since there will always be some vibration in any environment. It is necessary therefore to set realistic design criteria which minimise disturbance and adverse impacts on amenity. The recommended approach is discussed in **Section 7.2**.

7.1.2 Effects on Building Contents

People can perceive floor vibration at levels well below those likely to cause damage to building contents or affect the operation of typical equipment. As such, the controlling vibration criterion at most locations is determined by human comfort. It is therefore not necessary to set separate criteria for this project in relation to the effect of railway vibration on most building contents.

Some high technology manufacturing facilities, hospitals and laboratories include equipment that is highly susceptible to vibration. Typical examples of sensitive equipment include scanning electron microscopes and microelectronic manufacturing facilities. No such facilities have currently been identified adjacent to the proposed alignment.

7.1.3 Effects of Vibration on Structures

The levels of vibration required to cause damage to buildings tend to be at least an order of magnitude (10 times) higher than those at which people consider the vibration acceptable. Hence, the controlling criterion would still be the human comfort criterion, and it is not necessary to set separate criteria for this project in relation to building damage from LRV operations. This also applies to heritage structures, unless there is some reason to believe they are structurally unsound. With respect to operational vibration impacts on the heritage receivers listed in **Table 4**, it is noted that vibration levels from the light rail would much lower than vibration levels generated by the freight vehicles that used the line previously, and structural damage is therefore unlikely.

7.1.4 Ground-borne Noise

Ground-borne noise in buildings adjacent to rail corridors is most common in railway tunnel situations where there is an absence of airborne noise to mask the ground-borne noise emissions. Ground-borne noise results from the transmission of vibration rather than the direct transmission of noise through the air. The vibration is generated by wheel/rail interaction and is transmitted from the trackbed, via the ground and into the building structure.

The vibration entering the building then causes the walls and floors to faintly vibrate and hence to radiate noise (commonly termed "ground-borne noise" or "regenerated noise").

If of sufficient magnitude to be audible, this noise has a low frequency rumbling character, which increases and decreases in level as a train approaches and departs the site. This type of noise can be experienced in buildings adjacent to many urban underground rail systems.

For surface rail projects, the effect of ground-borne noise tends to be less of an issue than for underground rail projects. Ground-borne noise is also less of an issue for surface light rail than for conventional rail, as the vehicles are lighter and the forces transmitted to the ground are correspondingly less.

Although the light rail will run underground for a short section between Lilyfield and Leichhardt North, this section lies directly beneath a major road, the City West Link, which would be expected to dominate vibration and noise levels.

For these reasons, ground-borne noise has not been considered further in this assessment.

7.1.5 Vibration Propagation

The propagation of vibration (and ground-borne noise) through the ground is a complex phenomenon. Even for a simple source, the received vibration at any point may include the arrival of several different wave types, plus other effects such as damping, reflection, and impedance mismatch caused by changes in ground conditions along the propagation path.

It is useful to note that predictions of vibration normally involve a combination of empirical and analytical methods as the various characteristics are normally not sufficiently defined to enable full analytical modelling.

7.2 Vibration Goals

The vibration goals relating to ground-borne vibration emissions from the existing Light Rail vehicles are specified in the *Inner West Light Rail Extension Approval* dated 3 March 1999. These vibration goals are expressed in terms of RMS vibration velocity and are summarised in **Table 48**.

Table 48 Operational Vibration Goals (from Inner West Light Rail Extension Approval)

Category	Criterion dB re 1E-6 mm/s	Application
Existing or zoned residential or other sensitive receivers as identified by the Environment Protection Authority	103	Facade L_{max}
Commercial	112	Facade L_{max}

The DECCW's *Assessing Vibration – A Technical Guideline* specifies criteria for intermittent vibration such as that from rail vehicles in terms of Vibration Dose Values (VDVs). The VDV is a measure that takes into account the overall magnitude of the vibration levels during a train passby, as well as the total number of train passbys during the daytime and night-time periods.

For intermittent vibration at residential receiver locations, vibration trigger levels are expressed in terms of the VDV during the daytime (7.00 am to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods. The guideline nominates "preferred" and "maximum" vibration dose values.

For offices, schools, educational institutions and places of worship, the guideline nominates VDVs twice the residential daytime levels.

The acceptable VDVs for intermittent vibration from DECCW's *Assessing Vibration – A Technical Guideline* are summarised in **Table 49**.

Table 49 Acceptable VDVs for Intermittent Vibration

Location	Preferred VDV ($m/s^{1.75}$)		Maximum VDV ($m/s^{1.75}$)	
	Day[1]	Night[1]	Day	Night
Residential Properties	0.2	0.13	0.2	0.26
Offices, Schools, Educational Institutions and Places of Worship	0.4	0.4	0.8	0.8

Note 1 Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

The DECCW's *Assessing Vibration – A Technical Guideline* describes a method for estimating VDV based on RMS vibration velocity:

$eVDV = 0.07 \times v_{RMS} \times t^{0.25} m/s^{1.75}$

where eVDV is the estimated vibration dose, v_{RMS} is the maximum RMS vibration velocity during a passby (in m/s) and t is the total duration of all passbys in the time period of interest (in seconds).

Conservatively assuming a passby duration of 4 seconds for the 29 m LRVs (at 25 km/h), the eVDV resulting from the maximum vibration velocity criterion complies comfortably with the preferred VDV criteria. Therefore compliance with the 103 dB vibration velocity criterion at residential building facades will also indicate compliance with the vibration dose criterion.

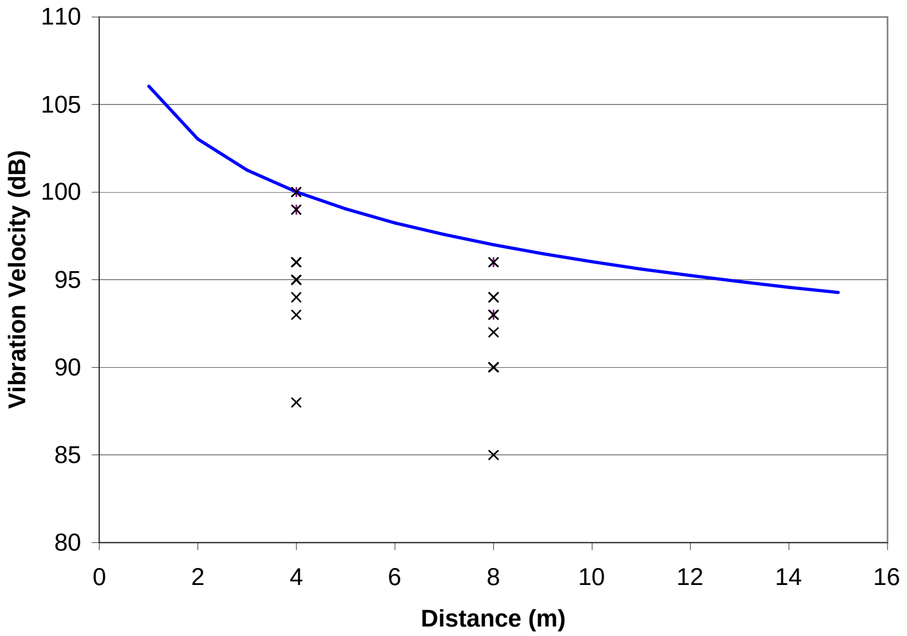
7.3 Source Vibration Levels

Vibration measurements are undertaken on an annual basis for the existing light rail at several locations. Of these measurements, those undertaken at 1 Lower Avon St Glebe are the most representative of situation along the proposed extended alignment. At 1 Lower Avon St Glebe the average observed speed is around 30 km/h and vibration measurements are undertaken at two locations (each a distance of approximately 4 m from the Up track and 8 m from the Down track).

Figure 15 provides a summary of the average vibration levels at 1 Lower Avon St as measured over several years of light rail operations. Whilst there is a noticeable spread in the measurement results, the maximum vibration levels remain below 100 dB (re 1E-6 mm/s) at the 4 m measurement location. The measured vibration levels are dependent on a number of factors including the source excitation (the roughness of the wheels and rails), and the properties of the ballast and ground.

The curve in **Figure 15** shows the reference vibration level vs distance relationship that has been assumed in this assessment to predict maximum vibration levels along the proposed extension, for a reference speed v_{ref} of 30 km/h. This curve, in conjunction with the typical 20 x log(v/v_{ref}) relationship has been used to predict the maximum future vibration levels adjacent to the SLRE. From the spread of compliance measurement data, it is expected that actual vibration levels at any single location will lie in a range up to 10 dB below the predicted maximum levels.

Figure 15 Assumed source vibration levels vs distance at 30 km/h



7.4 Predicted Operational Vibration Levels

On the basis of the above assumptions, two residential receivers (1 Short St and 4 Short St Dulwich Hill) have been identified as potentially exceeding the 103 dB vibration design goal. These receivers are located approximately 7 m from the nearest track. The predicted maximum vibration level at these receivers is 105 dB, indicating a marginal potential exceedance of the 103 dB criterion. This predicted maximum level corresponds to an RMS vibration velocity of less than 0.2 mm/s, which is normally considered 'barely noticeable' (see **Table 40**). The estimated VDV for these receivers is 0.03 m/s$^{1.75}$ during the night and 0.05 m/s$^{1.75}$ during the daytime, which complies comfortably with the preferred VDV criteria in **Table 49**.

No exceedances of the vibration criteria are expected for commercial or other sensitive receivers.

7.5 Recommendations for Compliance Monitoring

The assessment of operational vibration indicates that vibration levels are predicted to comply with the VDV criteria at all locations. Potential exceedances (up to 2 dB) of the more stringent façade vibration criterion on 103 dB have been predicted at two residences (1 and 4 Short St Dulwich Hill).

As shown in **Figure 15**, the vibration source levels assumed in this assessment are conservative. It is expected that actual peak vibration levels due to any one LRV passby would lie in a range up to 10 dB below the predicted maximum levels. It is also noted although the project design goal may be exceeded for some passbys, the maximum predicted RMS vibration velocity during each passby is likely to be barely noticeable.

Attended measurements of operational vibration are recommended at Short St after commencement of operations to confirm the predicted vibration levels.

8 SUBSTATION NOISE

Two new substations are proposed to be constructed as part of the project, to feed traction supply for the light rail operations. Three locations have been identified as potentially suitable. Detailed design would confirm the final two locations. For the purpose of this assessment, potential impacts at all three locations have been examined. The locations considered include:

- West of Catherine St (near the existing Lilyfield stop), on the Up side
- North of Marion St, on the Down side (near the Marion Stop)
- South of the Lewisham West Stop, on the Down side (opposite Summer Hill Mills)

The major noise sources at substations are electric transformers, which vibrate due to expansion and contraction of the transformer core. Transformers operate continually throughout the day and night. Other noise sources at substations are transformer cooling fans, which operate when required, and circuit breakers, which operate only when fault conditions cause over-current trips.

8.1 Criteria for Substation Noise Assessment

DECCW's NSW Industrial Noise Policy (INP) provides criteria for the assessment of noise impact associated with industrial activities. It aims to balance the need for industrial activity with the desire for quiet within the community. As the proposed substations are fixed facilities, all operational noise emissions need to be assessed in accordance with the INP.

The INP sets two separate noise criteria: one to account for intrusive noise and the other to protect the amenity of particular land uses. These criteria are to be met at the most-affected boundary of the receiver property. In addition, the online Application Notes for the INP state that the potential for sleep disturbance should also be assessed.

8.1.1 INP Criteria for Intrusive Noise

To provide for protection against intrusive noise, the INP states that the L_{Aeq} noise level of the source, measured over a period of 15 minutes, should not be more than 5 dBA above the ambient (background) L_{A90} noise level (or RBL), measured during the daytime, evening and night-time periods at the nearest sensitive receivers. Because noise from substation transformers is continuous, the most stringent intrusive noise criteria for the project are the night-time L_{A90} noise levels plus 5 dBA. In this case, the intrusiveness criteria are determined from the night-time RBL in **Table 2** measured at the receiver locations nearest the proposed substations, ie B01, B03 and B05.

8.1.2 INP Criteria for Amenity

To provide protection against impacts on amenity, the INP specifies suitable maximum noise levels for particular land uses and activities during the daytime, evening and night-time periods. For this assessment, the existing residences in the vicinity of the proposed substations are considered to be ‘Urban’. According to the INP, an ‘Urban’ area has an acoustical environment that is dominated by ‘urban hum’ or industrial source noise, or that has through traffic with characteristically heavy and continuous flows during peak periods. In comparison, a ‘Suburban’ area would be characterised by local traffic with intermittent traffic flows, decreasing noise levels in the evening period; and/or evening ambient noise levels defined by the natural environment and infrequent human activity.

The INP amenity criteria for residences are presented in **Table 50**.

Table 50 INP Amenity Noise Levels

Type of Receiver	Indicative Noise Amenity Area	Time of Day	Recommended L_{Aeq} Noise Level (dBA)	
			Acceptable	Recommended Maximum
Residence	Rural	Day	50	55
		Evening	45	50
		Night	40	45
	Suburban	Day	55	60
		Evening	45	50
		Night	40	45
	Urban	Day	60	65
		Evening	50	55
		Night	45	50

The Catherine St location is in close proximity to the heavily used City West Link Rd. The Lewisham West location is close to the existing heavy rail lines. At night-time unattended noise monitoring recorded existing L_{Aeq} values of 59 dBA at both these locations, and background L_{A90} noise levels of 42 dBA. The Marion location, while experiencing lower existing noise levels than the other locations, has also been classified as 'urban'. At this location the evening RBL is only 2 dB lower than the daytime RBL, and the existing night-time L_{Aeq} of 53 dBA is already higher than the recommended maximum level in urban areas. The current night-time background L_{A90} noise level is 36 dBA.

According to the INP, where existing industrial L_{Aeq} noise levels exceed the 'Acceptable' noise level by 2 dB or more, and the existing noise level is unlikely to decrease in future, the noise criteria should be taken to be the existing noise level minus 10 dB. This approach is also applicable to areas with high traffic noise. In this case, existing evening and night-time L_{Aeq} noise levels near all three proposed substation locations exceed the acceptable noise levels by 8 dB or more. Existing daytime L_{Aeq} noise levels also exceed the acceptable levels, by 5 dB at B01, by 2 dB at B03 and by 1 dB at the B05. Amenity criteria are therefore set based on modifications to the existing noise levels.

8.1.3 Modifying Factor Adjustments

Where a noise source contains certain characteristics, such as tonality, impulsiveness, intermittency, irregularity or dominant low-frequency content, there is evidence to suggest that it can cause greater annoyance than other noise sources at the same level. To account for this additional annoyance, the INP describes modifying factors to be applied.

Substation transformer noise occurs at approximately 100 Hz (and harmonics of 100 Hz), with a humming or buzzing characteristic, which could be considered both low-frequency and tonal. The modifying factors recommended in the INP for tonal/low frequency noise are presented in **Table 51**.

Table 51 INP Modifying Factor Corrections

Factor	When to apply	Correction [1]
Tonal Noise	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 above 400 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 below 160 Hz	5 dB[2]
Low frequency noise	Measure/assess C- and A-weighted levels over same time period. Correction to be applied if the difference between the two levels is 15 dB or more	5 dB[2]

Note 1. Corrections to be added to the measured or predicted levels.

Note 2. Where a source emits tonal and low frequency noise, only one 5 dB correction is to be applied if the tone is in the low frequency range.

The INP states that modifying factors are to be applied to the noise from the source measured or predicted at the receiver, before comparison with the intrusiveness or amenity criteria. For this assessment, the modifying factor is required to account for the potentially annoying tonal and low-frequency characteristic of substation noise. As described in **Table 51**, the total penalty applied is 5 dB.

8.1.4 Sleep Disturbance

The DECCW's current approach to assessing potential sleep disturbance is to apply an initial screening criterion of background plus 15 dBA (as described in the Application Notes to the INP), and to undertake further detailed analysis if the screening criterion cannot be achieved. The sleep disturbance screening criterion applies outside bedroom windows during the night-time period.

Where the screening criterion cannot be met, the additional analysis should consider the number of potential sleep disturbance events during the night, the level of exceedance and noise from other events. It may also be appropriate to consider other guidelines including the ECRTN which contains additional guidance relating to the potential sleep disturbance impacts.

A review of research on sleep disturbance in the ECRTN indicates that in some circumstances, higher noise levels may occur without significant sleep disturbance. Based on studies into sleep disturbance, the ECRTN concludes that:

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

It is generally accepted that internal noise levels in a dwelling, with the windows open, are 10 dBA lower than external noise levels. Based on a worst case minimum attenuation, with windows open, of 10 dBA, the first conclusion above suggests that short term external noises of 60 dBA to 65 dBA are unlikely to cause awakening reactions. The second conclusion suggests that one or two noise events per night with maximum external noise levels of 75 dBA to 80 dBA are not likely to affect health and wellbeing significantly.

8.2 Noise Goals for the Substations

A summary of the operational noise goals for the substations is provided in **Table 52**.

Table 52 Summary of Operational Noise Goals for the Substations

Location	Period	Existing Noise Levels (dBA)		Operational Noise Goals (dBA)		
		RBL	LAeq(Period)	LAeq(15min) Intrusive	LAeq(Period) Amenity	LA1(60sec) Sleep Disturbance Screening Level
Residential receivers near Catherine St substation	Daytime	53	65	58	55	-
	Evening	49	63	54	53	-
	Night	42	59	47*	49	57*
Residential receivers near Marion substation	Daytime	48	62	53	52	
	Evening	46	58	51	48	
	Night	36	53	41*	43	51*
Residential receivers near Lewisham West substation	Daytime	50	61	55	52	-
	Evening	47	60	52	50	-
	Night	42	59	47*	49	57*

Note: Asterisks indicate controlling design criteria.

Since the transformer noise emissions associated with the operation of traction substations are reasonably continuous, the $L_{Aeq(15minute)}$ and the $L_{Aeq(period)}$ noise criteria are directly comparable parameters and the more stringent of the intrusiveness or the amenity criteria sets the noise goals. For this project, the night-time intrusiveness criterion is controlling at all three locations.

8.3 Substation Operational Noise Assessment

Detailed information on the substation design is not available at this stage. Calculations using assumed source levels have therefore been used to determine potential worst case noise impacts and to assess if a more detailed analysis of the substation noise impacts is warranted.

8.3.1 Substation Noise Sources

The substations would be enclosed in brick buildings, have approximate dimensions of 16 m by 5 m and would produce 1.5 MW each. Source sound power level data is not yet available, therefore Heggies has assumed conservative source sound power levels on the basis of previous projects as shown in **Table 53.** It is noted that the transformer sound power levels shown in **Table 53** are for a larger (5 MW) substation, without an enclosure. A noise reduction of 10 dB has been assumed across the enclosure, assuming it will incorporate open windows or louvres for ventilation. In practice a higher attenuation could be achieved if required for the enclosure. Transformer noise is assessed against the INP intrusiveness and amenity noise goals.

Circuit breakers can emit an impulsive "bang" when a fault causes a breaker to trip. Circuit breaker noise events would be highly infrequent and would only occur if there was a fault. The source sound power level stated in **Table 53** is also an assumed level based on previous substation assessment data. As the noise emissions from the circuit breakers could occur at any time of the day (if a fault occurs), it is appropriate to assess the potential noise emissions against the night-time sleep disturbance goals.

Table 53 Substation Noise Modelling Source Levels and Scenarios

Scenario	Source	Sound Power Level (dBA re 10^{-12} W)
1	Transformer (continuous)	68
2	Transformer (continuous with fans operating)	77
3	Circuit breakers (maximum)	111

8.3.2 Predicted Noise Levels at Nearest Receivers

The nearest residential receivers to the proposed Catherine St substation are approximately 80 m away. The distance to the nearest existing receivers at Marion is approximately 90 m, and at Lewisham West the nearest residential receiver is around 60 m away (and is shielded by existing industrial buildings).

The predicted L_{Aeq} and L_{Amax} noise levels at the nearest sensitive receiver to each of the substations are presented in **Table 54** for the scenarios describe in **Table 53**. As discussed in **Section 8.1.3**, a 5 dBA correction factor for tonal/low frequency noise has been added to the predicted L_{Aeq} levels in accordance with the INP.

Table 54 Predicted Substation Noise Levels

Substation	Nearest Receiver Distance	Predicted Noise Level (dBA)		
		Scenario 1 L_{Aeq}	Scenario 2 L_{Aeq}	Scenario 3 L_{Amax}
Lewisham West	60 m	16	25	64
Catherine St	80 m	14	23	62
Marion	90 m	13	22	61

The predicted noise levels in **Table 54** show compliance with the intrusiveness and amenity criteria at all existing residences.

The sleep disturbance screening criteria are exceeded at all three locations by between 4 dB and 10 dB. However, taking account of the existing noise environment and the probable low frequency of circuit breaker events, sleep disturbance due to the substation circuit breakers is considered unlikely at any nearby residential receivers.

8.4 Recommendations

The analysis of substation noise levels indicates compliance with the INP intrusiveness and amenity criteria at all existing residences. While the sleep disturbance screening criteria are predicted to be exceeded, circuit breaker events would occur very infrequently during night-time periods and the existing noise environment at these locations indicate that sleep disturbance is unlikely for existing residential receivers. Additional mitigation of the substation noise (beyond the proposed enclosure) is not required.

It is noted that this assessment is based on assumed source sound power levels for substations, and that actual source sound power levels should be checked against the assumed levels in the detailed design phase to confirm the conclusions of the substation noise assessment.

9 CONCLUSIONS

An assessment of the noise and vibration impacts of the project has been completed. The assessment has considered aspects of the project including construction noise and vibration, operational noise and vibration, and noise from the proposed substations.

9.1 Construction Noise

Construction Noise Management Noise Levels (NMLs) have been set in accordance with the DECCW's *Interim Construction noise Guideline*.

Because of the temporary nature of construction works, the potential noise and vibration impacts during the construction phase of a project are often less significant than the long-term operational impacts. Notwithstanding the noise and vibration emissions are typically higher during the construction phase of projects than during operations. Construction often requires the use of heavy machinery which can generate significant noise and vibration emissions at nearby buildings and receivers and there is limited opportunity to mitigate the noise and vibration levels in a cost-effective manner and hence the potential impacts need to be effectively managed and minimised.

At the key construction sites, predicted levels for excavation and construction at the sites indicate minor to significant exceedances of the NMLs for daytime operations at sensitive receivers. These are a direct result of the relative close proximity of some receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. Where works are required out of normal construction hours, higher exceedances are predicted as a result of the lower NMLs. The night-time works will require careful management of all noise-producing equipment and activities.

Site-specific Construction Noise and Vibration Management Plans (CNVMPs) would be developed in the detailed design phase when more information is available on the schedule for the works and the equipment to be used. The proponent should also inform all potentially impacted residents of the the nature of works to be carried out, and the expected noise levels and duration. Where night works are required, the proponent should apply all feasible and reasonable work practices in the CNVMP. Where all feasible and reasonable practices have been applied and night-time noise would be more than 5 dBA above the noise affected level, the proponent should negotiate with the community to determine the schedule for the works.

9.2 Construction Vibration

The potential impacts of vibration caused by construction activities has been assessed, considering both the risk of damage to structures (including heritage structures) and potential exceedances of the human comfort vibration criteria. To minimise the risk of structural damage, safe working distances have been identified for vibration intensive plant. At any locations where vibration intensive plant is proposed to be used within the identified safe working distances, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure is recommended to determine the applicable safe vibration level.

Some items of equipment proposed to be used to construct the project have the potential to result in exceedances of the human comfort criteria at distances of up to around 40 m from the works, depending on the duration and nature of the construction activity. Any exceedances would be expected to be of short duration. Where vibration intensive activities are proposed close to sensitive receivers, these works should be scheduled during the day where possible. Potential vibration impacts should be considered in the site-specific CNVMPs, to be developed in the detailed design phase when more information is available on the schedule for the works and the equipment to be used.

9.3 Operational Noise

Operational noise criteria for the project have been determined in consultation with the DECCW. For airborne noise created by operation of the light rail, the criteria for the day, evening and night-time periods are 60 dBA $L_{Aeq(day)}$, 55 dBA $L_{Aeq(evening)}$ and 50 dBA $L_{Aeq(night)}$. A L_{Amax} criterion of 82 dBA also applies at the facade of residential receivers.

Modelling of operational noise impacts from the project has identified compliance with the operational noise criteria along most of the alignment, although potential exceedances have been identified at seven locations. The identified exceedances are between 1 dB and 4 dB.

Attended monitoring of operational noise is recommended at the locations where potential exceedances have been identified to confirm the need for noise mitigation. The potential mitigation measures (if required) could include rail dampers, noise barriers, upgraded fences or building treatments. Measurements would also be undertaken at other representative locations across the project area for the purpose of validating the noise level predictions and to determine if any additional feasible and reasonable mitigation measures are required.

9.4 Operational Vibration

Operational vibration criteria for the project have been determined in consultation with the DECCW. Vibration levels have also been assessed against the ‘human comfort’ VDV criteria described in *Assessing Vibration: A Technical Guidleline.*

The assessment of operational vibration indicates that vibration levels are predicted to comply with the VDV criteria at all locations. Potential exceedances (of up to 2 dB) of the facade vibration design goal of 103 dB have been predicted at two residences, however as vibration levels may be variable, the actual levels could be up to 10 dB lower than the maximum predictions. Attended measurements of operational vibration are recommended at these locations to confirm the predicted levels.

The levels of vibration required to cause damage to buildings tend to be at least an order of magnitude (10 times) higher than those at which people consider the vibration acceptable. Hence, the controlling criterion is the human comfort criterion, and it is not necessary to set separate criteria for this project in relation to building damage from LRV operations. This also applies to heritage structures, unless there is some reason to believe they are structurally unsound.

9.5 Substation Noise

The analysis of substation noise levels in accordance with the INP indicates compliance with the intrusiveness, amenity and sleep disturbance criteria is likely at all existing residences. Mitigation of the substation noise (other than the proposed enclosures) is not likely to be required.

ACOUSTIC TERMINOLOGY

1 Sound Level or Noise Level

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

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

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

2 “A” Weighted Sound Pressure Level

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

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

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

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

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

3 Sound Power Level

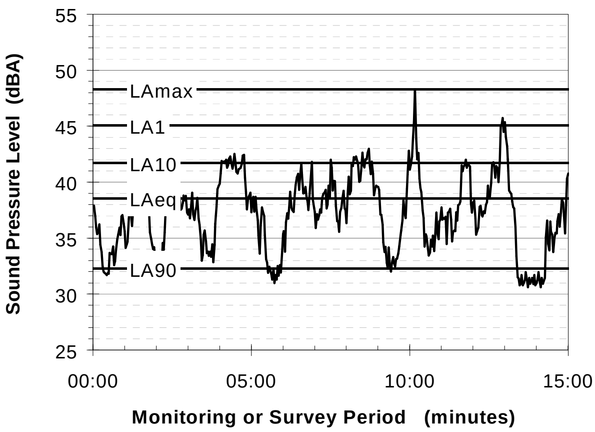
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 10^{-12} W.

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

4 Statistical Noise Levels

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

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



Of particular relevance, are:

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

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

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

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

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

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

5 Tonality

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

6 Impulsiveness

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

7 Frequency Analysis

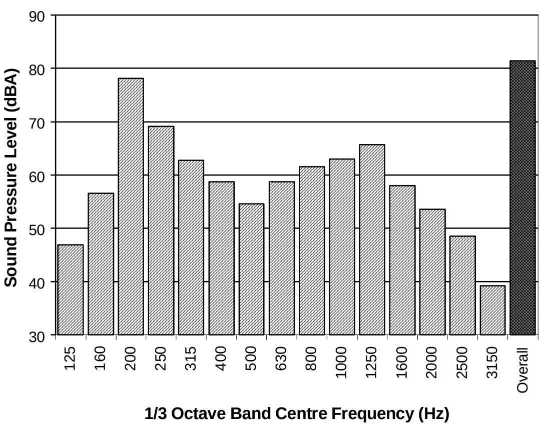
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

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

Frequency analysis can be in:

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

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



8 Vibration

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

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

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

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

9 Human Perception of Vibration

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

10 Over-Pressure

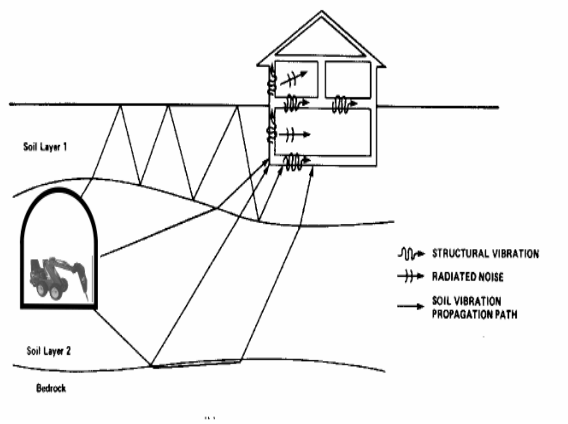
The term "over-pressure" is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

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

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

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

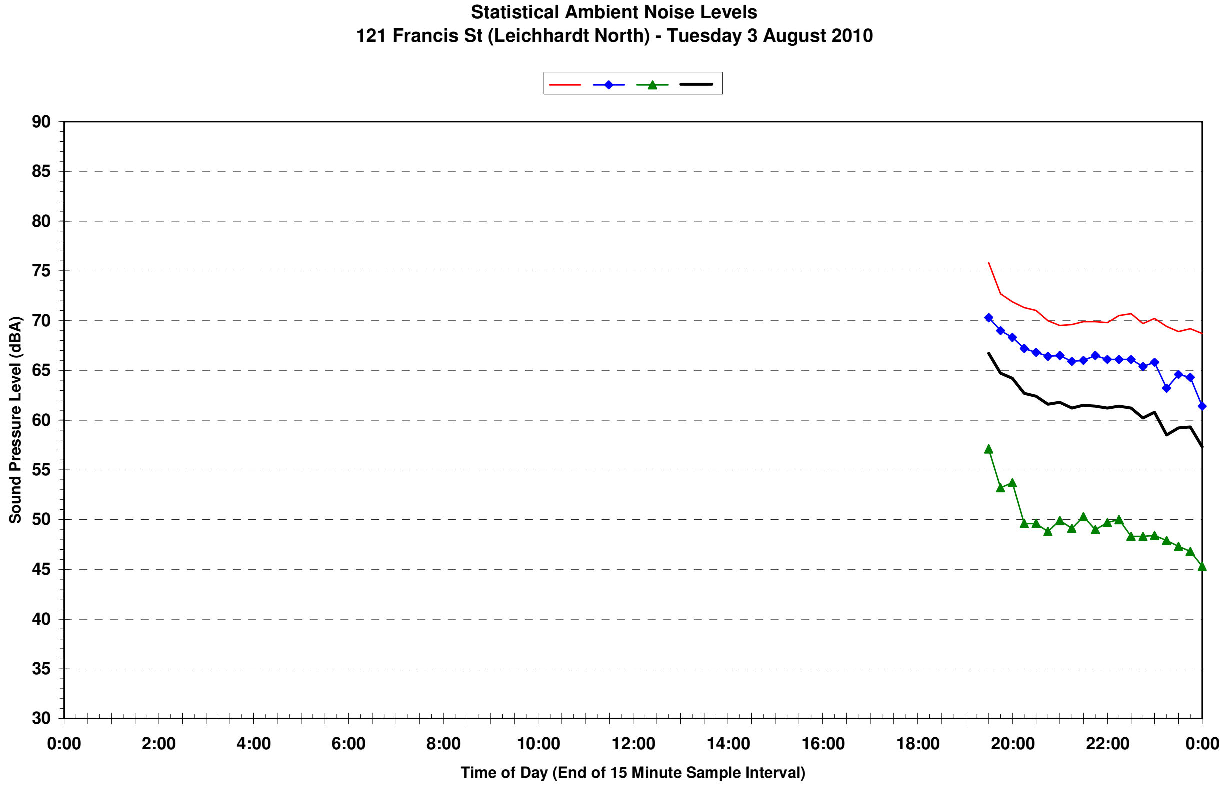
The following figure presents the various paths by which vibration and ground-borne noise may be transmitted between a source and receiver for construction activities occurring within a tunnel.

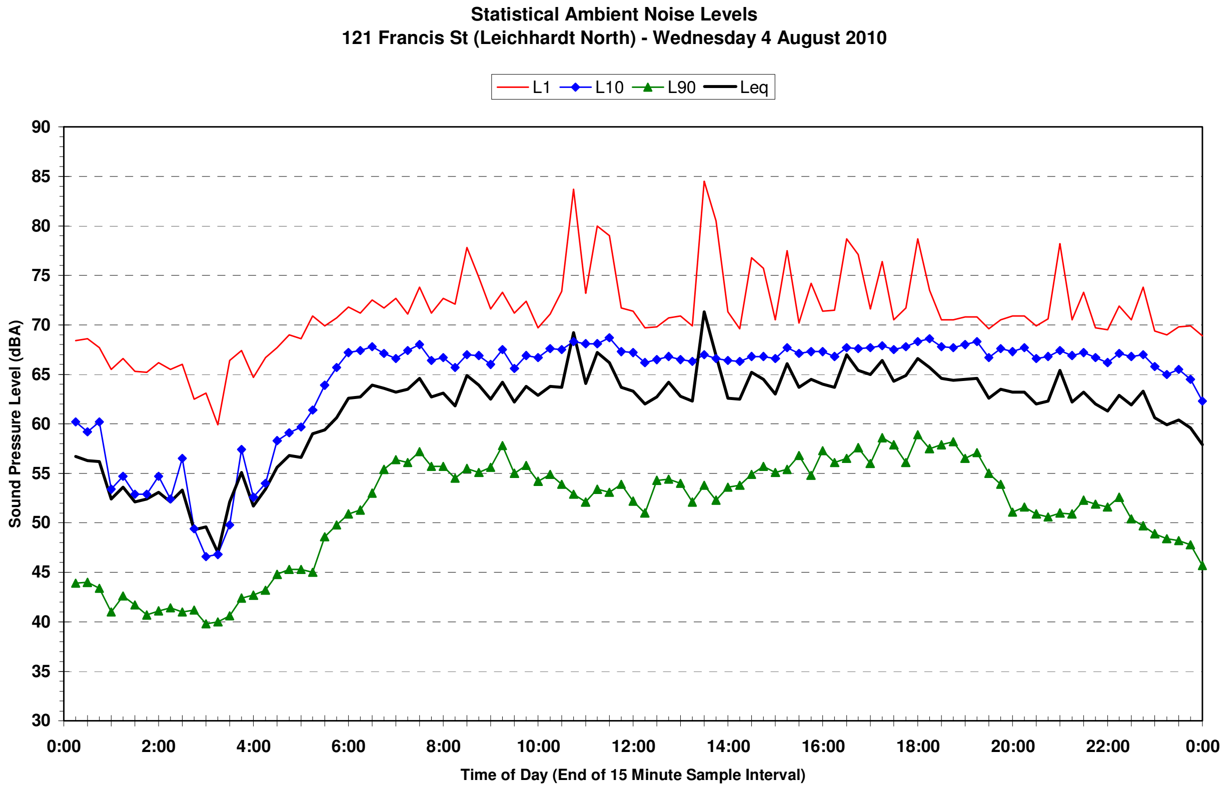


The term "regenerated noise" is also used in other instances where energy is converted to noise away from the primary source. One example would be a fan blowing air through a discharge grill. The fan is the energy source and primary noise source. Additional noise may be created by the aerodynamic effect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

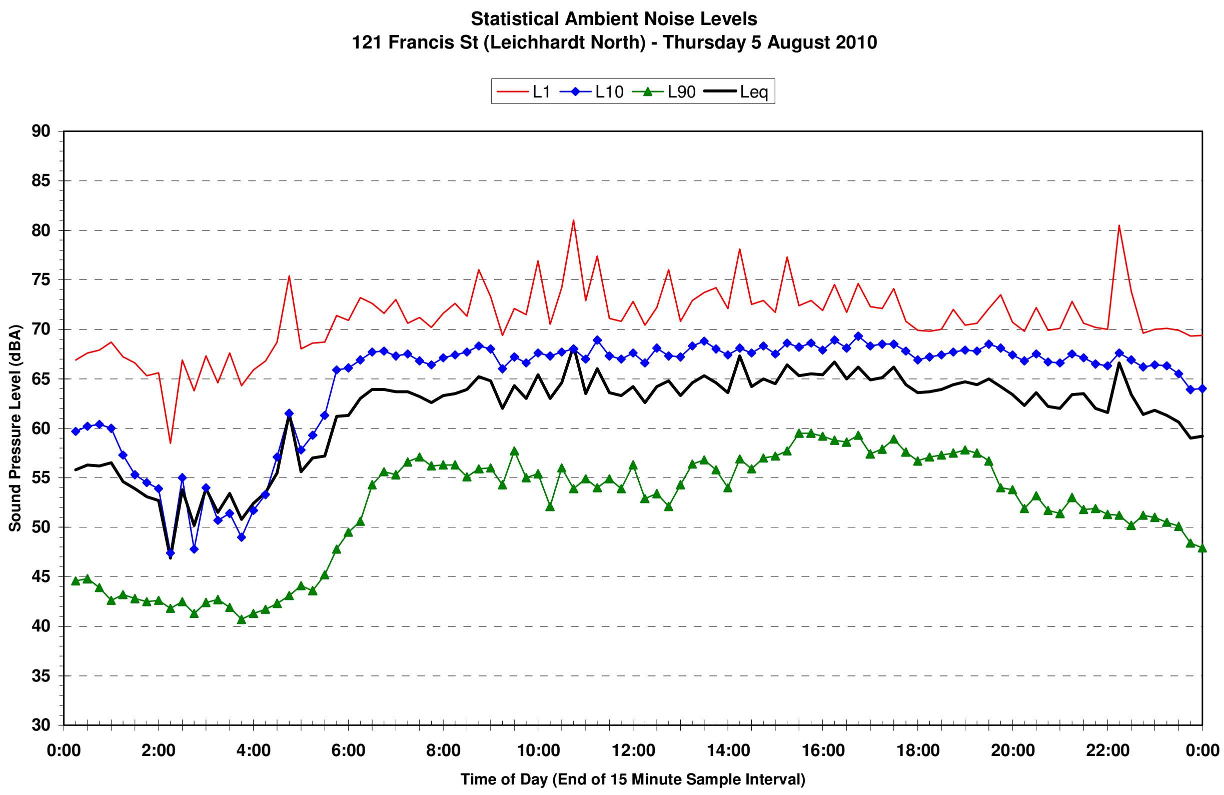
Ambient Noise Measurements

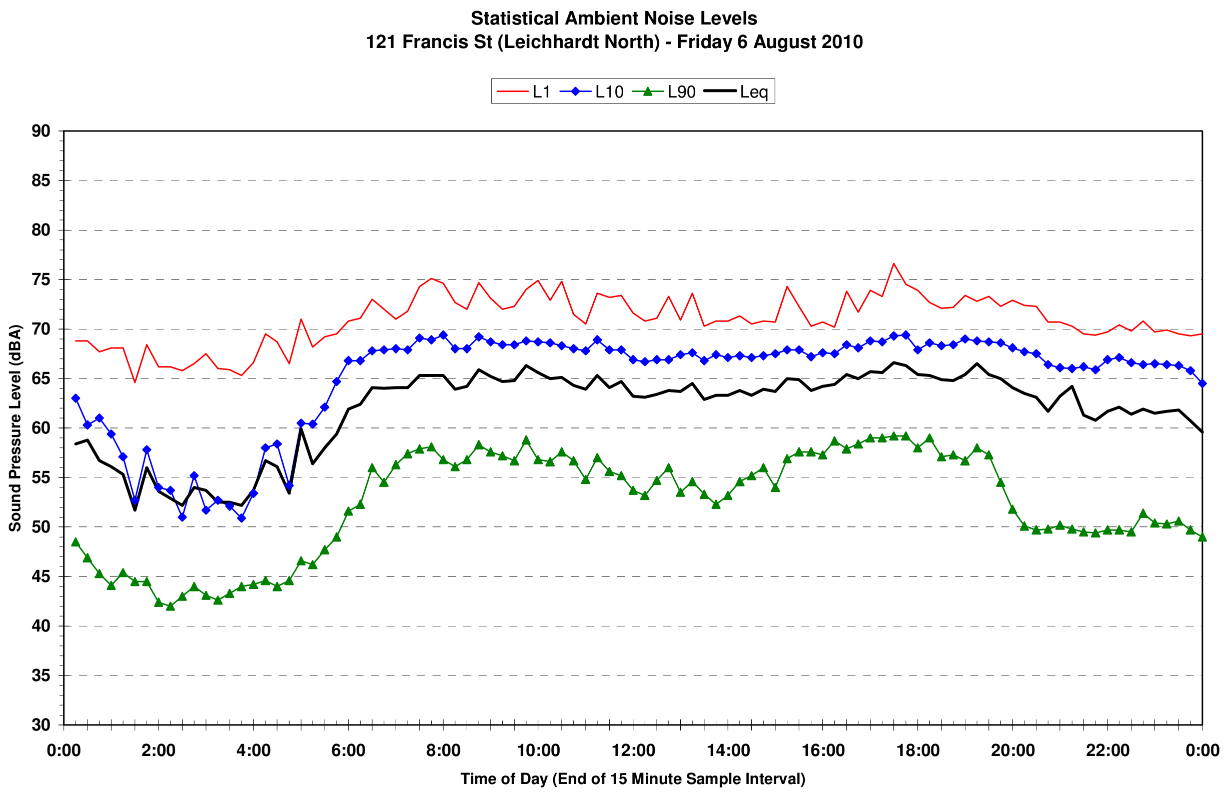
B01 – 121 Francis St



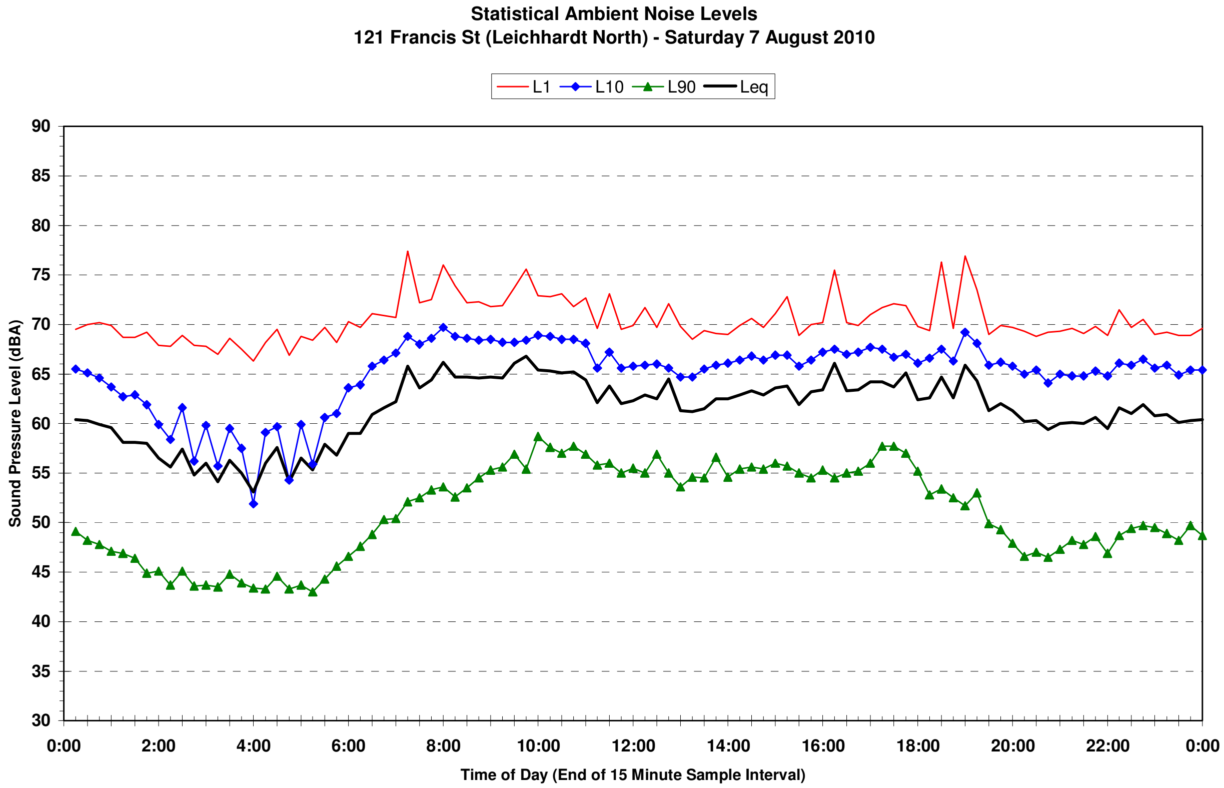


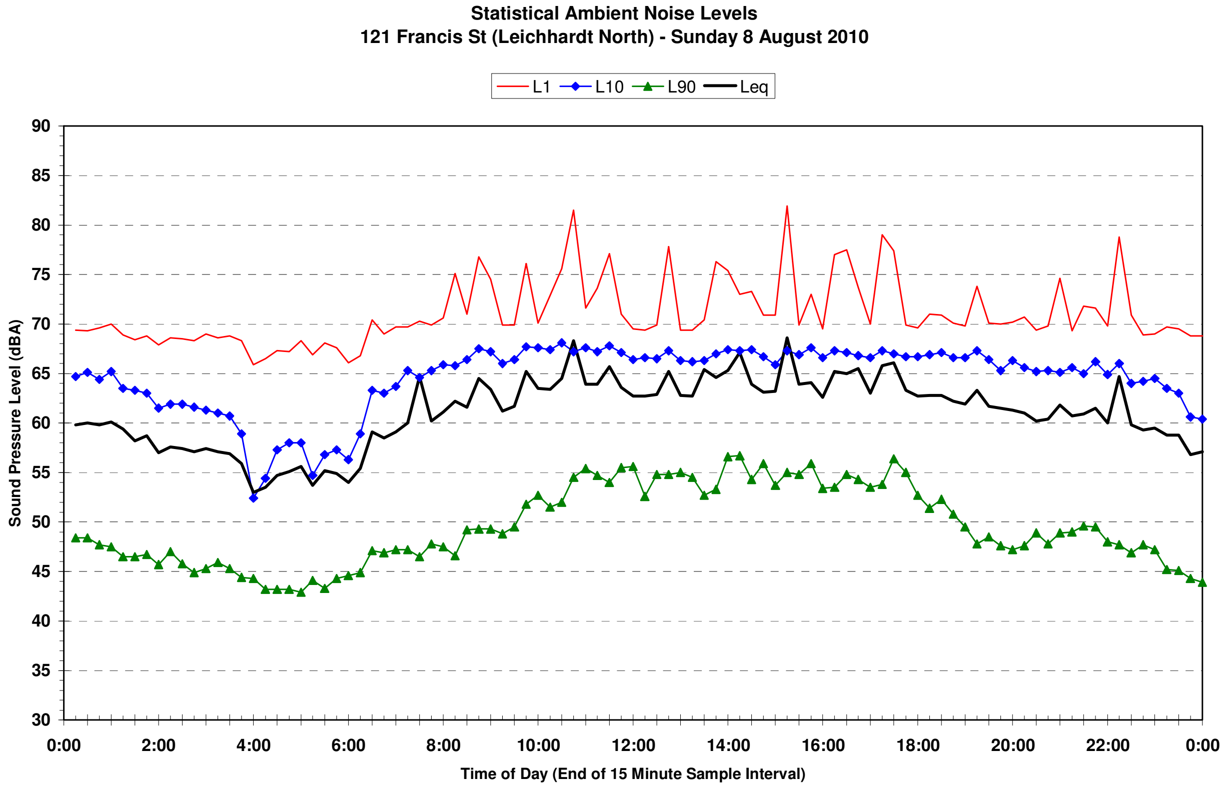
Ambient Noise Measurements



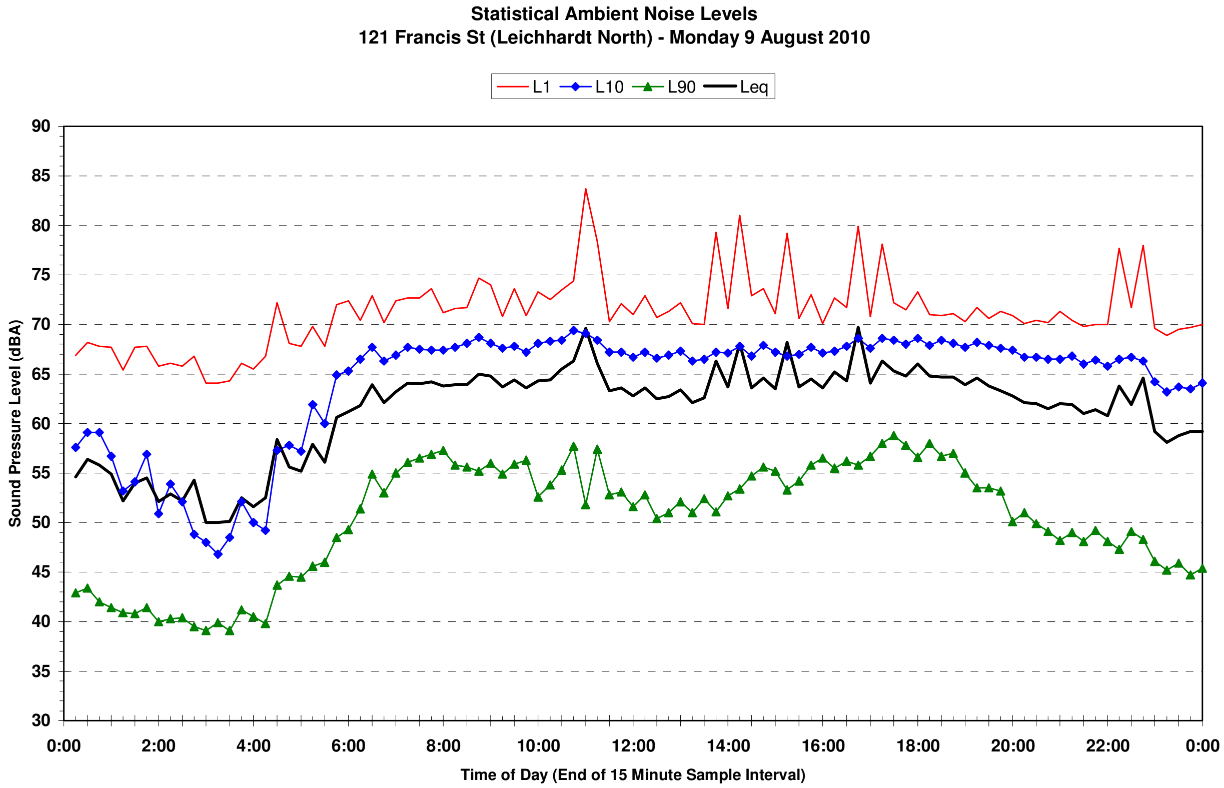


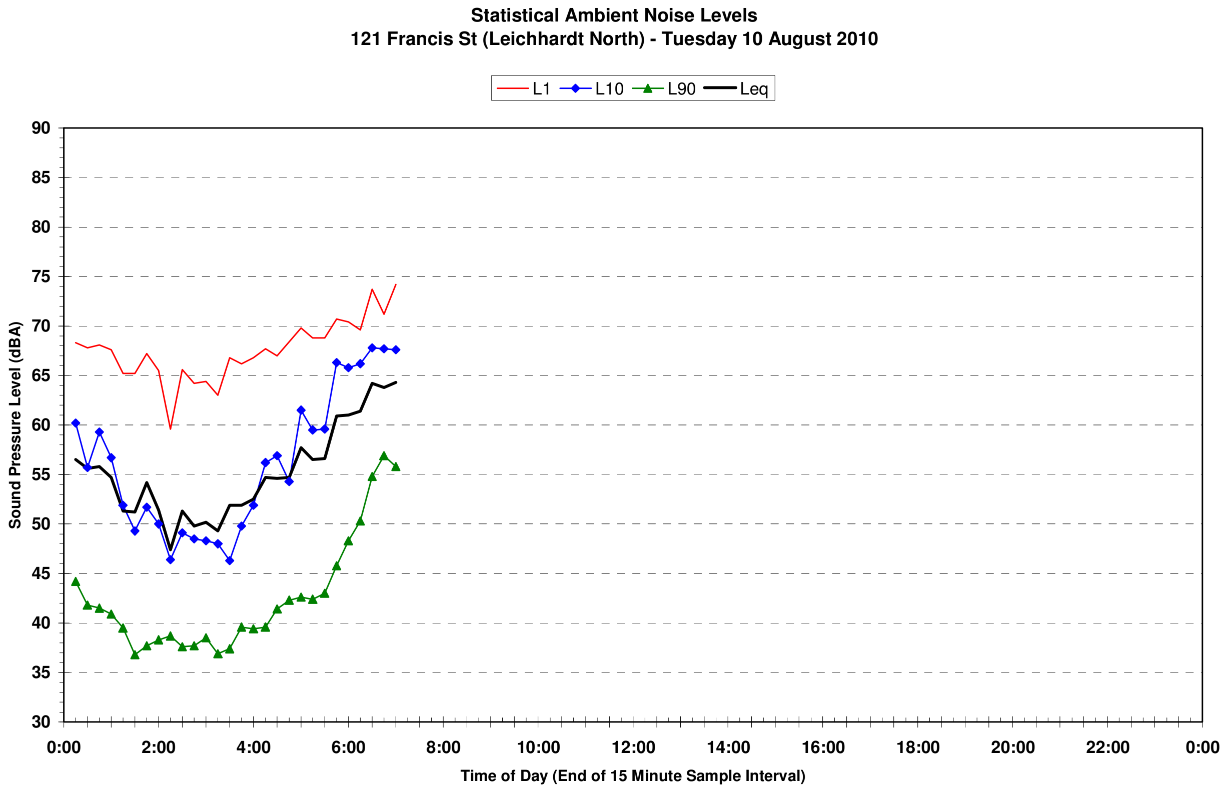
Ambient Noise Measurements



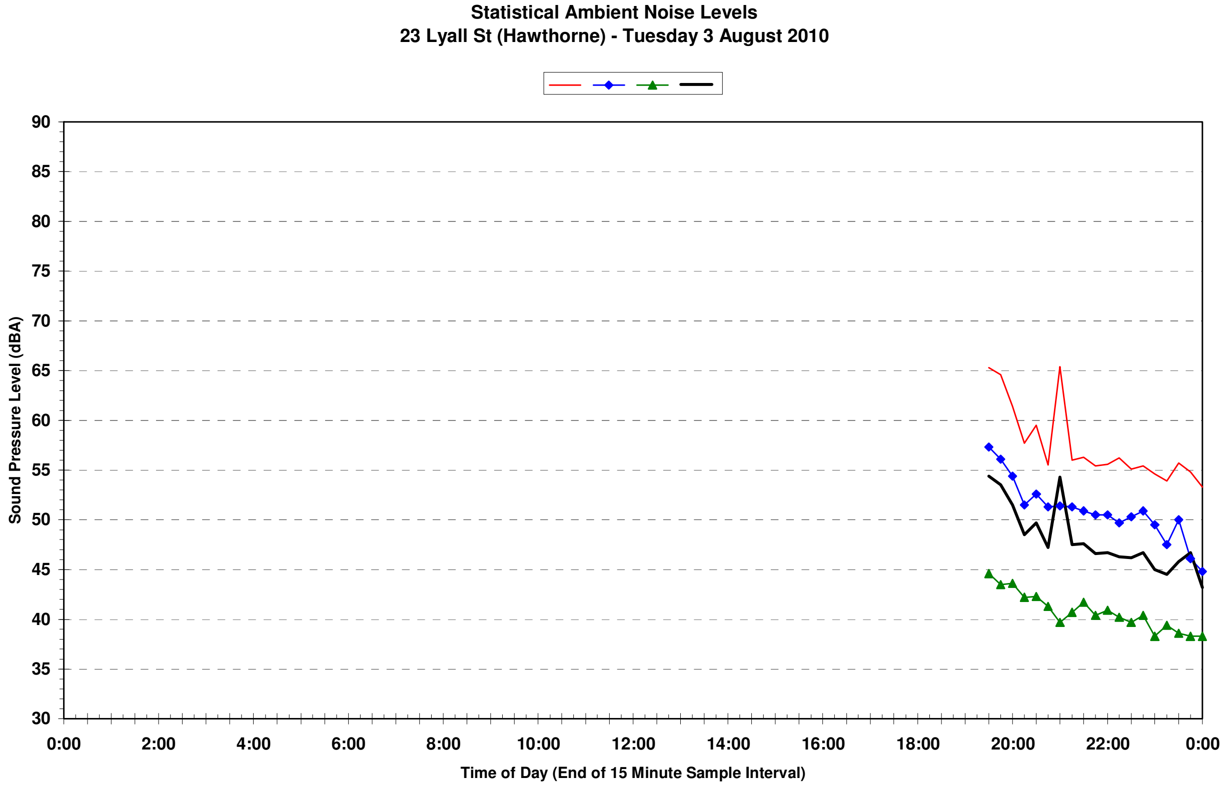


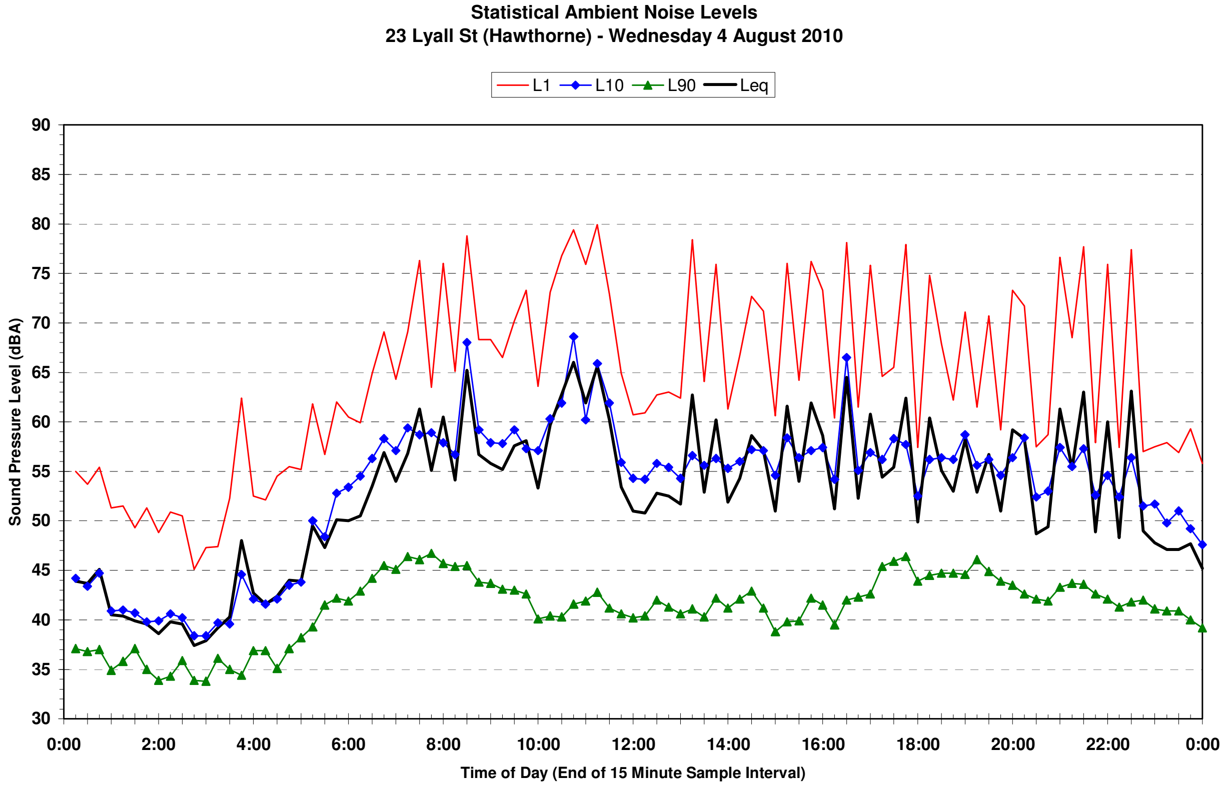
Ambient Noise Measurements





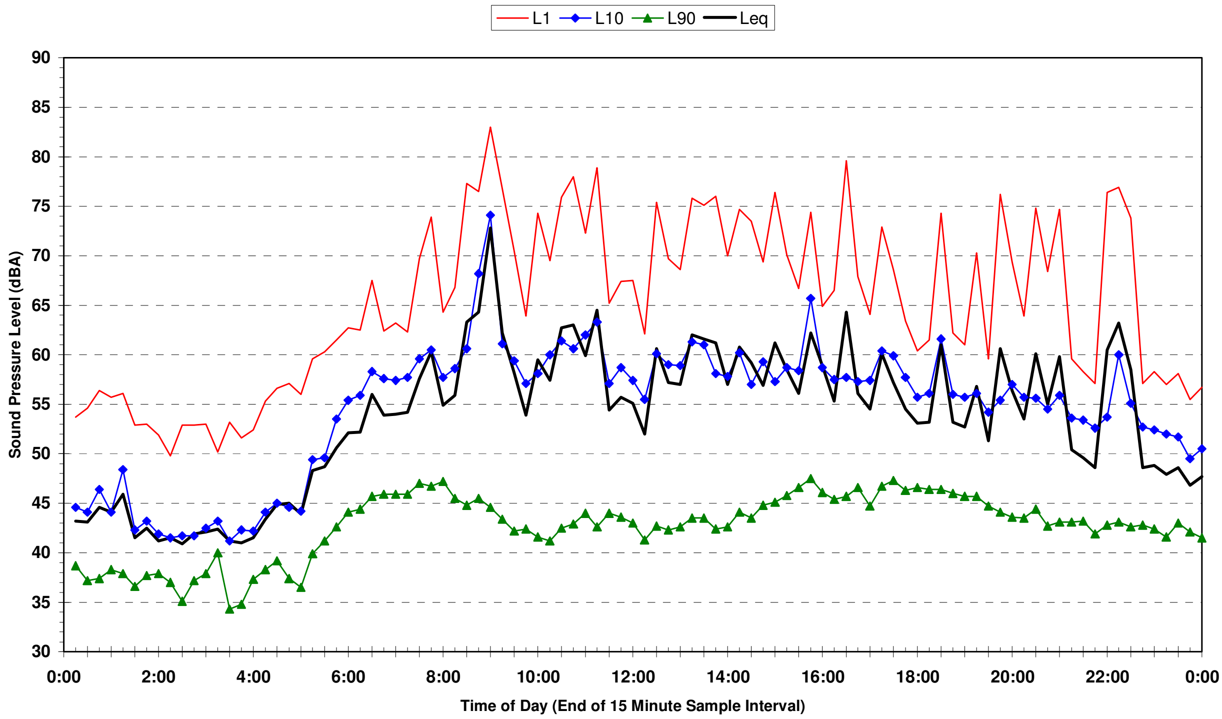
B02 – 23 Lyall St



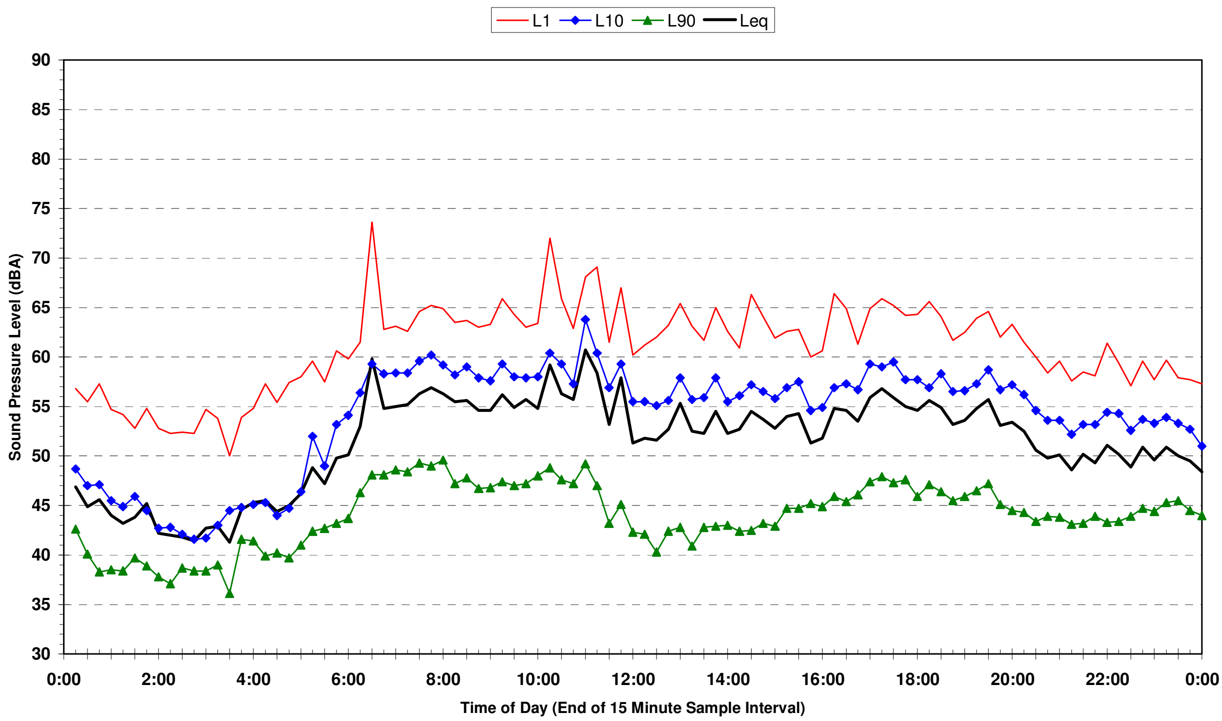


Ambient Noise Measurements

Statistical Ambient Noise Levels
23 Lyall St (Hawthorne) - Thursday 5 August 2010

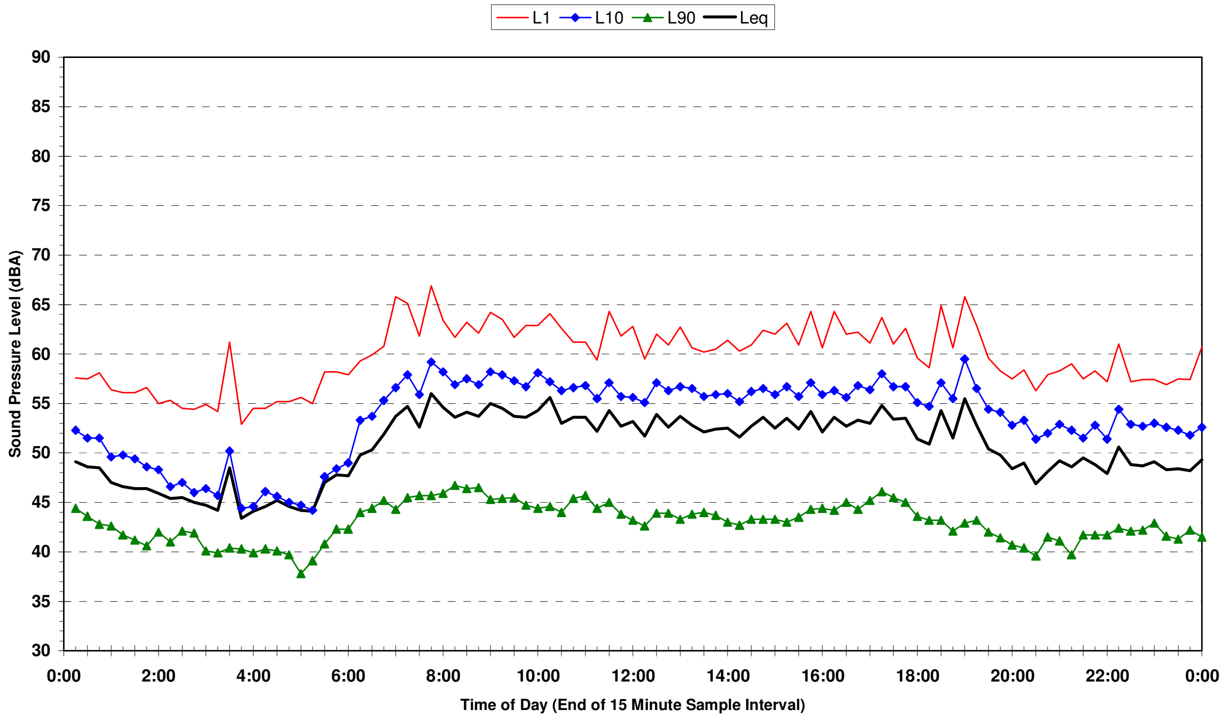


Statistical Ambient Noise Levels
23 Lyall St (Hawthorne) - Friday 6 August 2010

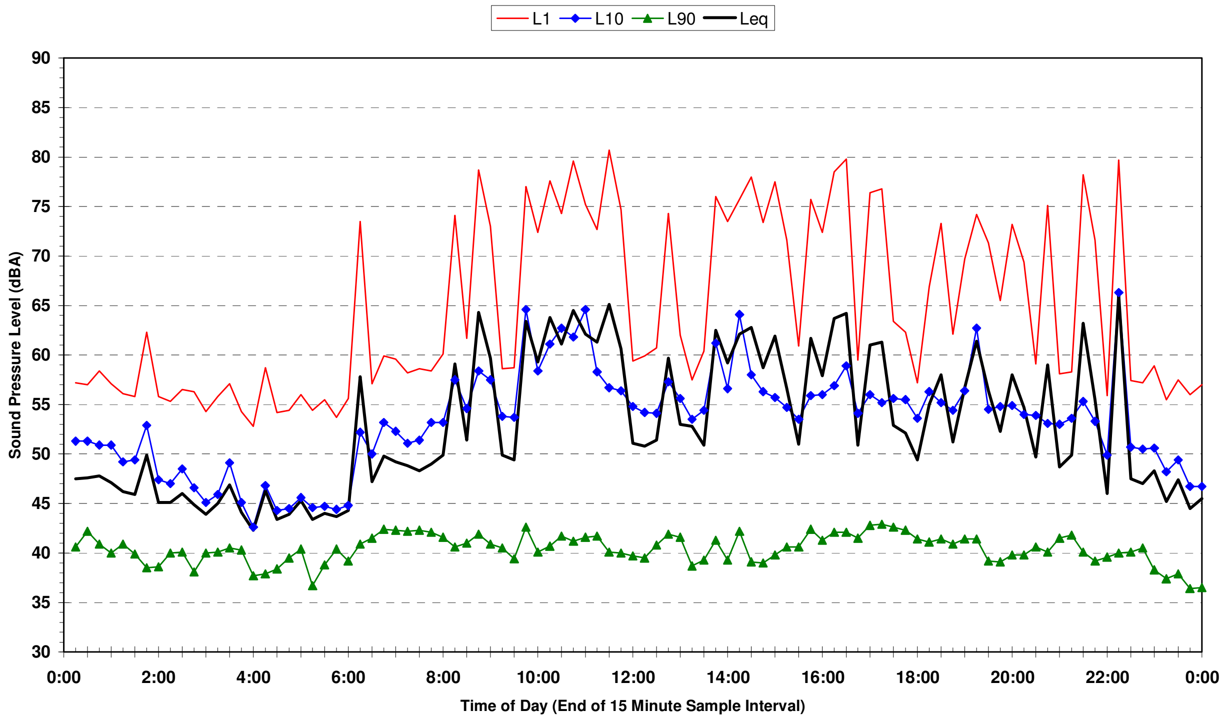


Ambient Noise Measurements

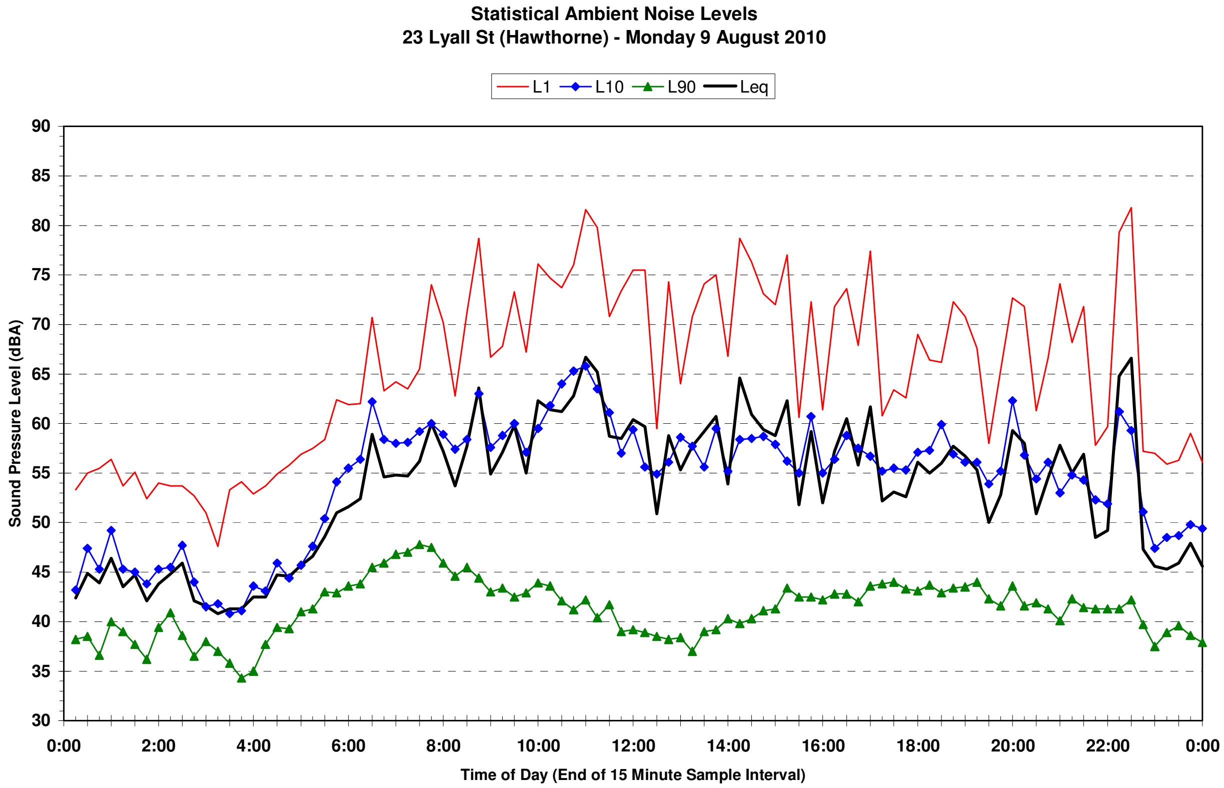
Statistical Ambient Noise Levels
23 Lyall St (Hawthorne) - Saturday 7 August 2010

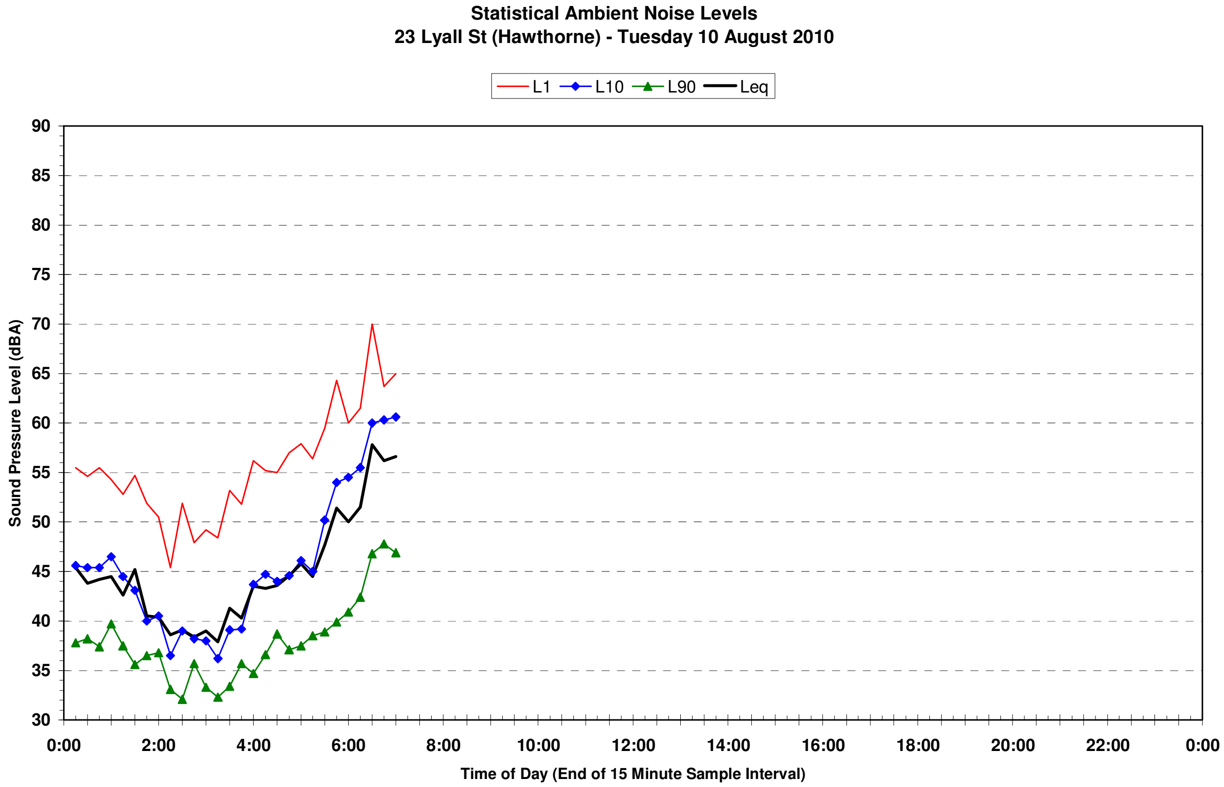


Statistical Ambient Noise Levels
23 Lyall St (Hawthorne) - Sunday 8 August 2010

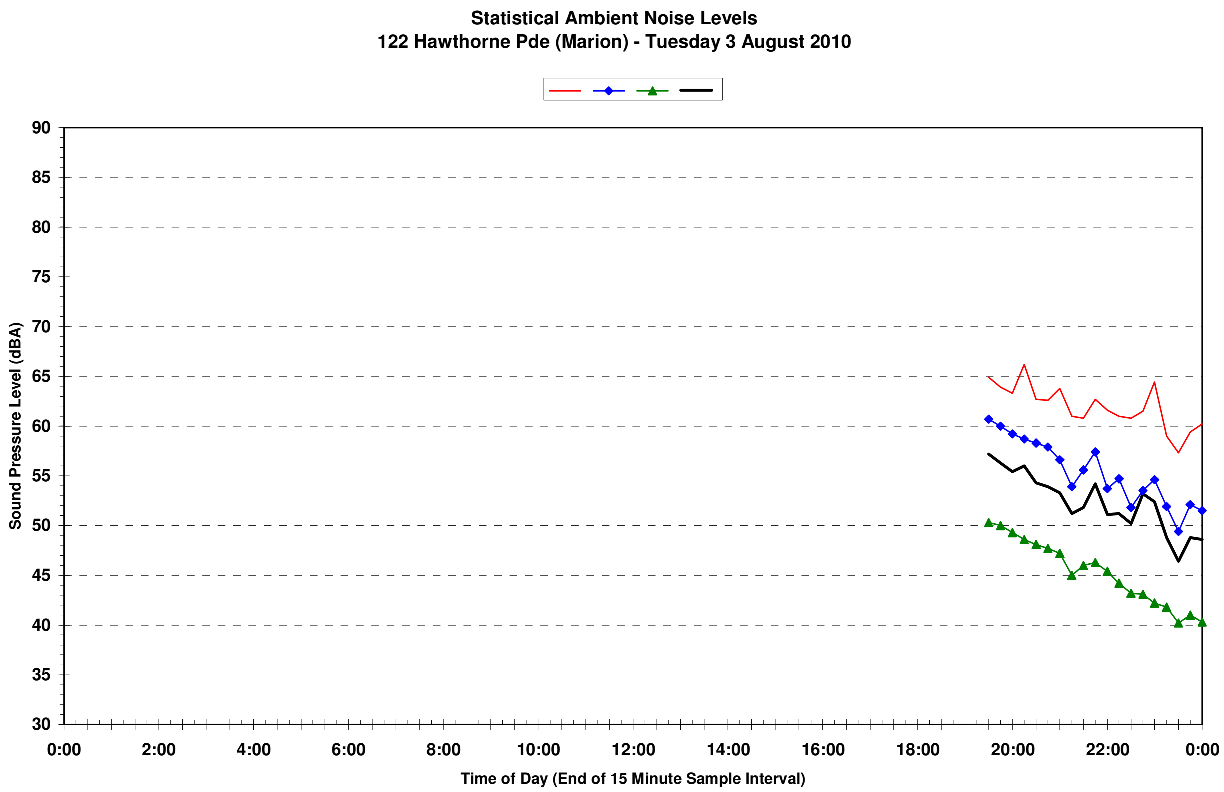


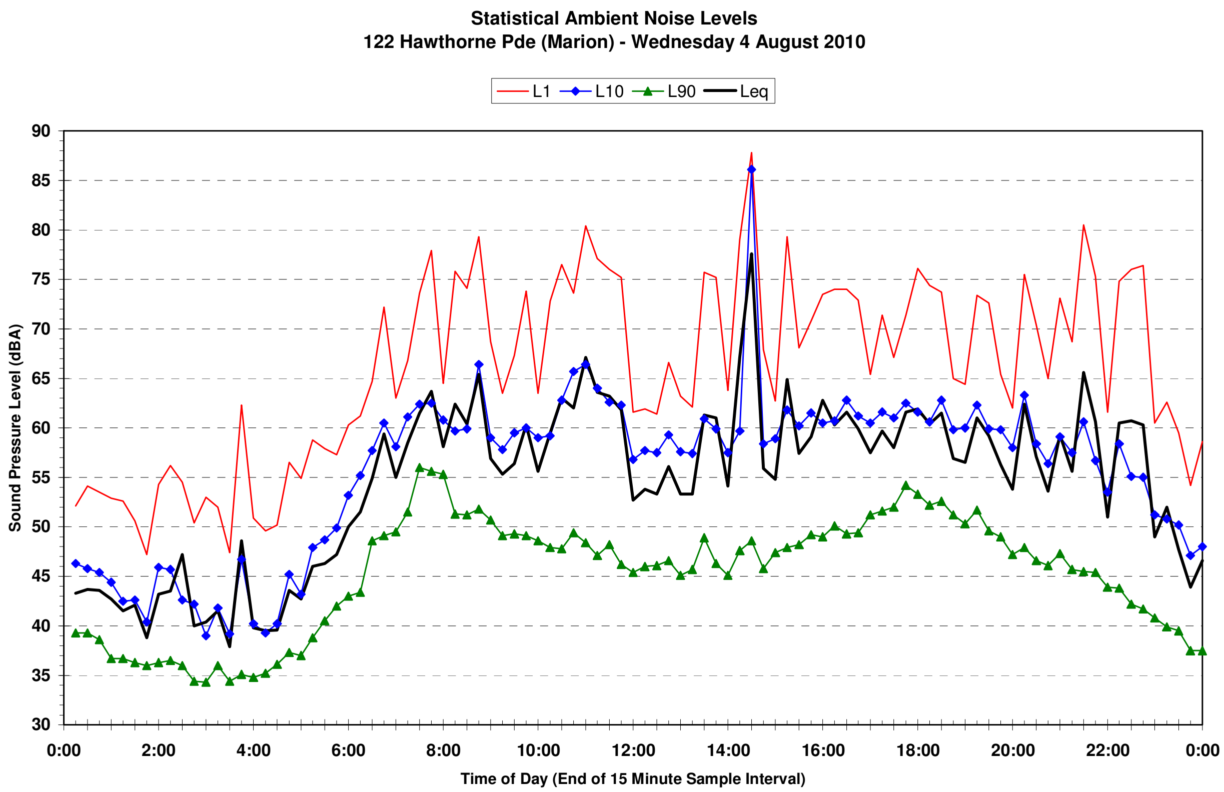
Ambient Noise Measurements

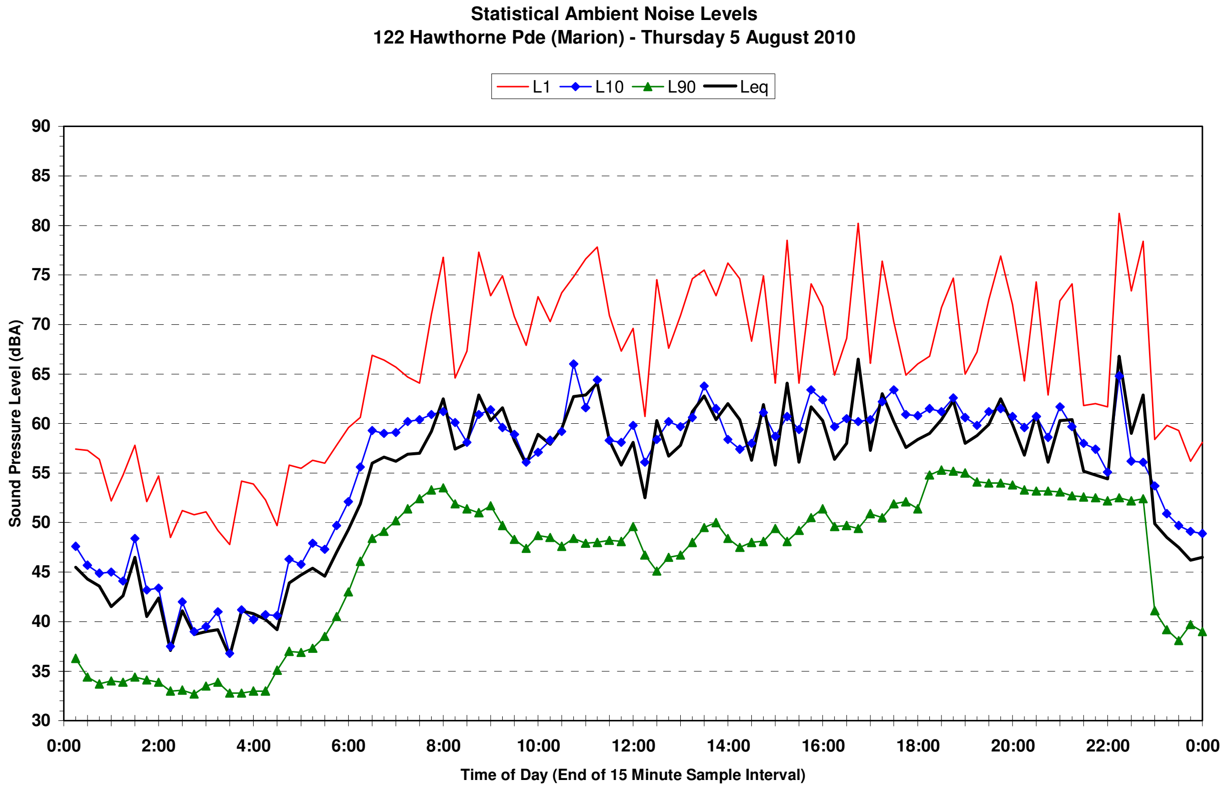


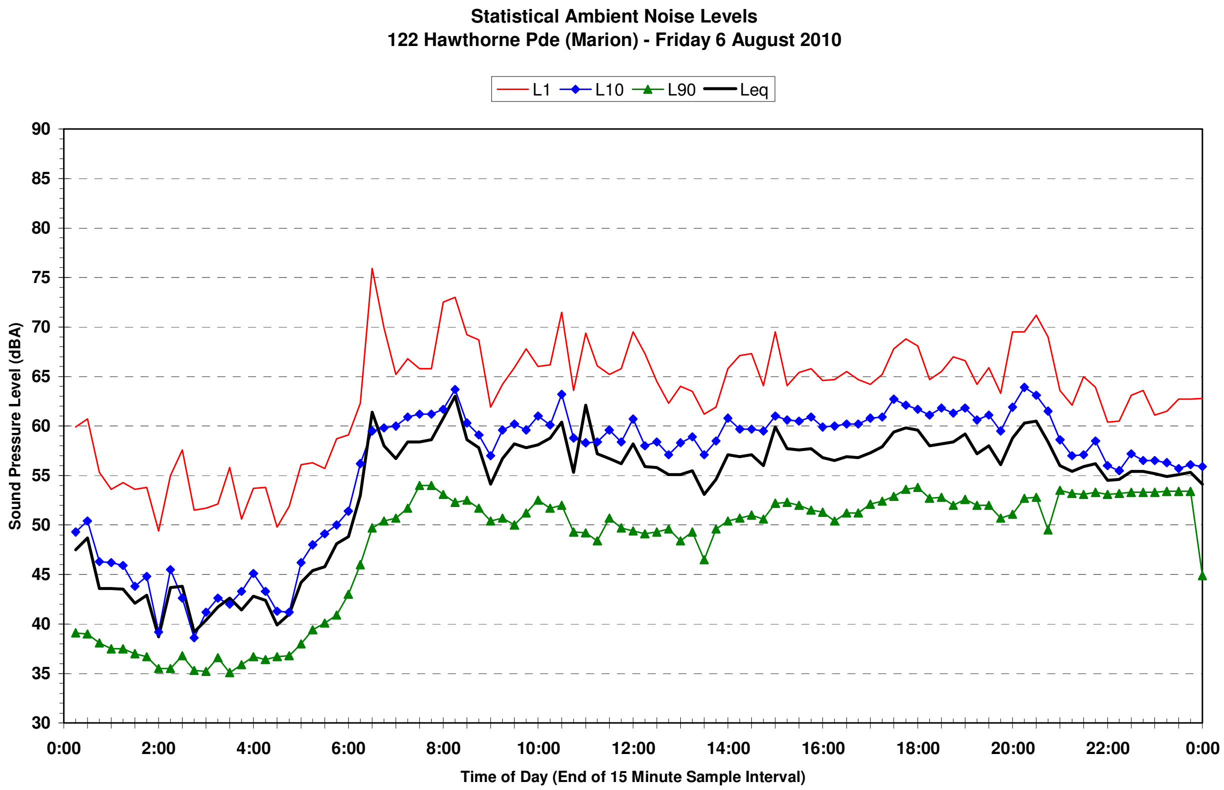


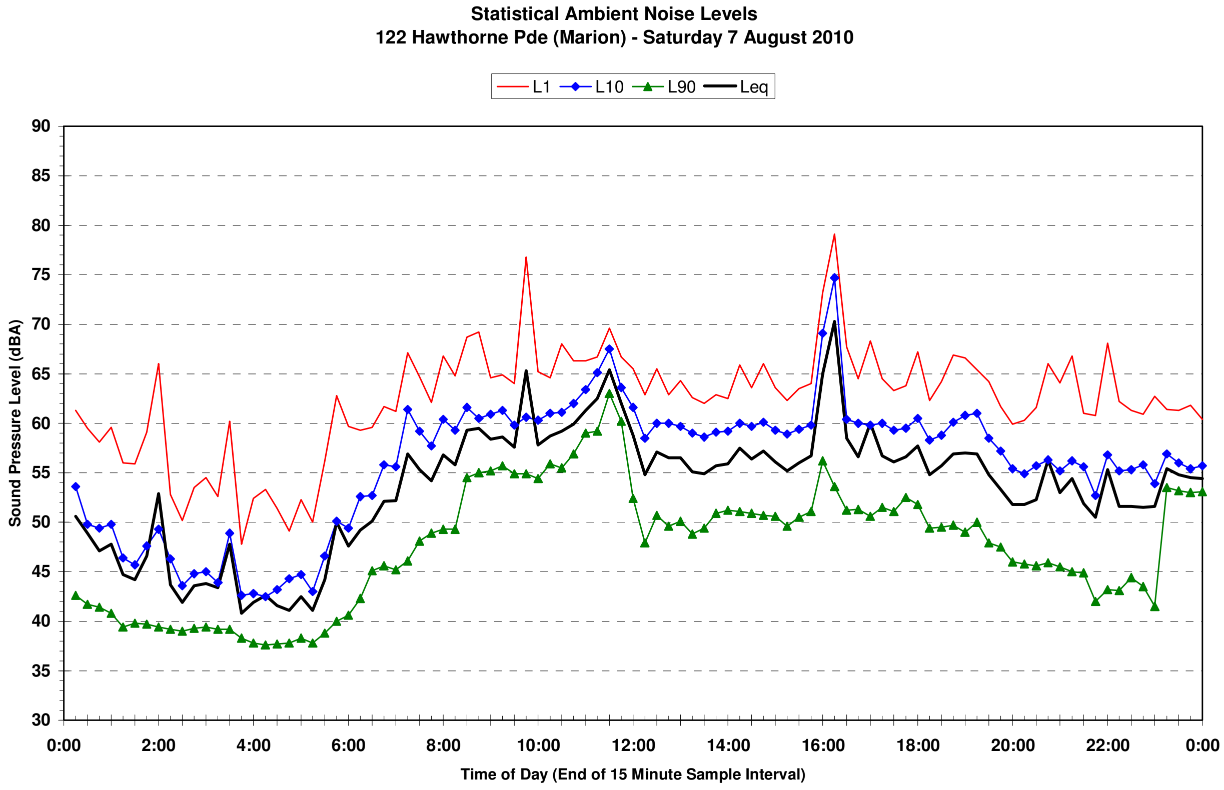
B03 – 122 Hawthorne Pde

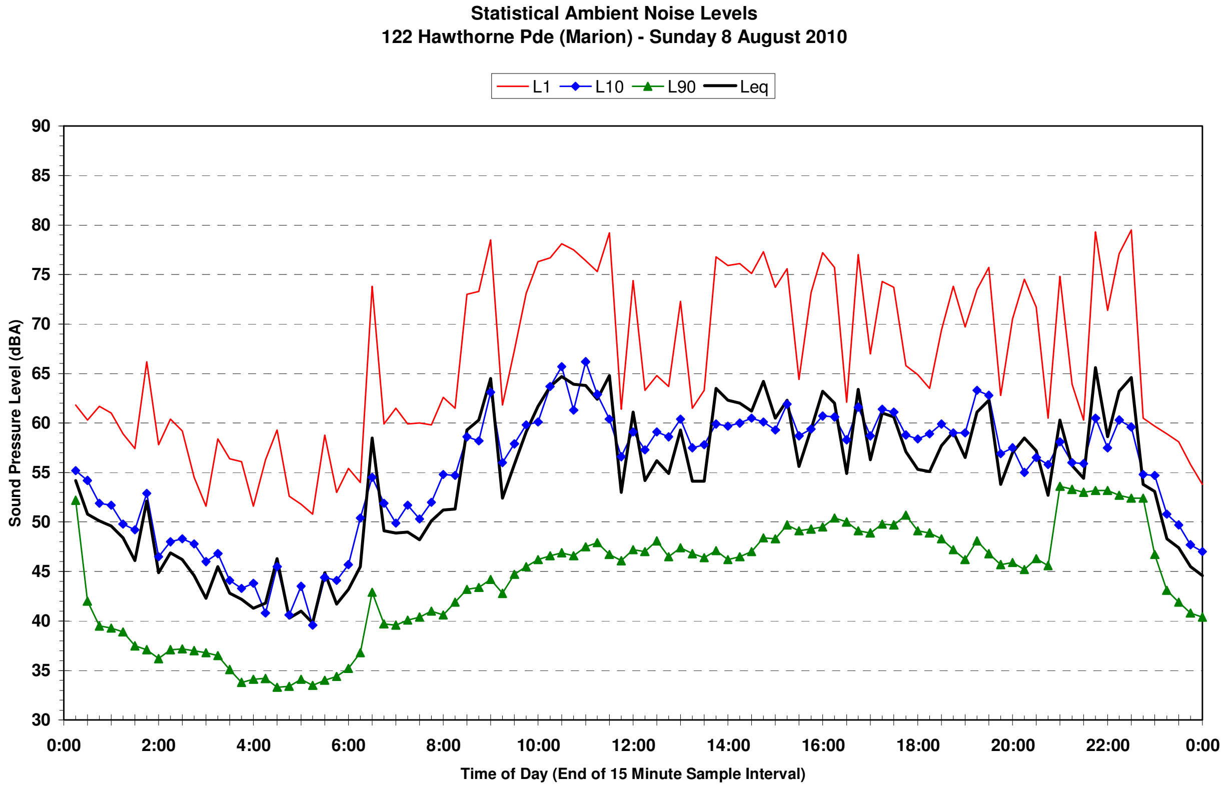




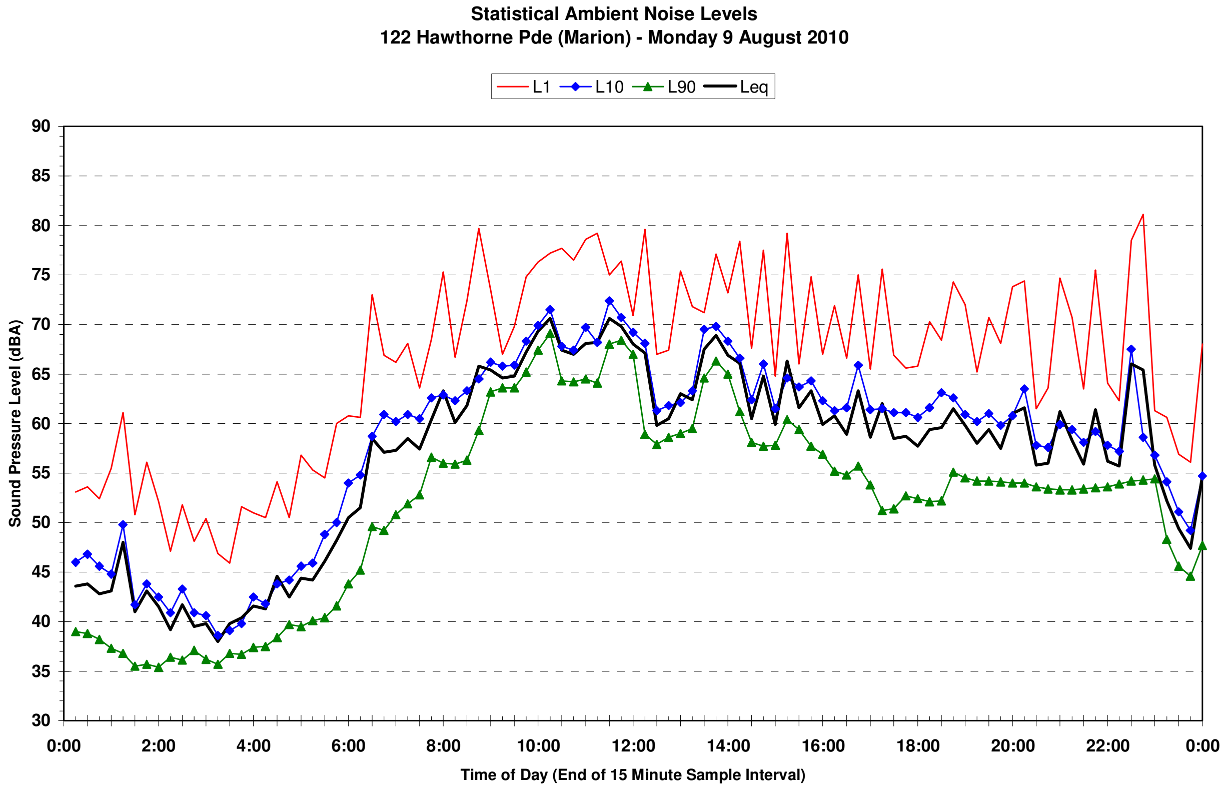

Statistical Ambient Noise Levels
122 Hawthorne Pde (Marion) - Thursday 5 August 2010
L1
L10
L90
Leq
Sound Pressure Level (dBA)
90
85
80
75
70
65
60
55
50
45
40
35
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Time of Day (End of 15 Minute Sample Interval)

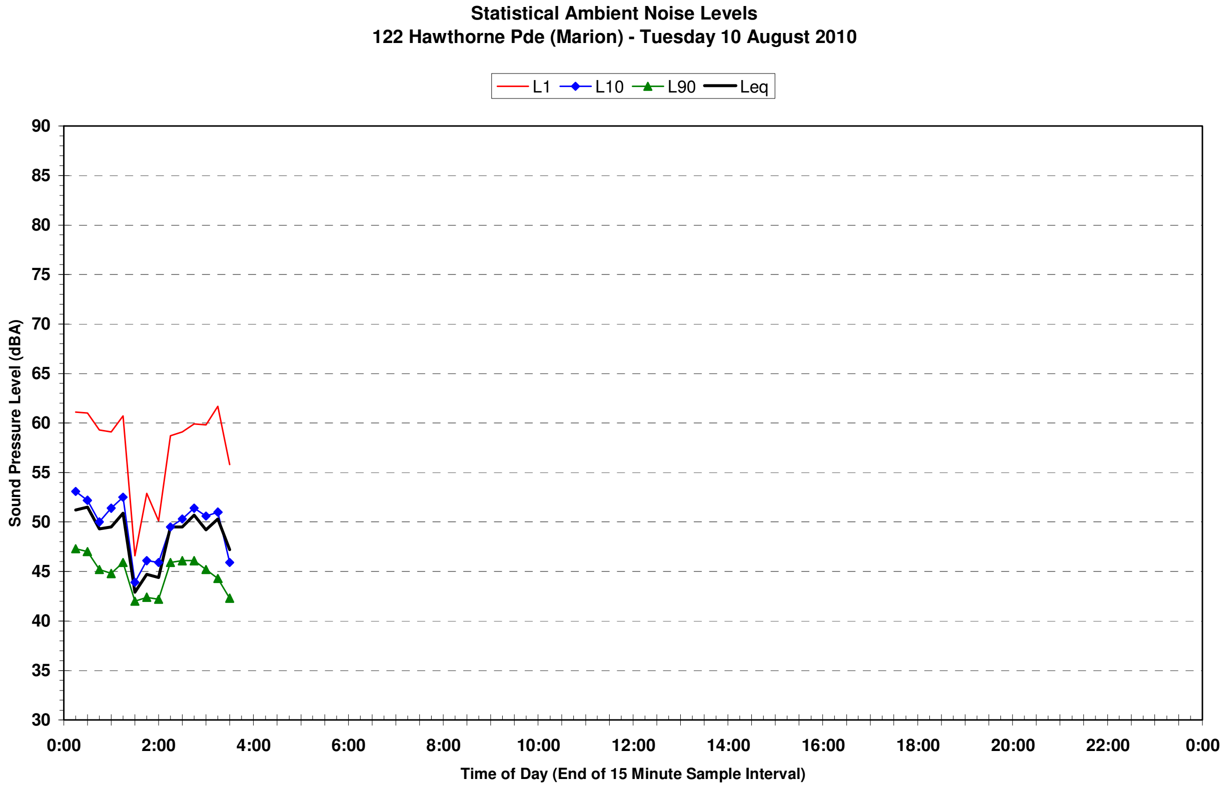

Statistical Ambient Noise Levels
122 Hawthorne Pde (Marion) - Friday 6 August 2010
L1
L10
L90
Leq
Sound Pressure Level (dBA)
90
85
80
75
70
65
60
55
50
45
40
35
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Time of Day (End of 15 Minute Sample Interval)


Statistical Ambient Noise Levels
122 Hawthorne Pde (Marion) - Saturday 7 August 2010
L1
L10
L90
Leq
Sound Pressure Level (dBA)
90
85
80
75
70
65
60
55
50
45
40
35
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Time of Day (End of 15 Minute Sample Interval)

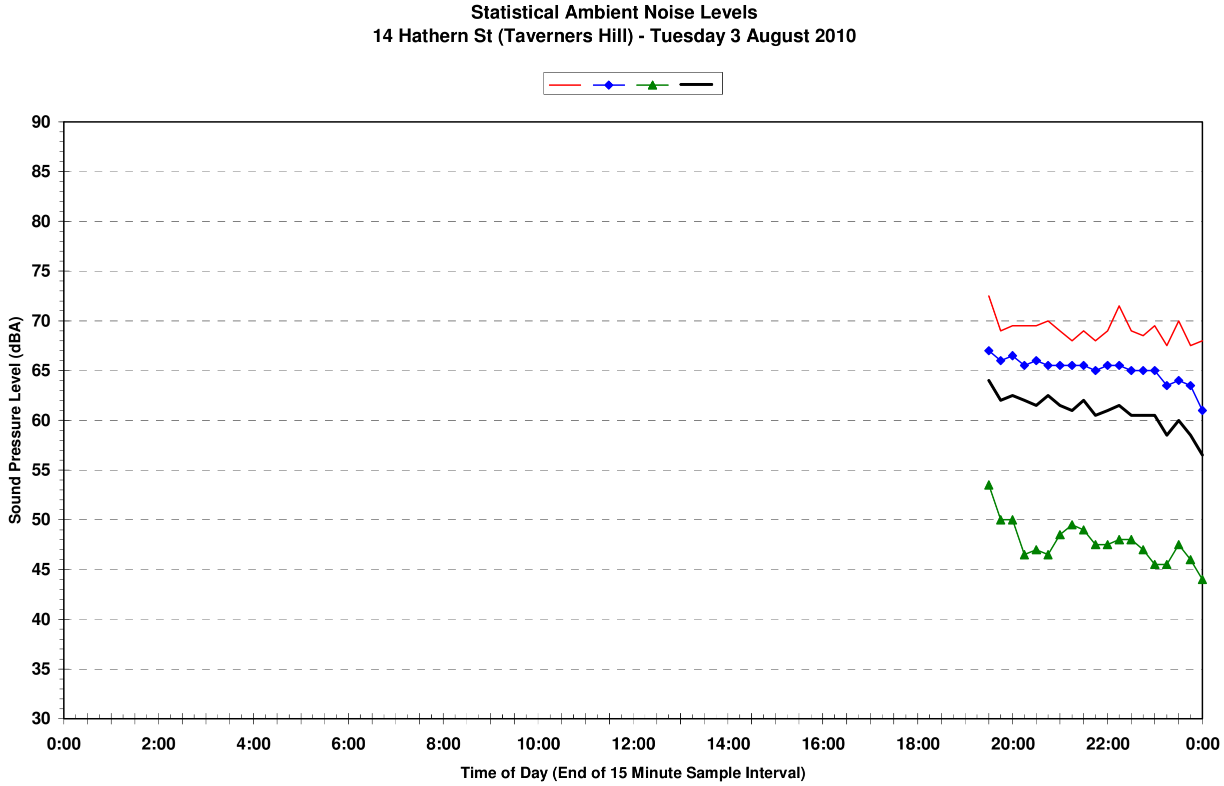

Statistical Ambient Noise Levels
122 Hawthorne Pde (Marion) - Sunday 8 August 2010
L1
L10
L90
Leq
Sound Pressure Level (dBA)
90
85
80
75
70
65
60
55
50
45
40
35
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Time of Day (End of 15 Minute Sample Interval)

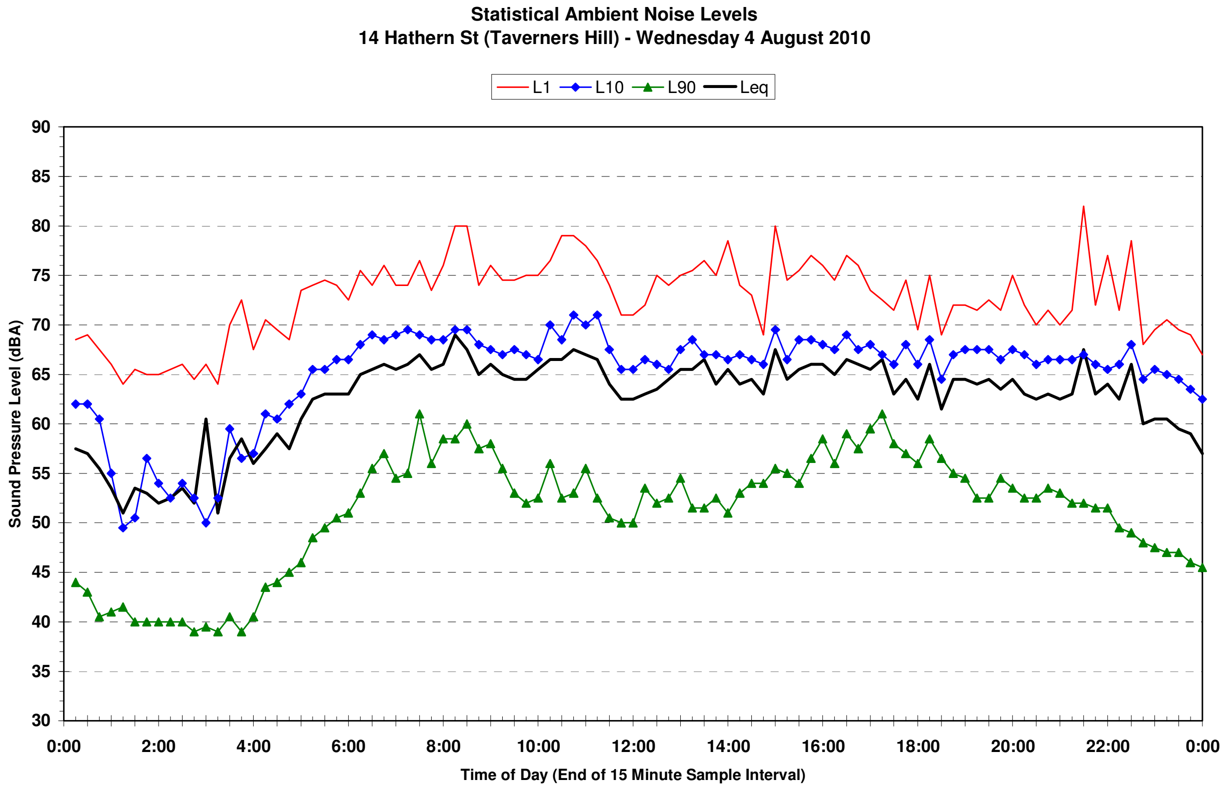
Ambient Noise Measurements



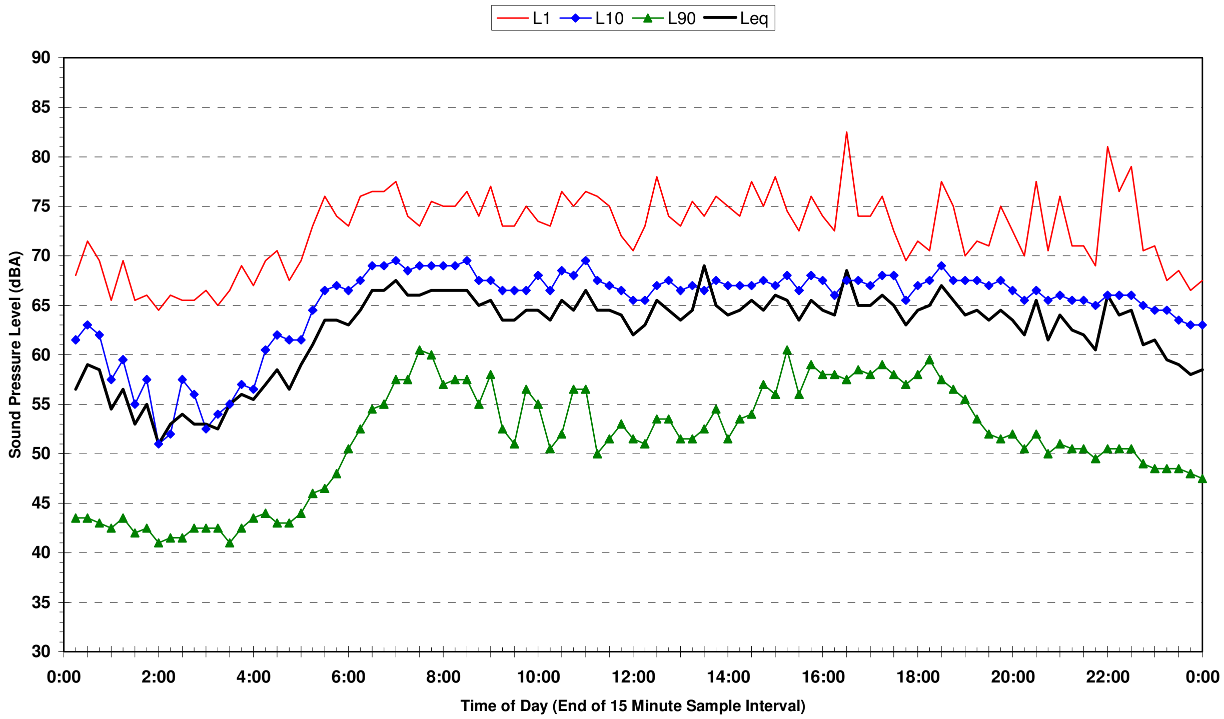


B04 – 14 Hathern St

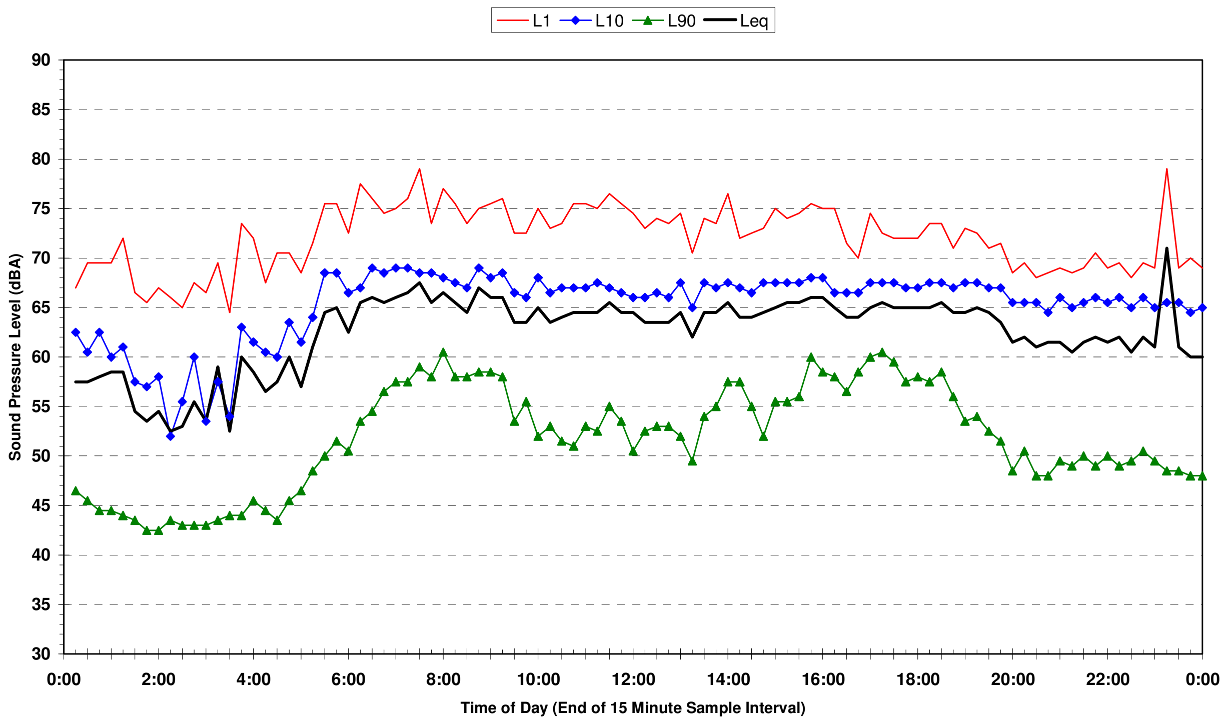




Statistical Ambient Noise Levels
14 Hathern St (Taverners Hill) - Thursday 5 August 2010

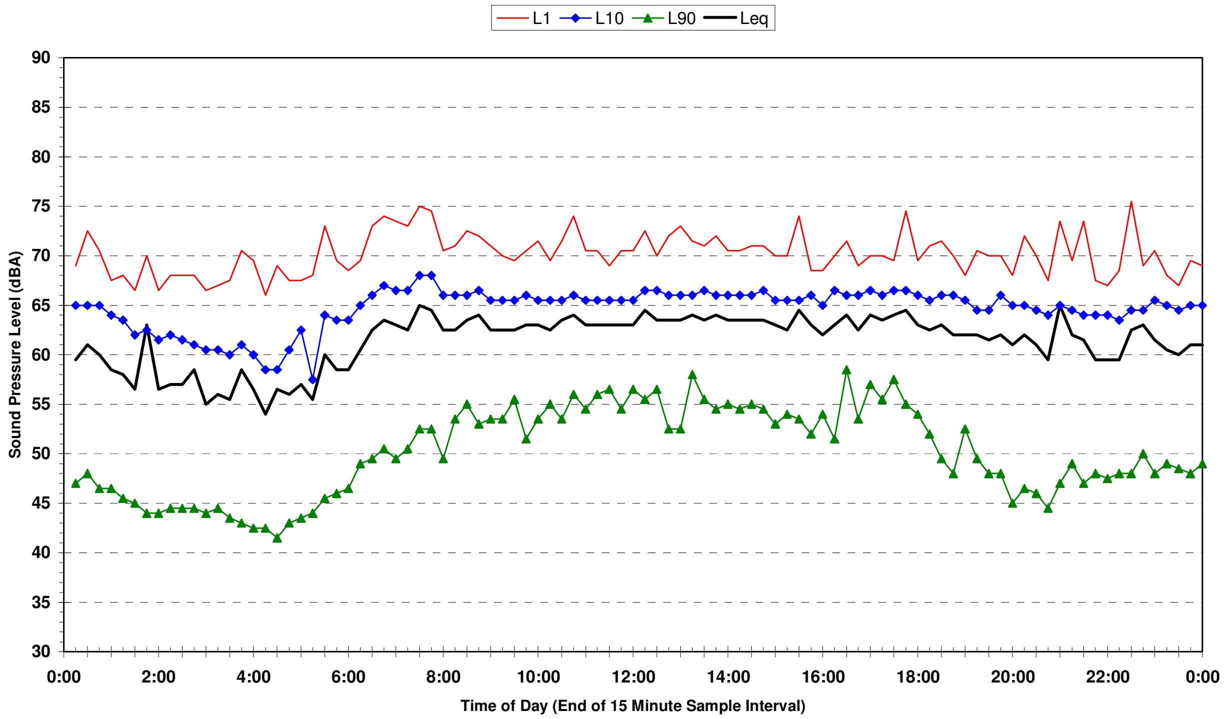


Statistical Ambient Noise Levels
14 Hathern St (Taverners Hill) - Friday 6 August 2010

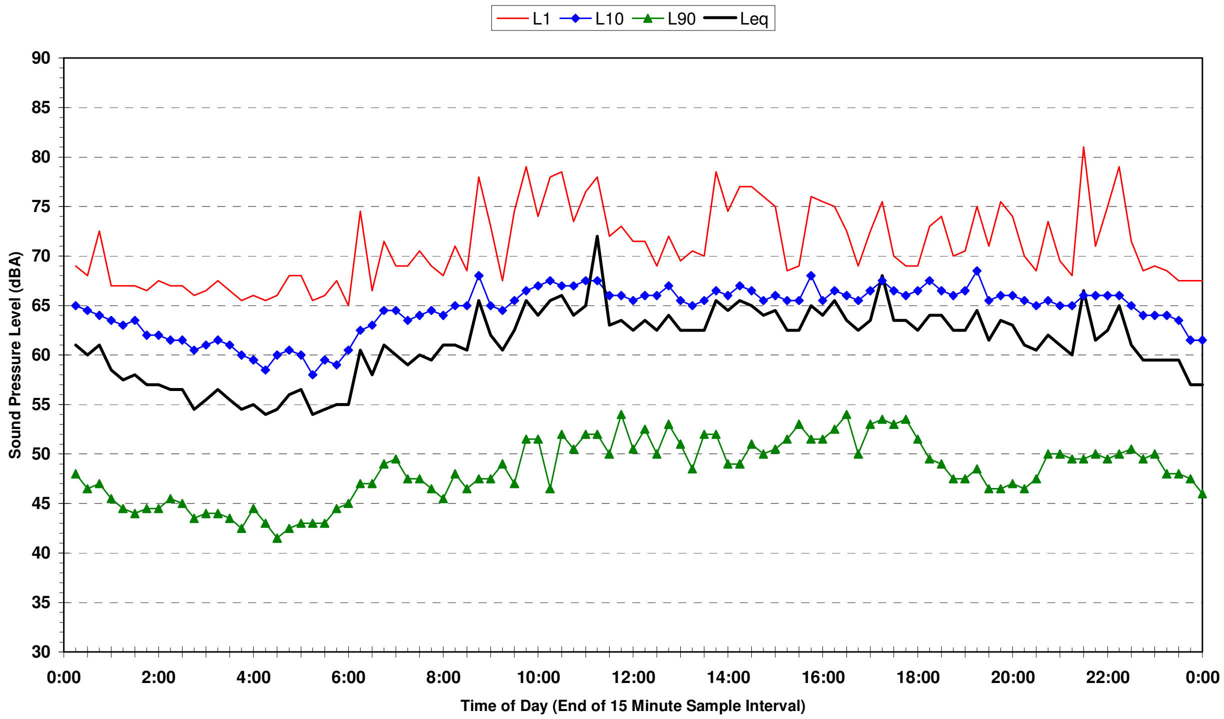


Ambient Noise Measurements

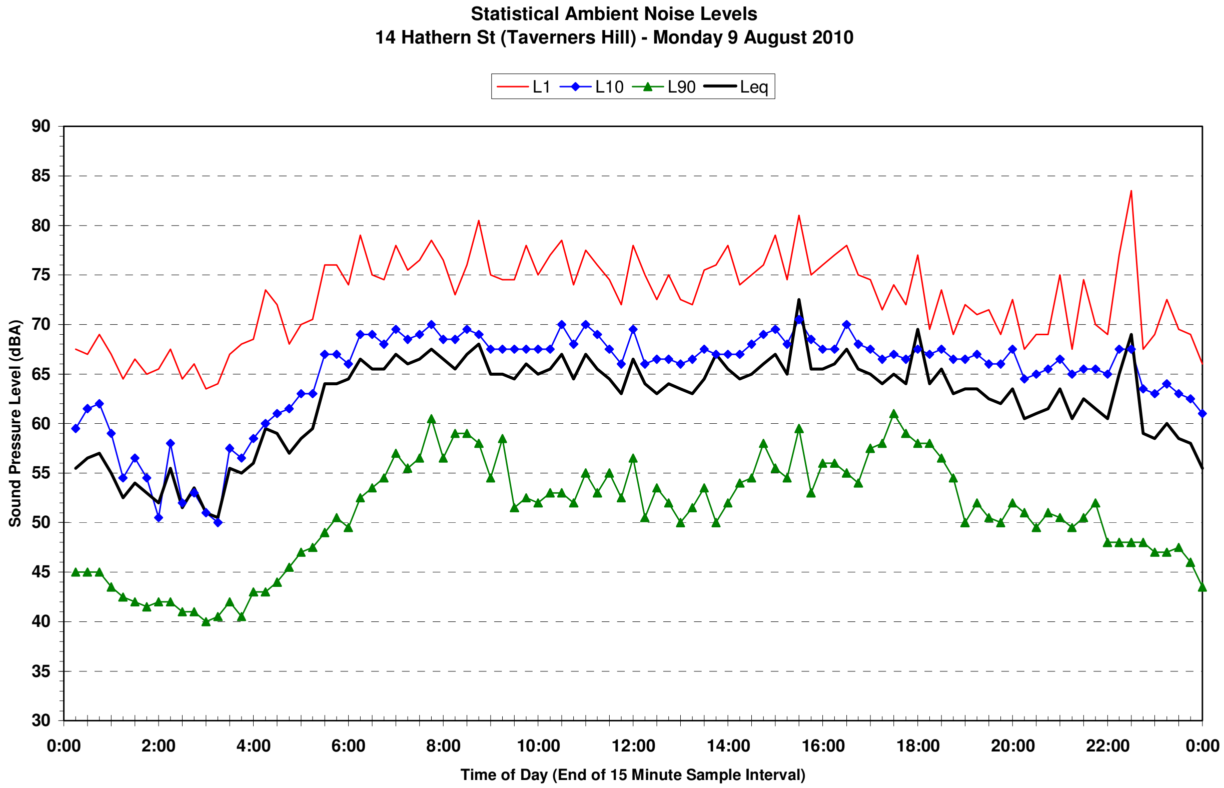
Statistical Ambient Noise Levels
14 Hathern St (Taverners Hill) - Saturday 7 August 2010

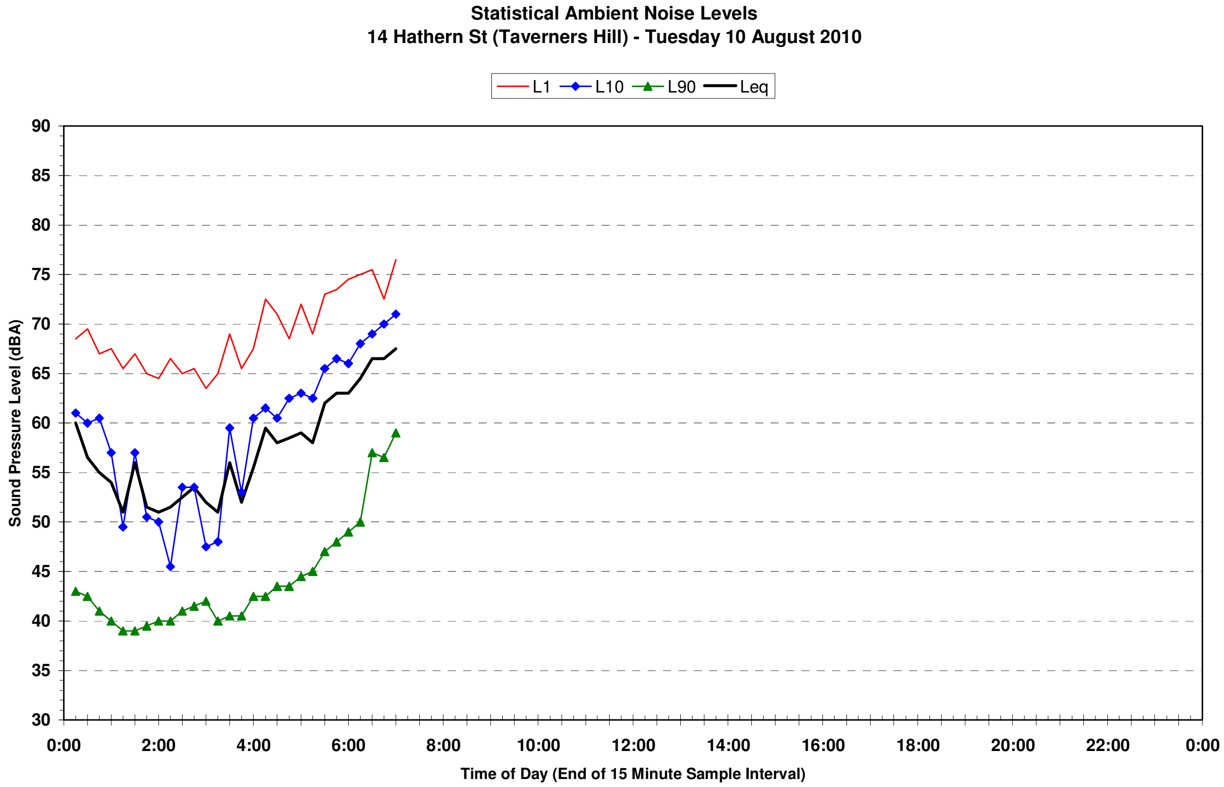


Statistical Ambient Noise Levels
14 Hathern St (Taverners Hill) - Sunday 8 August 2010

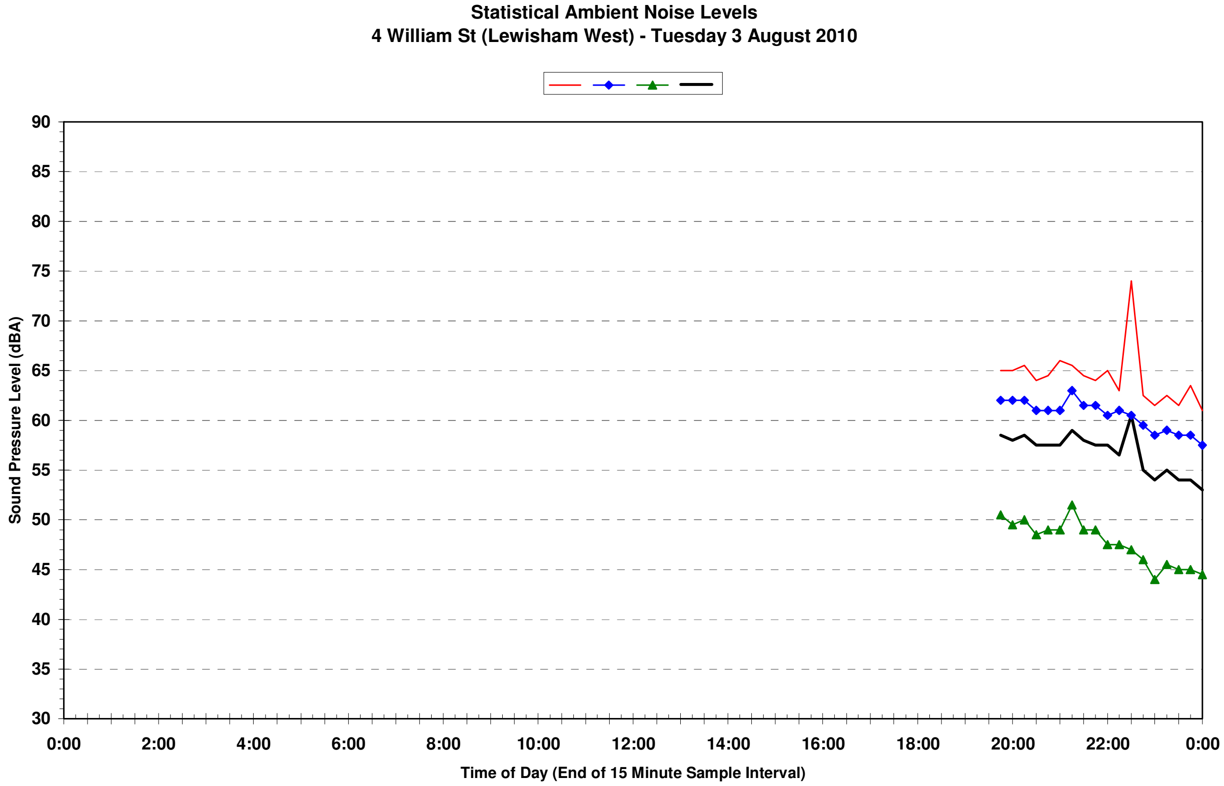


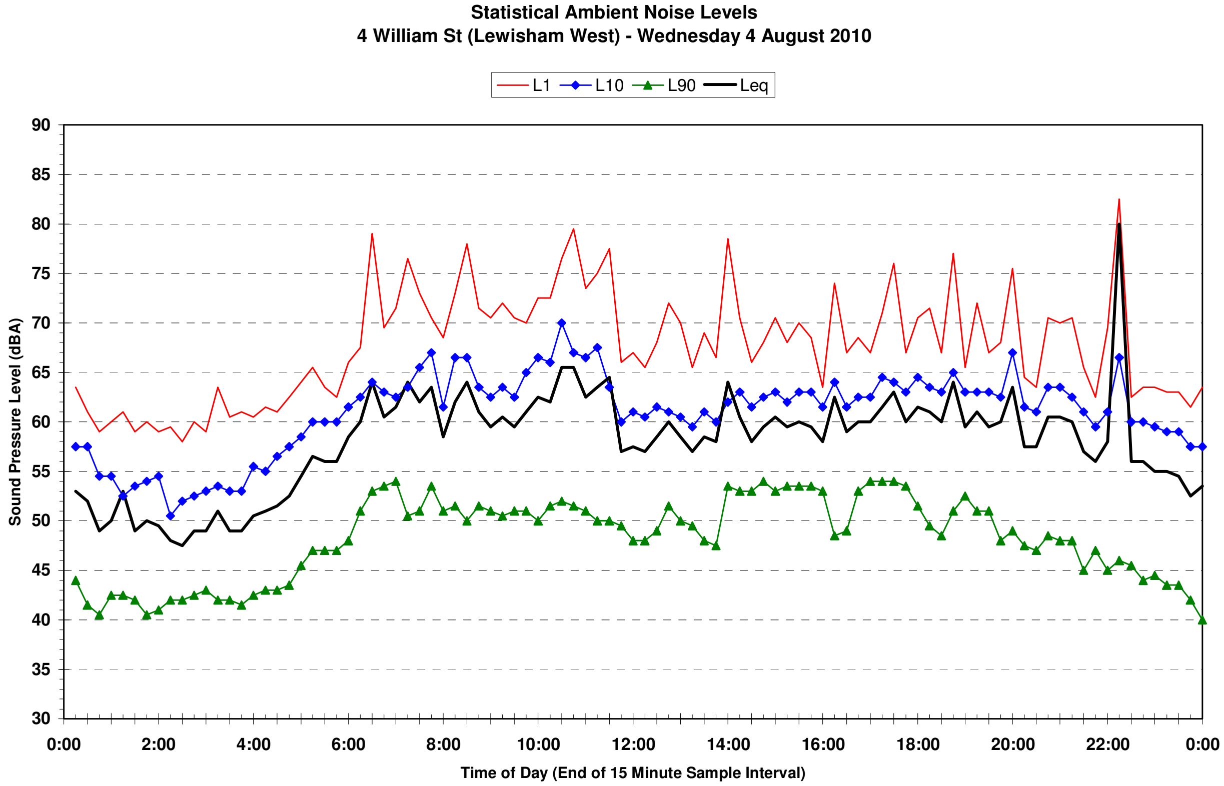
Ambient Noise Measurements



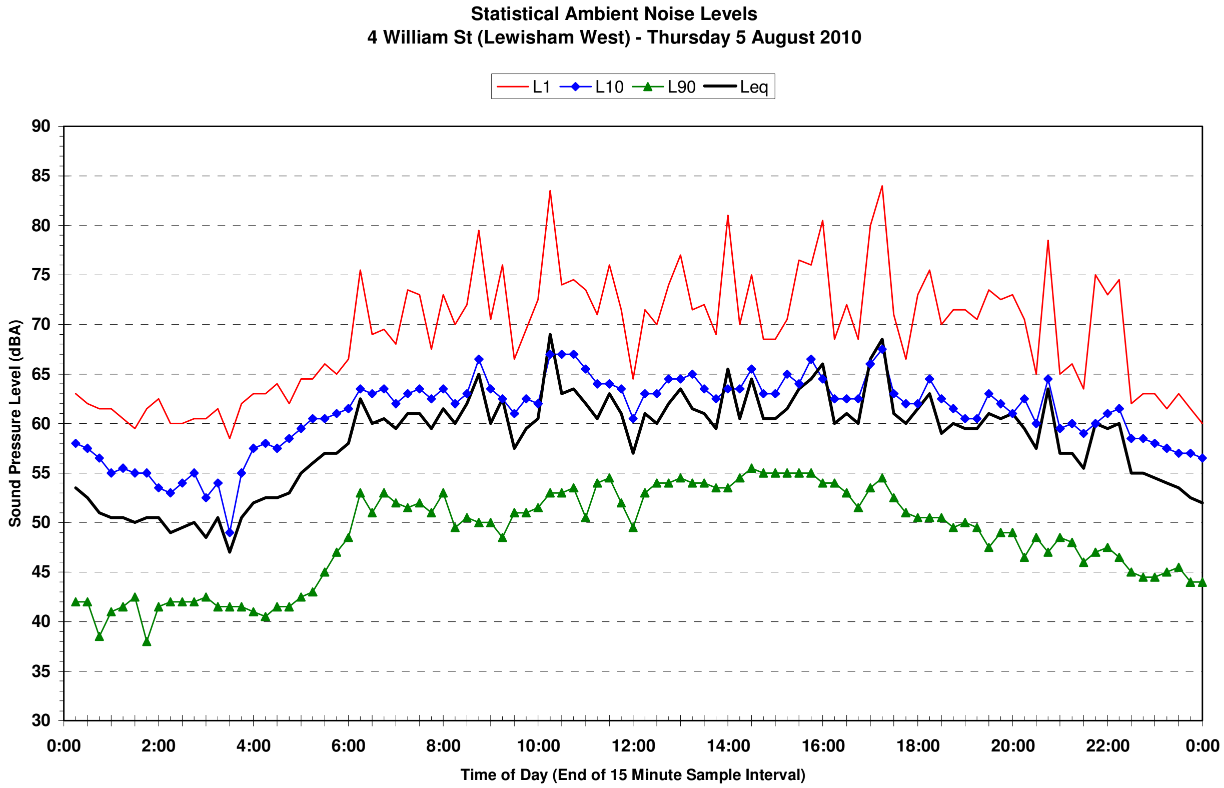


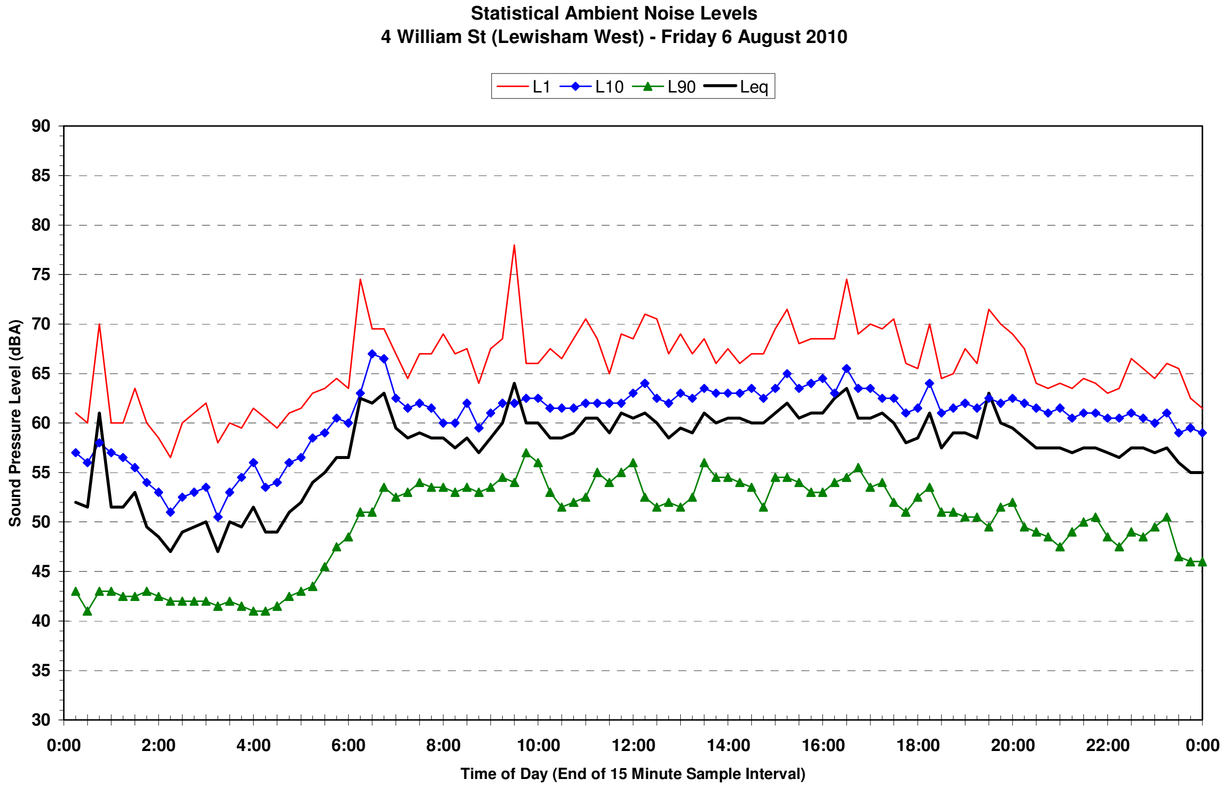
B05 – 4 William St



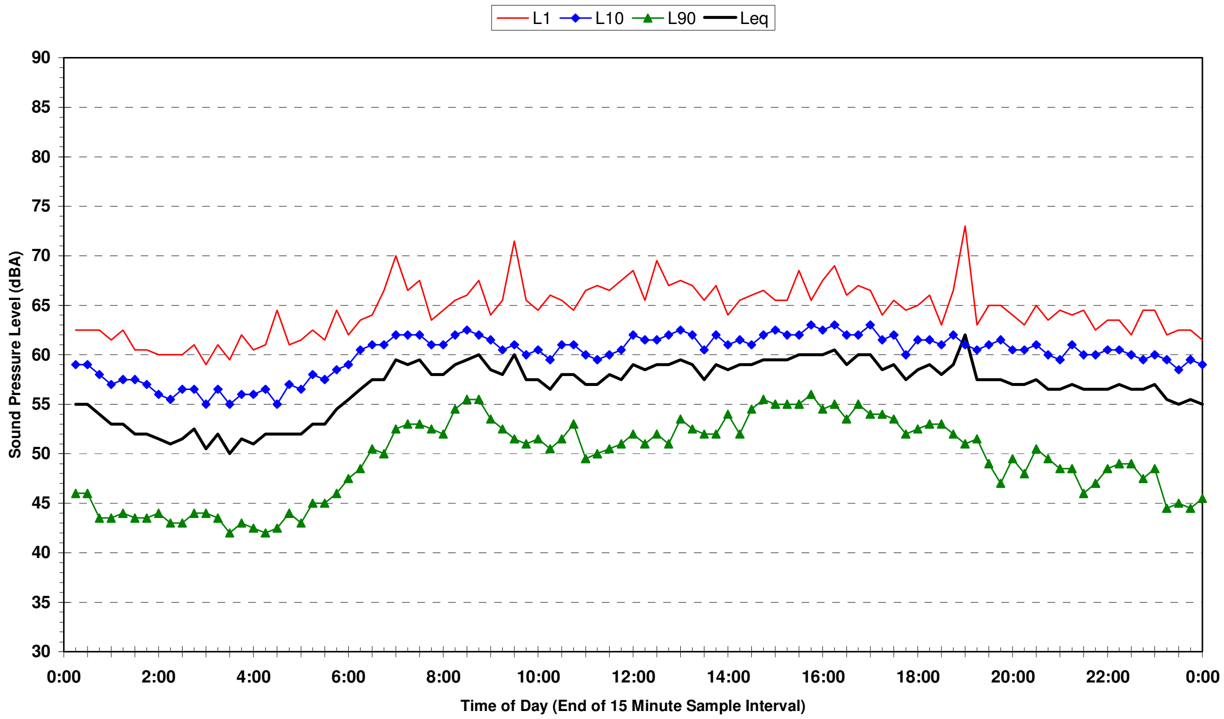


Ambient Noise Measurements

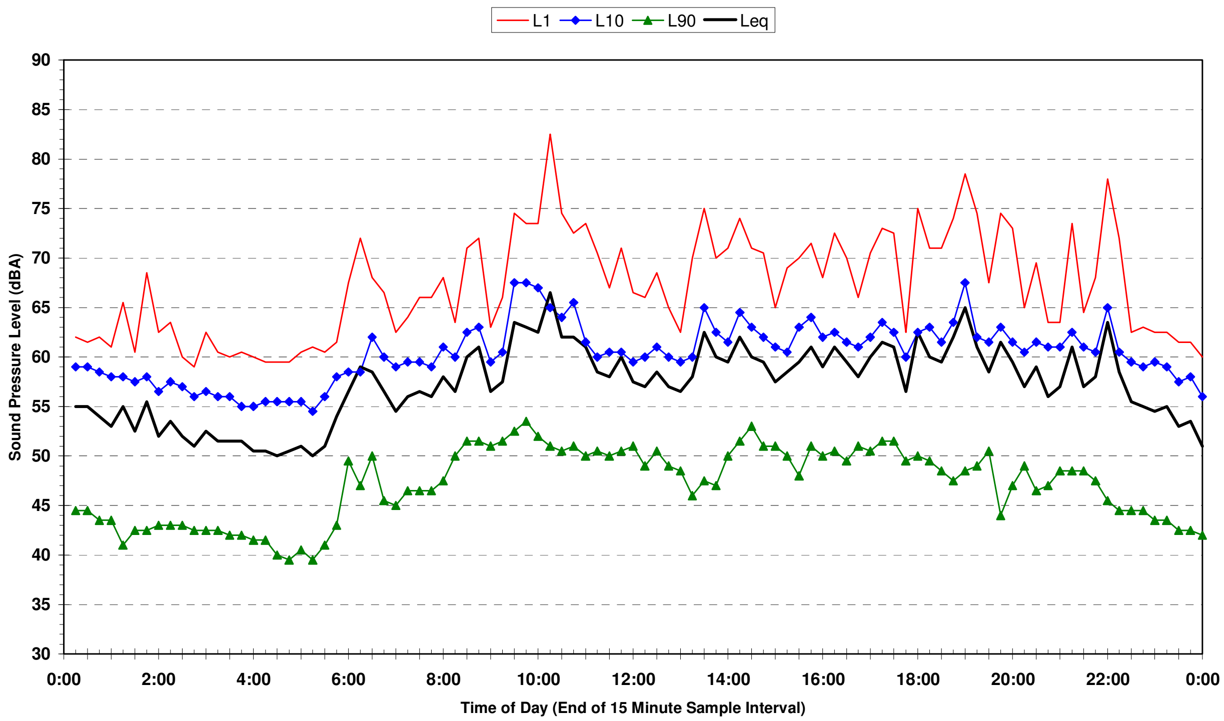




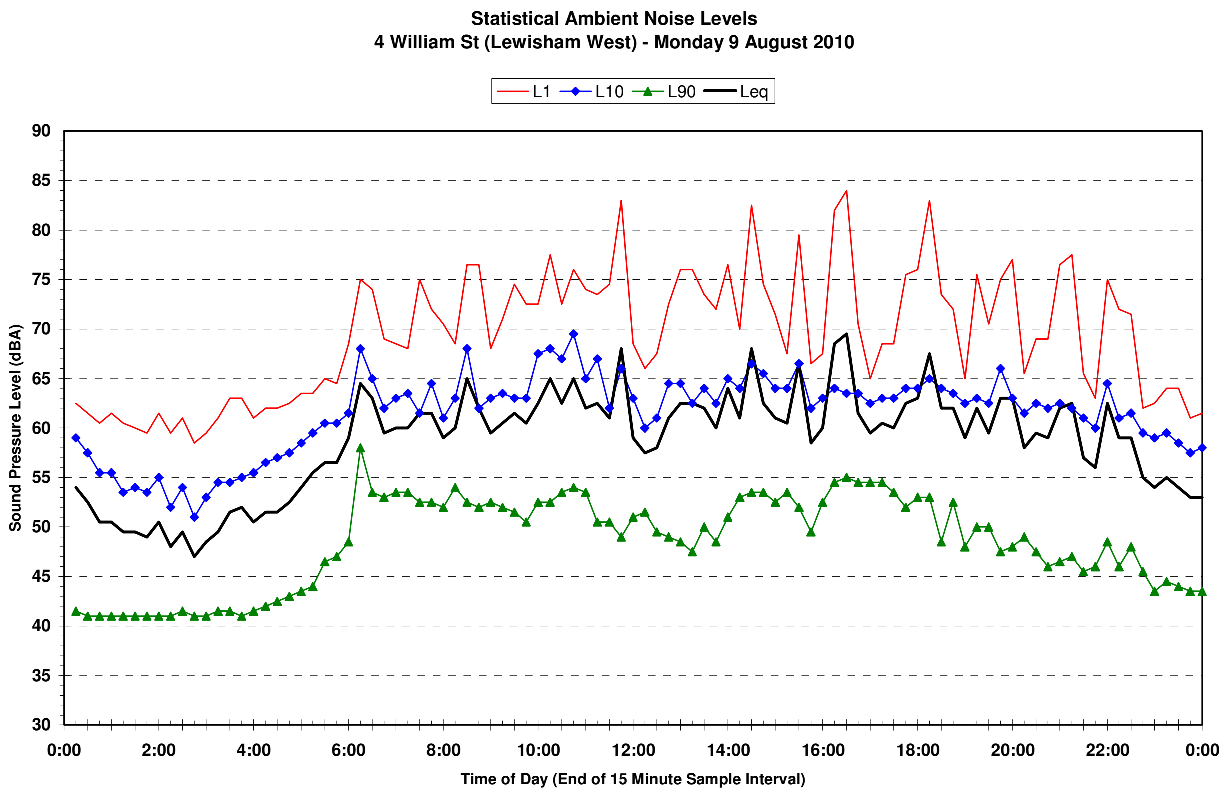
Statistical Ambient Noise Levels
4 William St (Lewisham West) - Saturday 7 August 2010

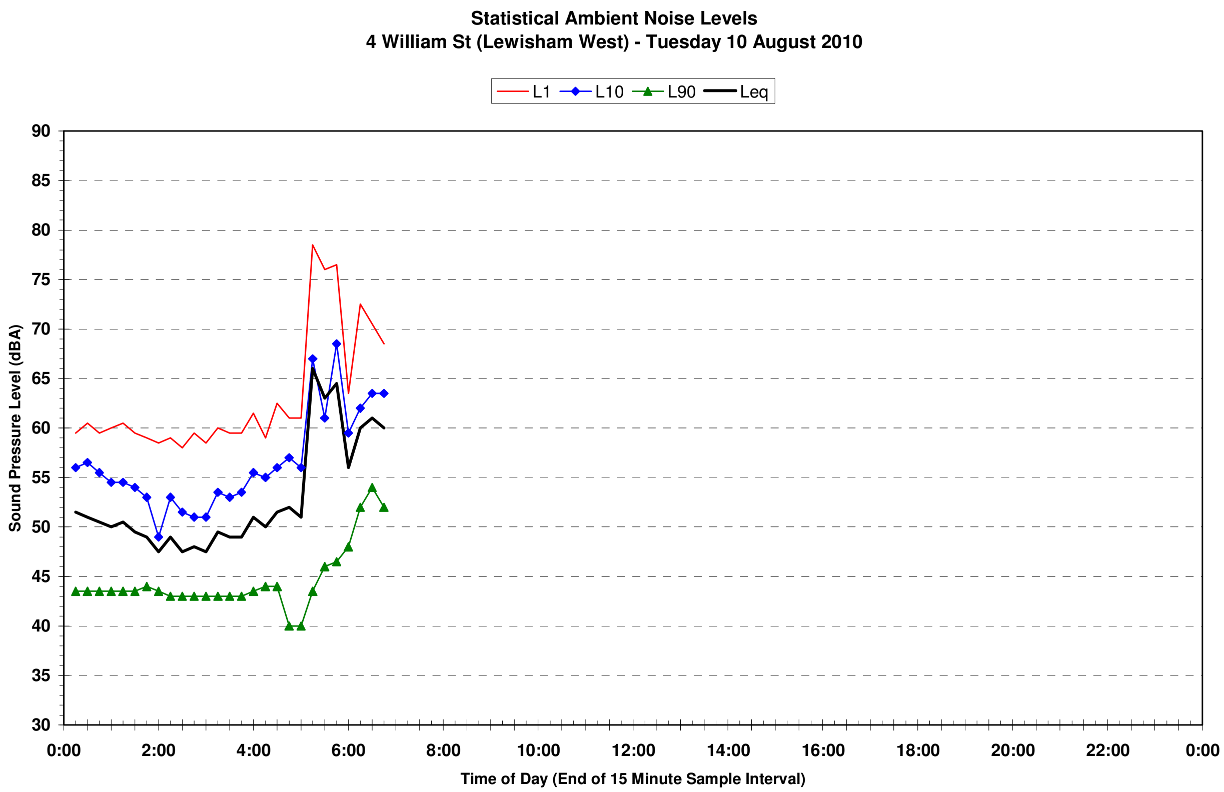


Statistical Ambient Noise Levels
4 William St (Lewisham West) - Sunday 8 August 2010

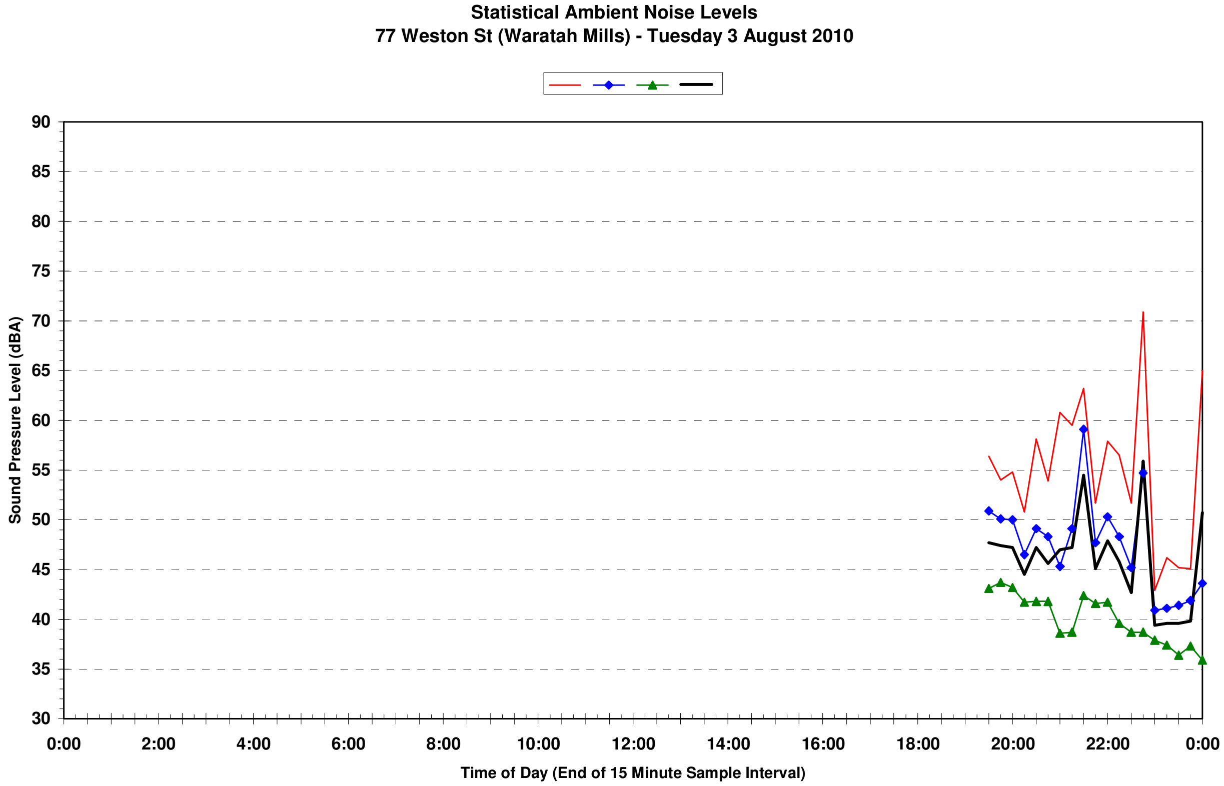


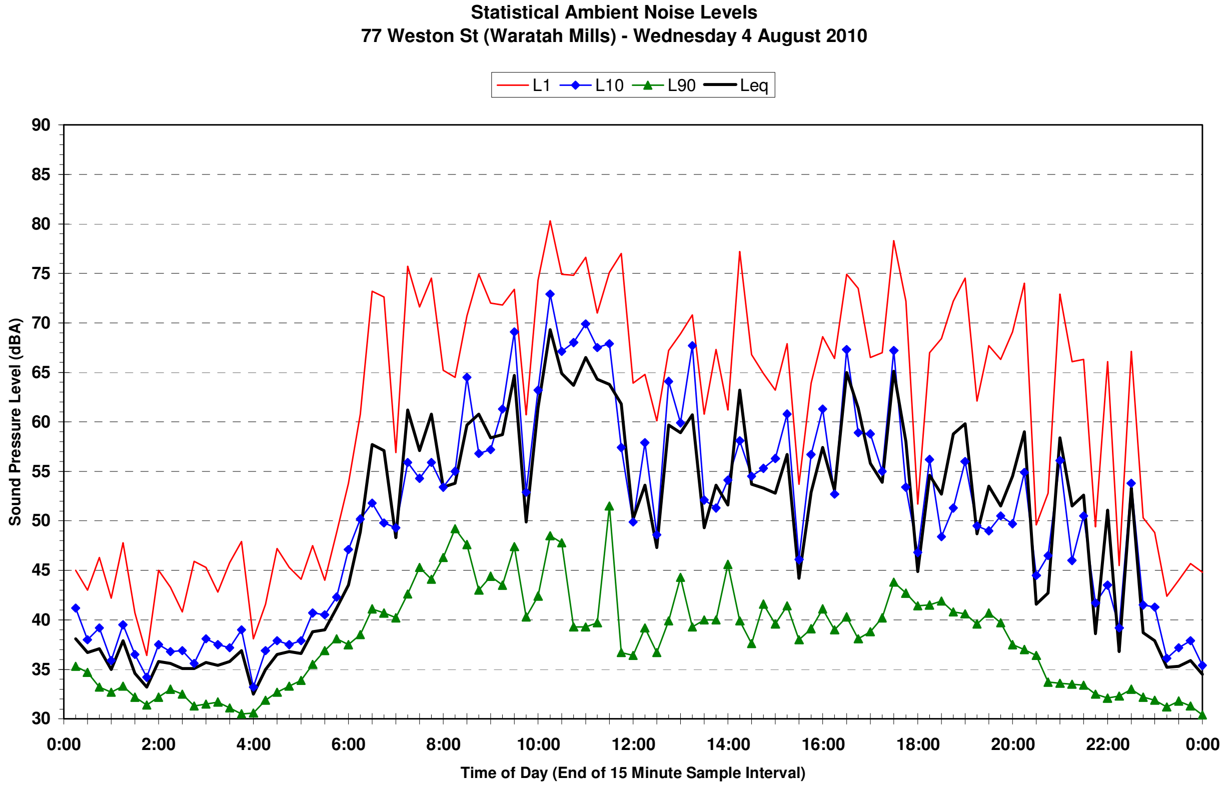
Ambient Noise Measurements





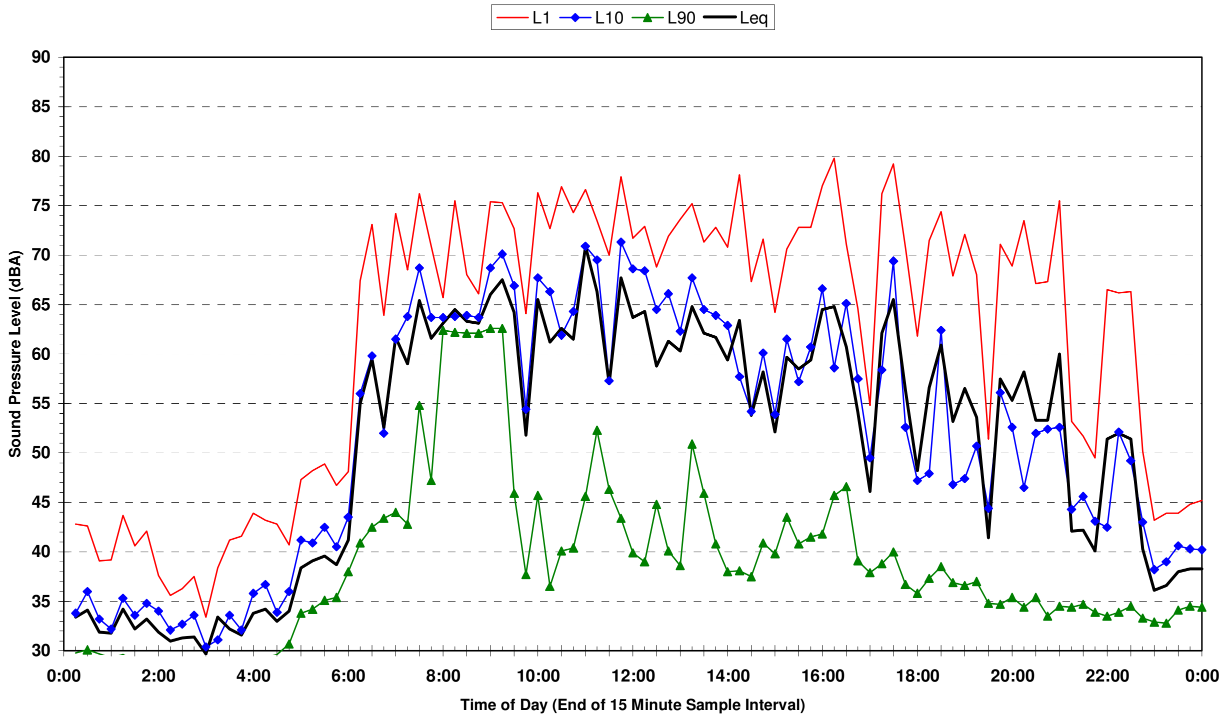
B06 – 77 Weston St



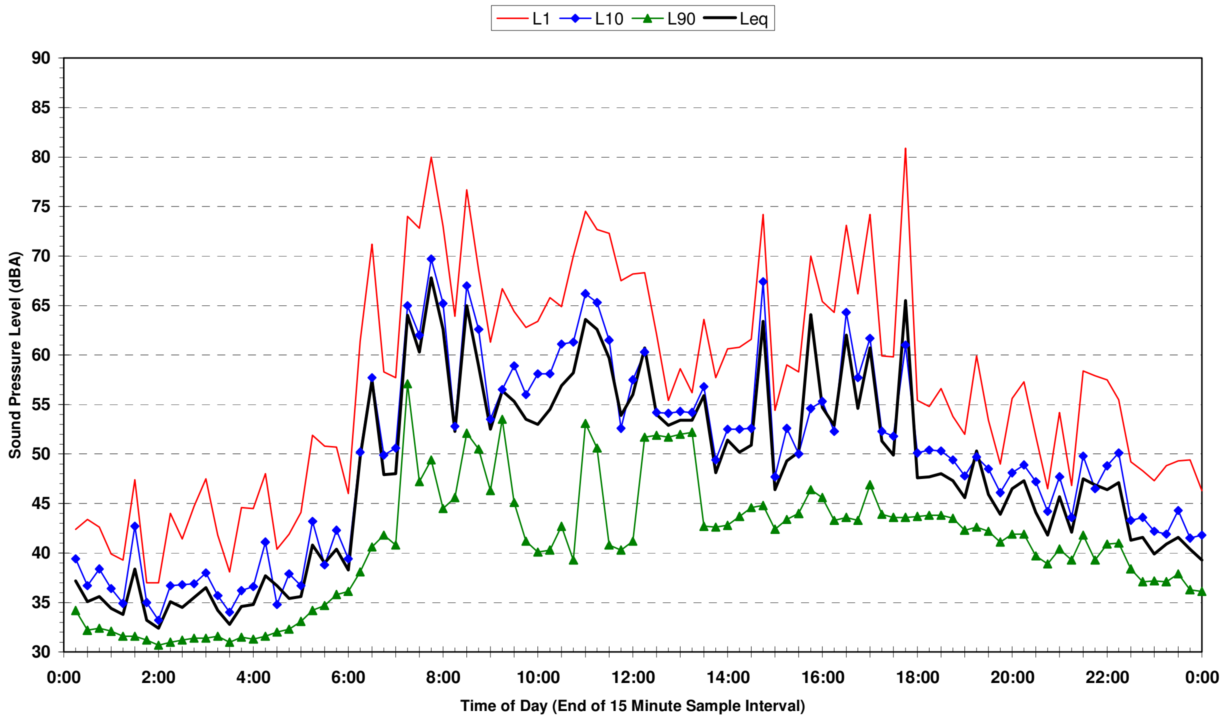


Ambient Noise Measurements

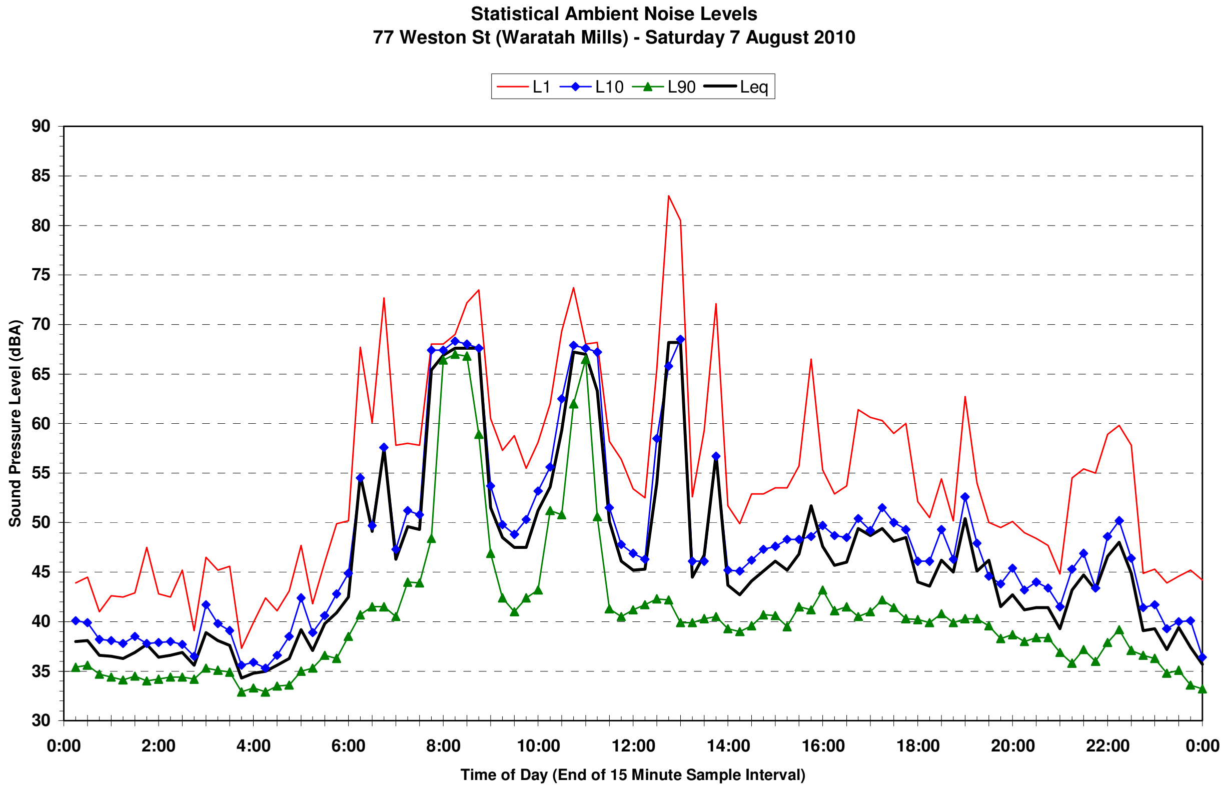
Statistical Ambient Noise Levels
77 Weston St (Waratah Mills) - Thursday 5 August 2010

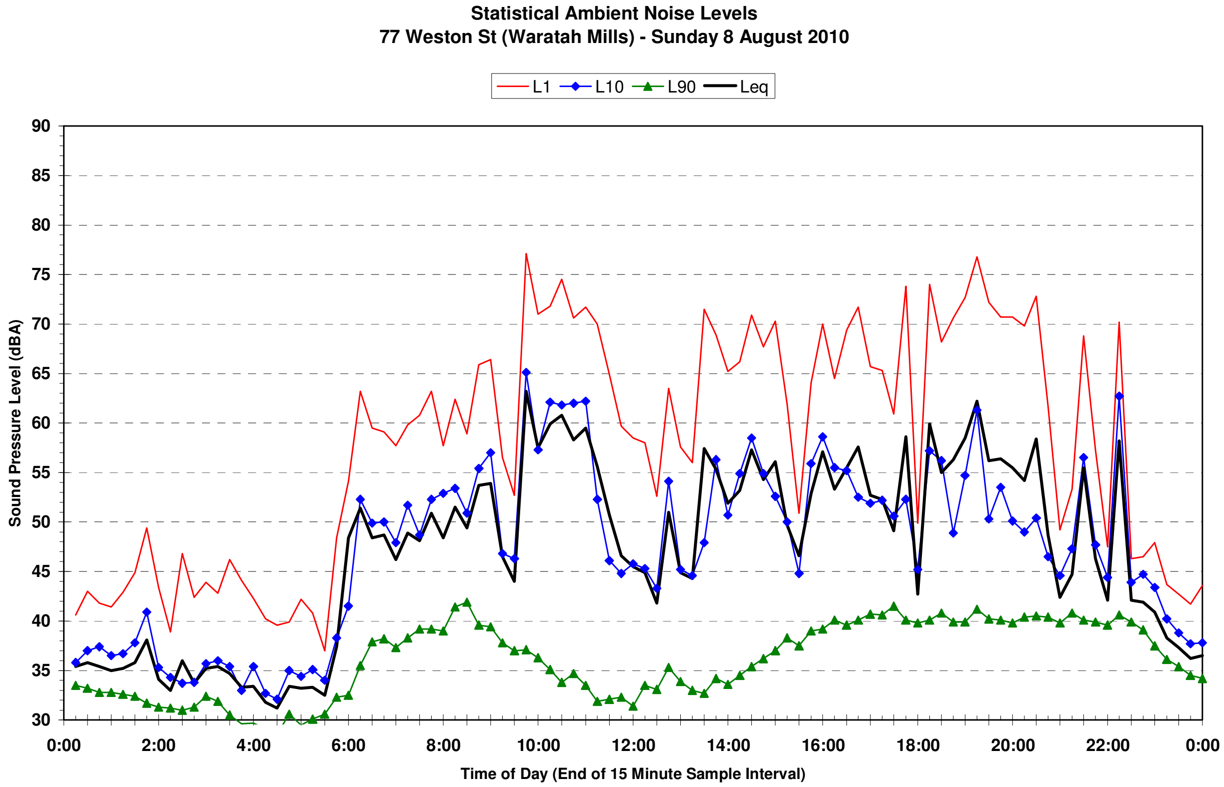


Statistical Ambient Noise Levels
77 Weston St (Waratah Mills) - Friday 6 August 2010

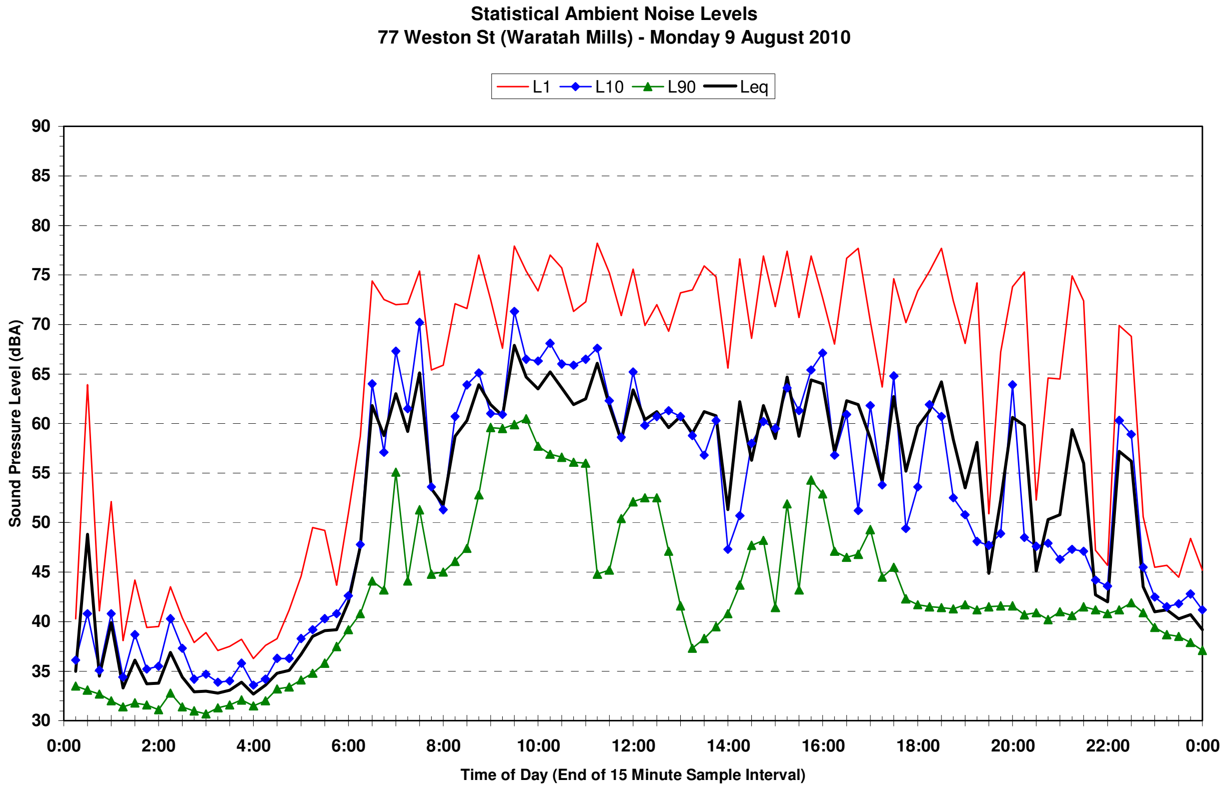


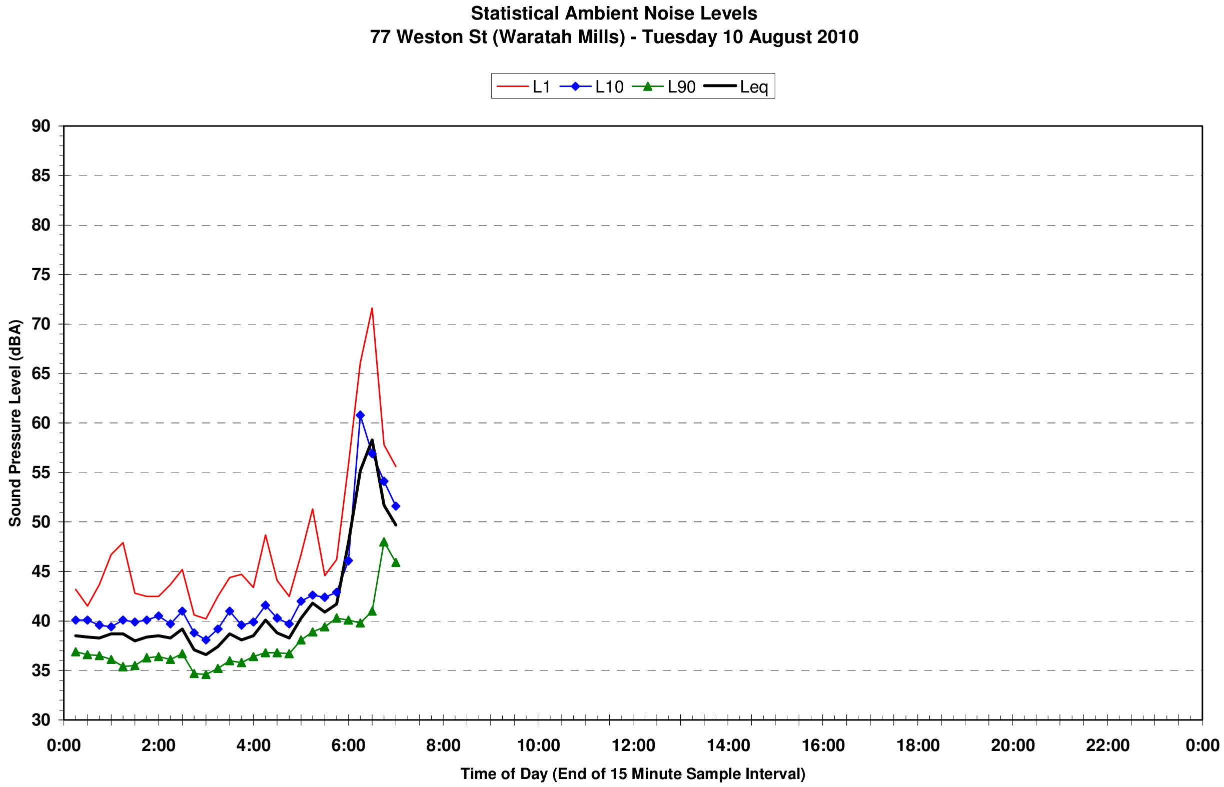
Ambient Noise Measurements



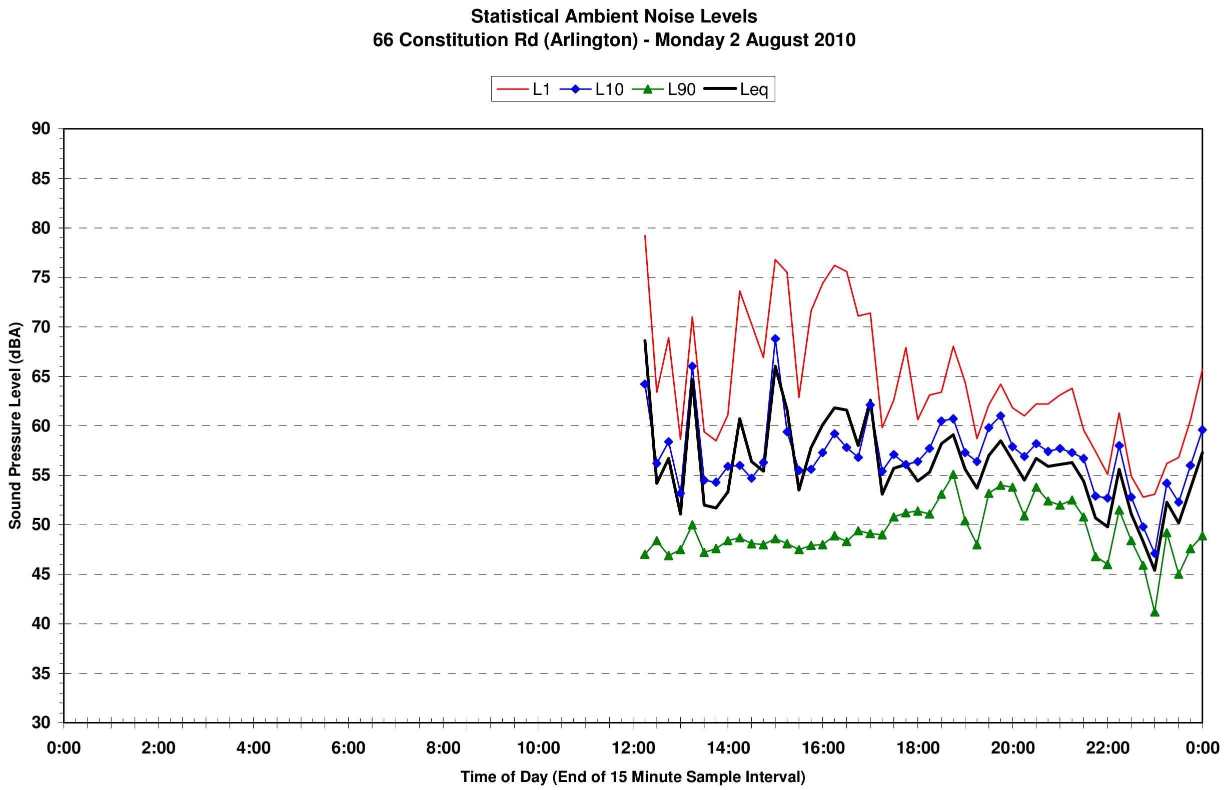


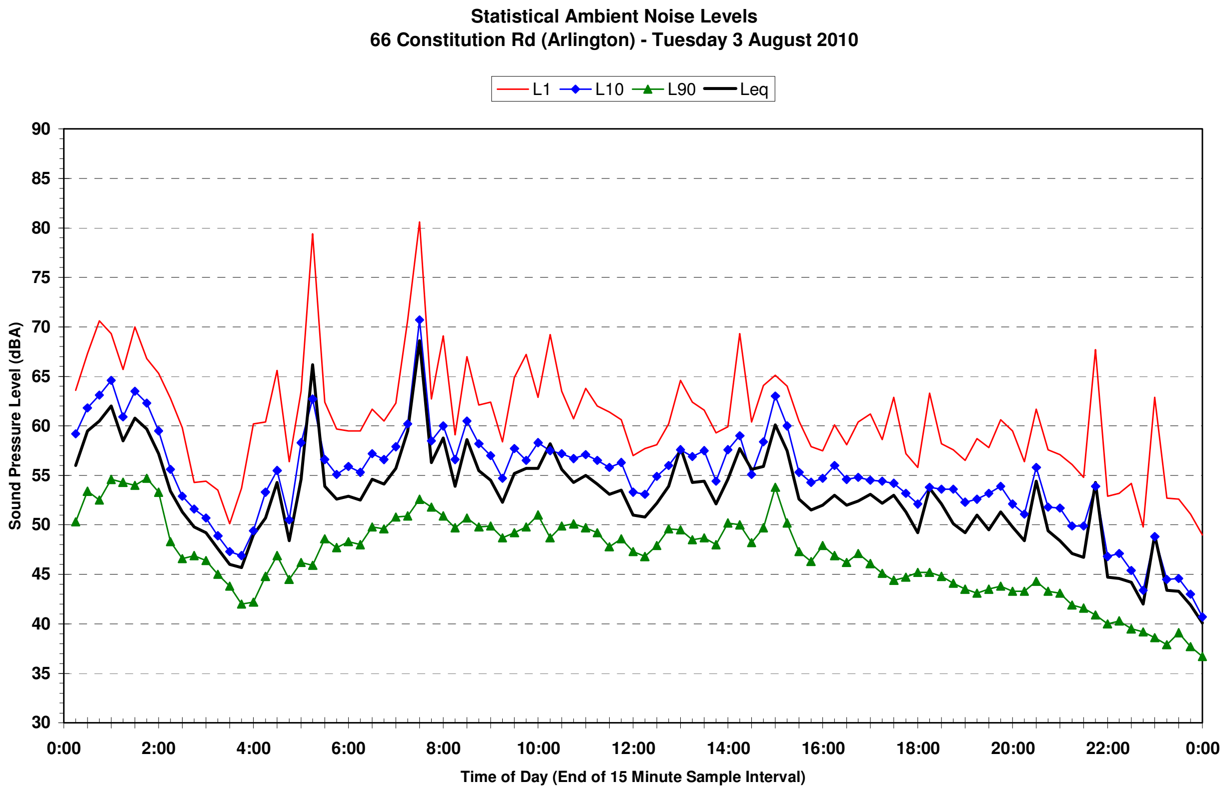
Ambient Noise Measurements



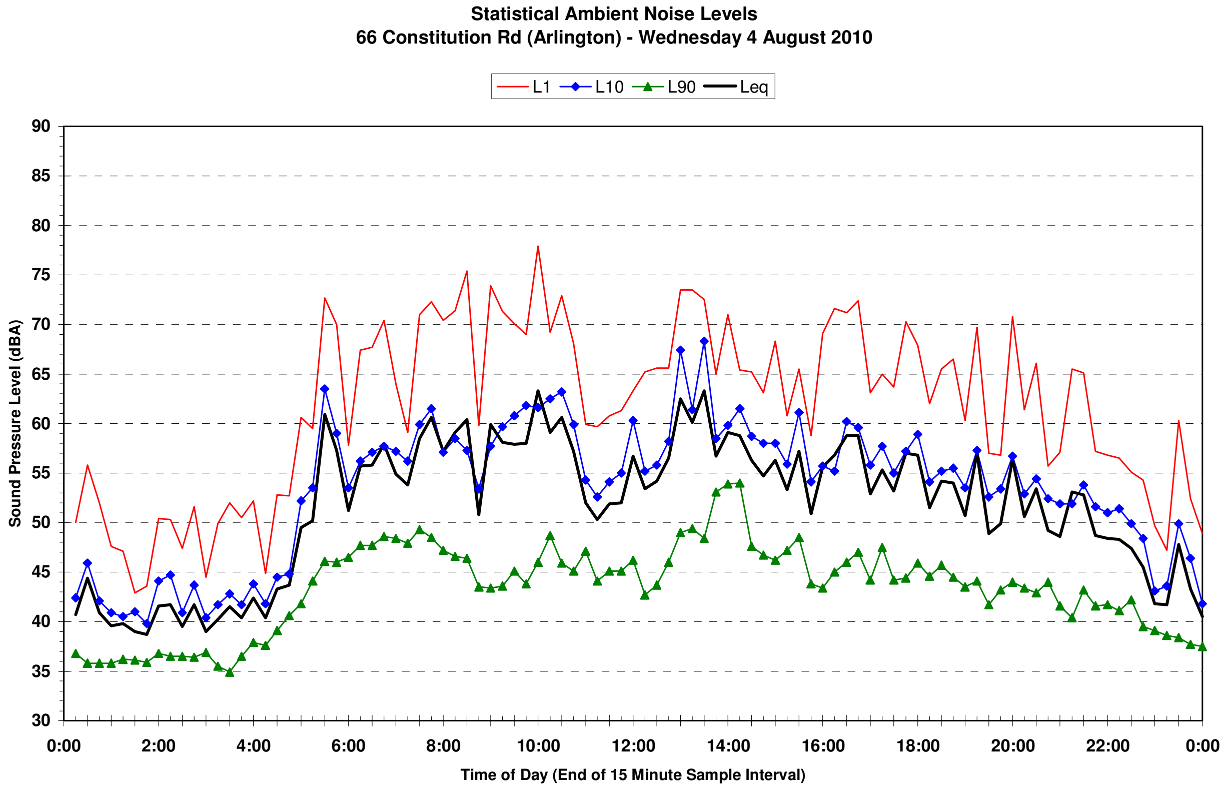


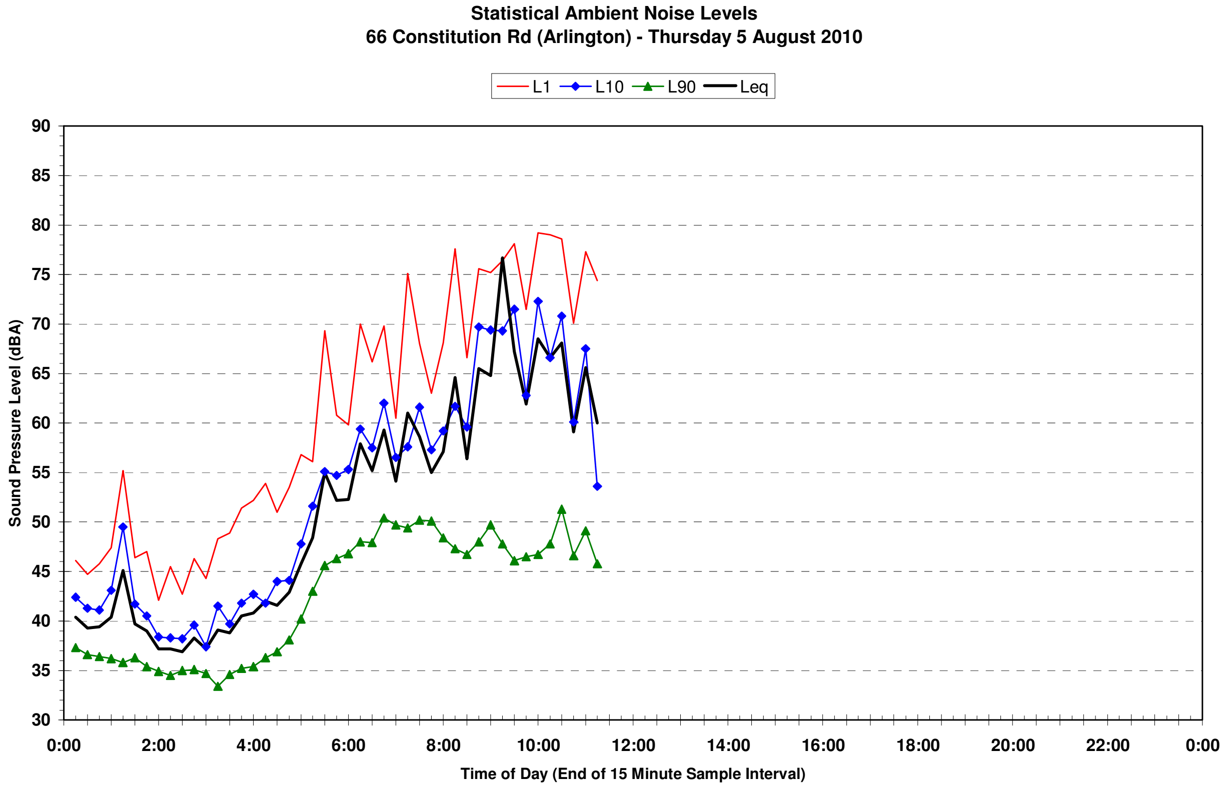
B07 – 66 Constitution Rd



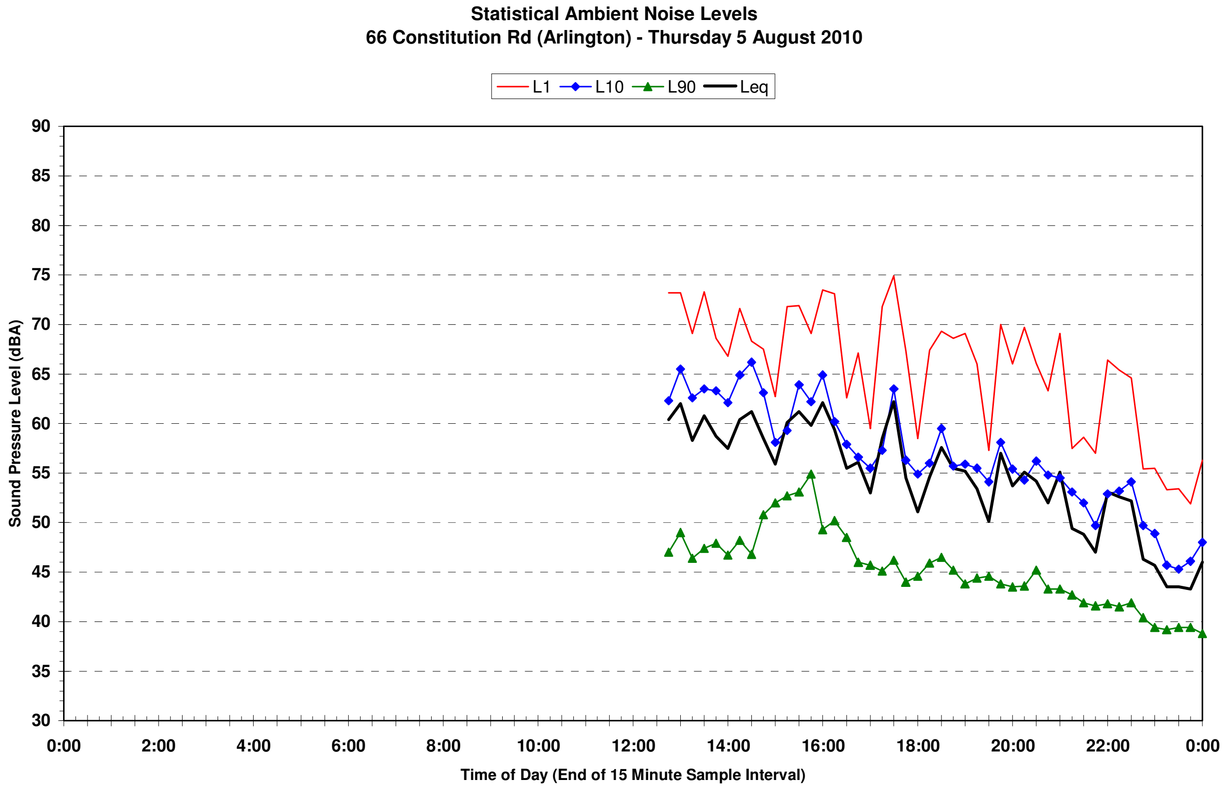


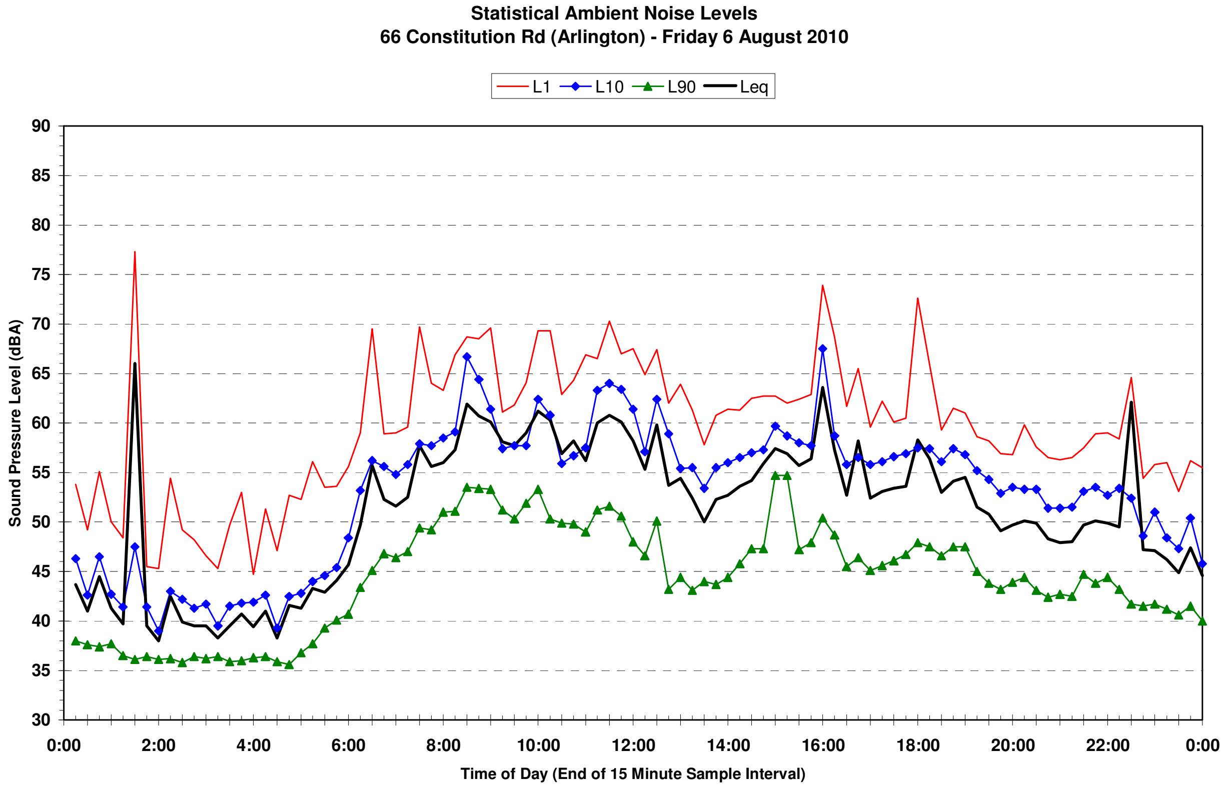
Ambient Noise Measurements



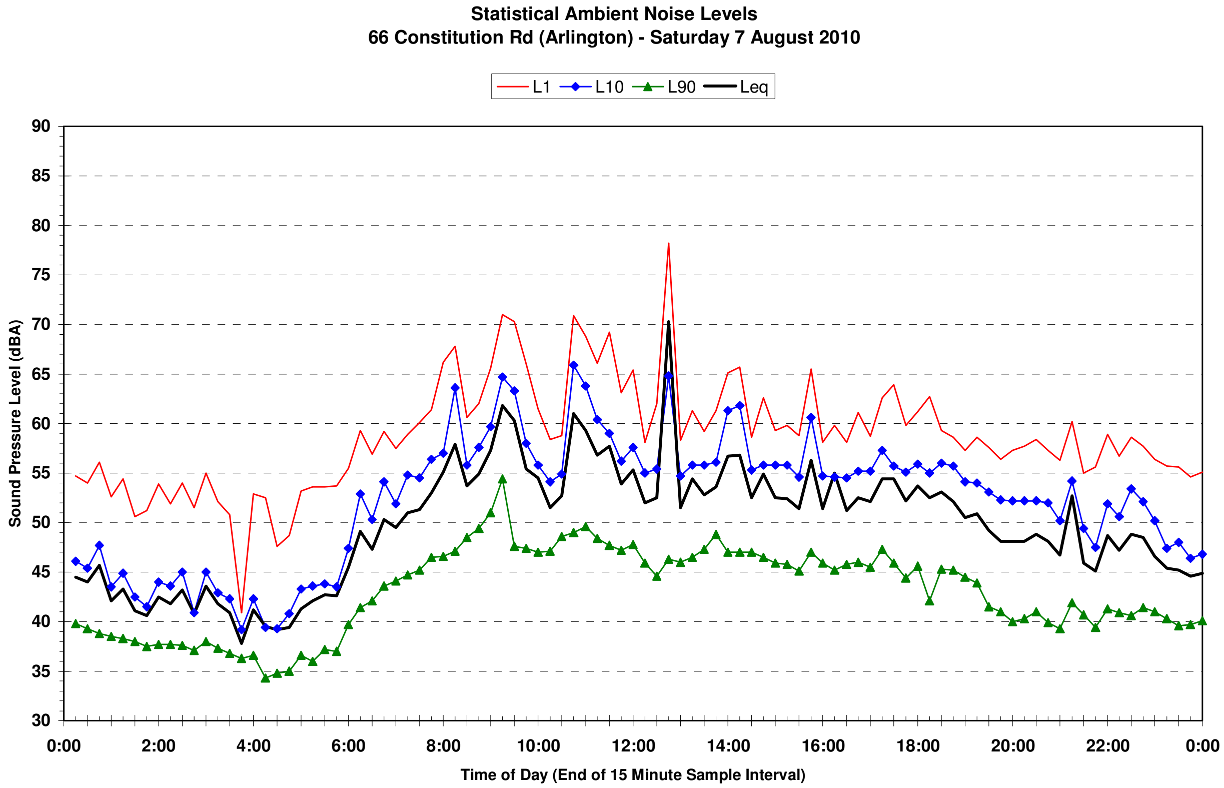


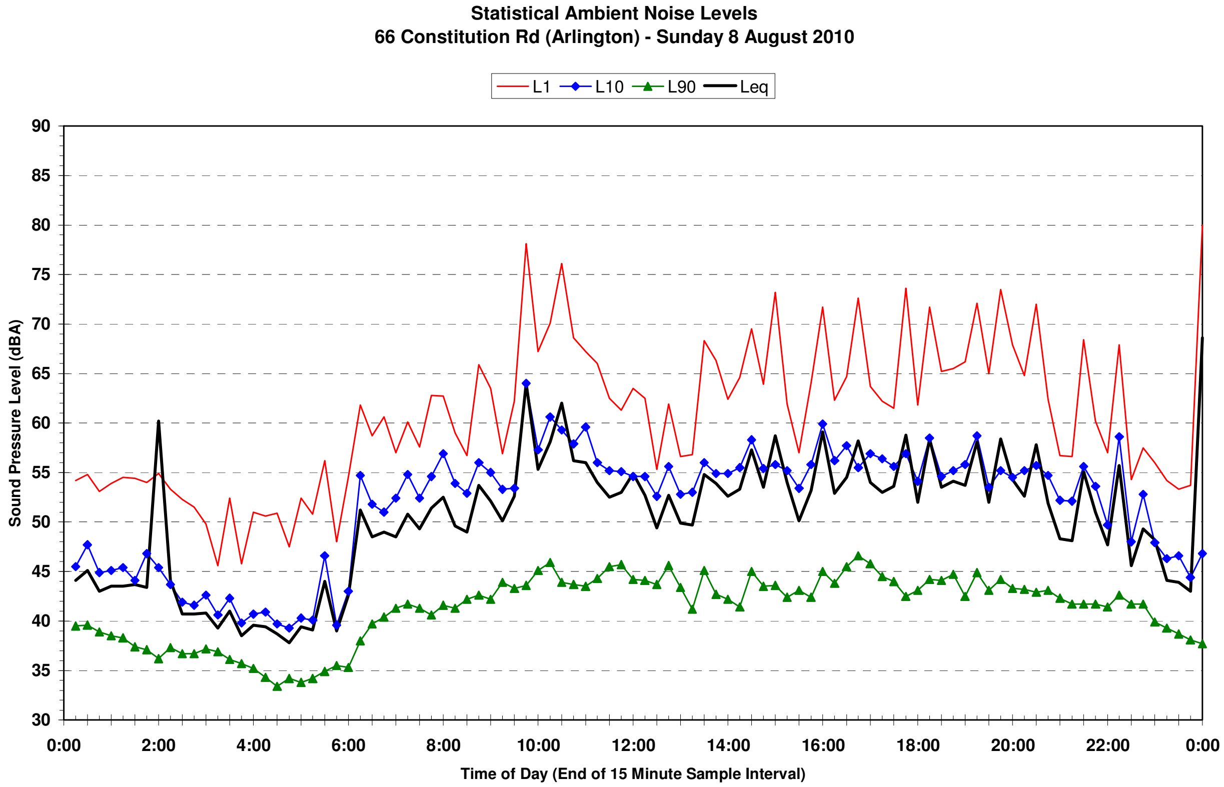
Ambient Noise Measurements



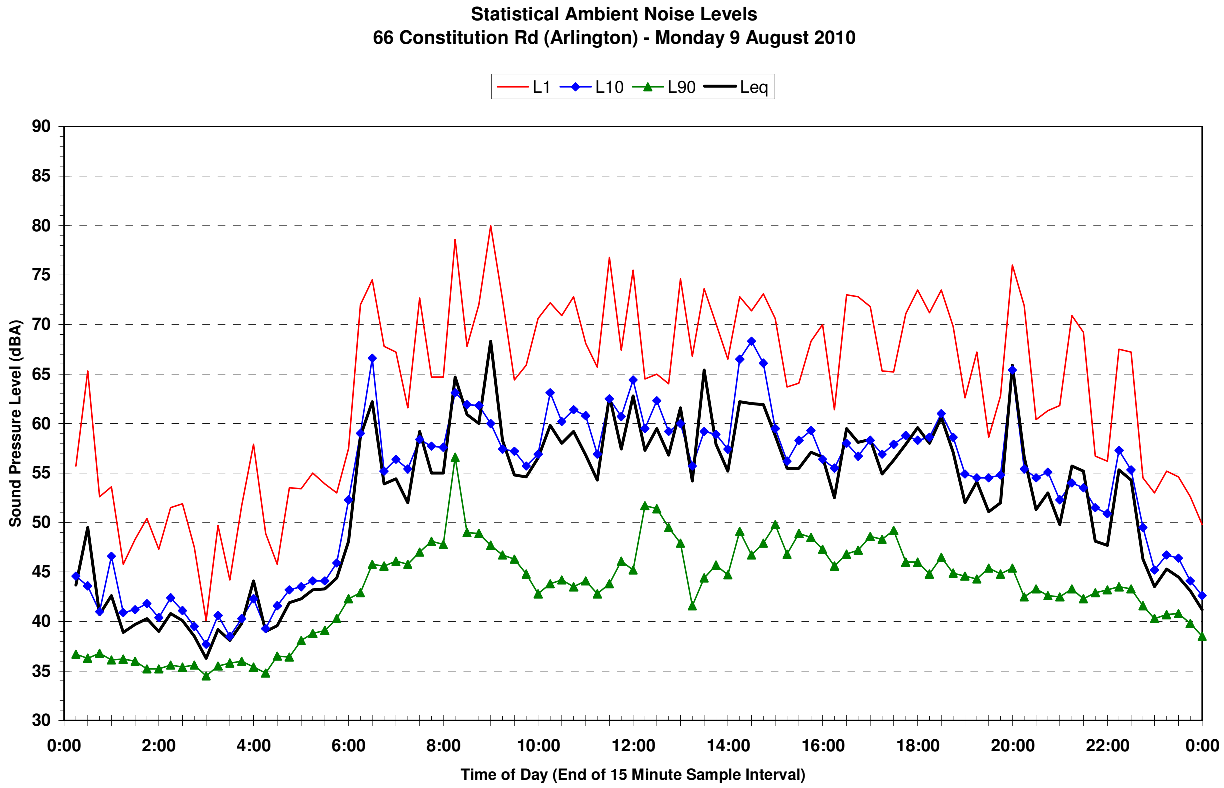


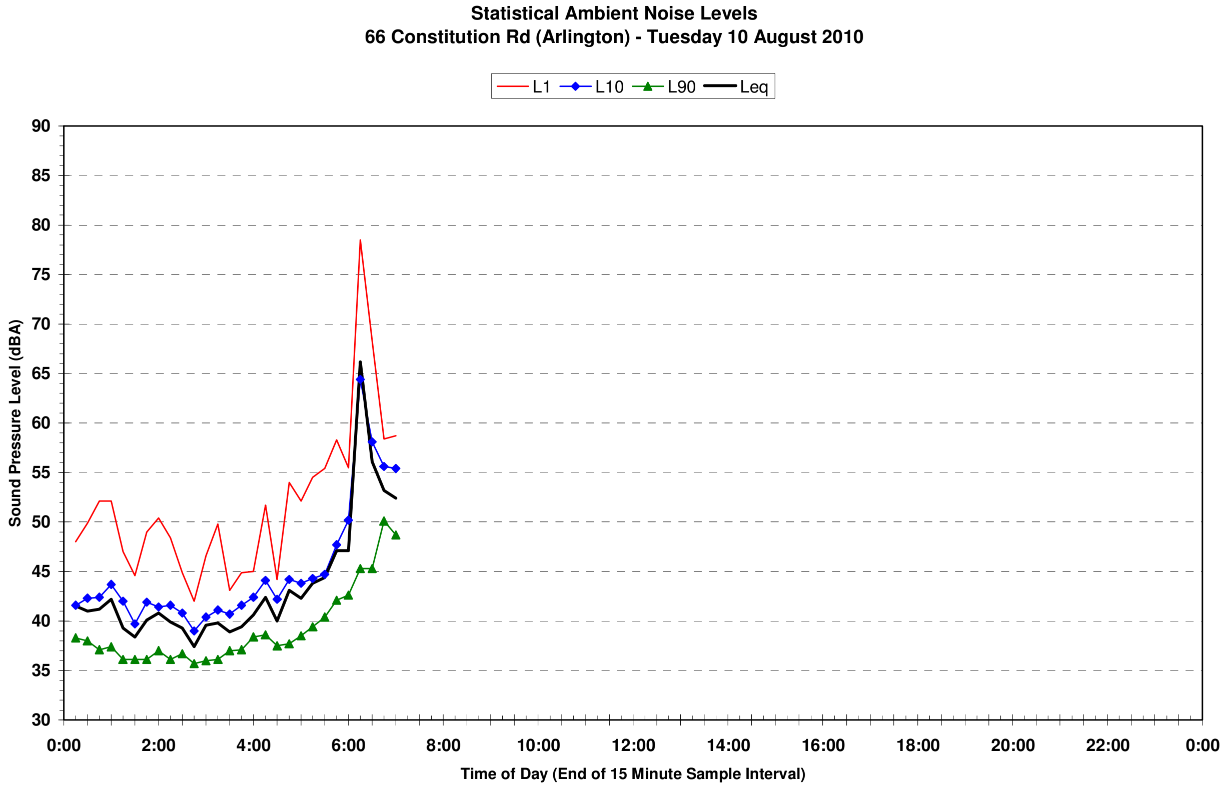
Ambient Noise Measurements



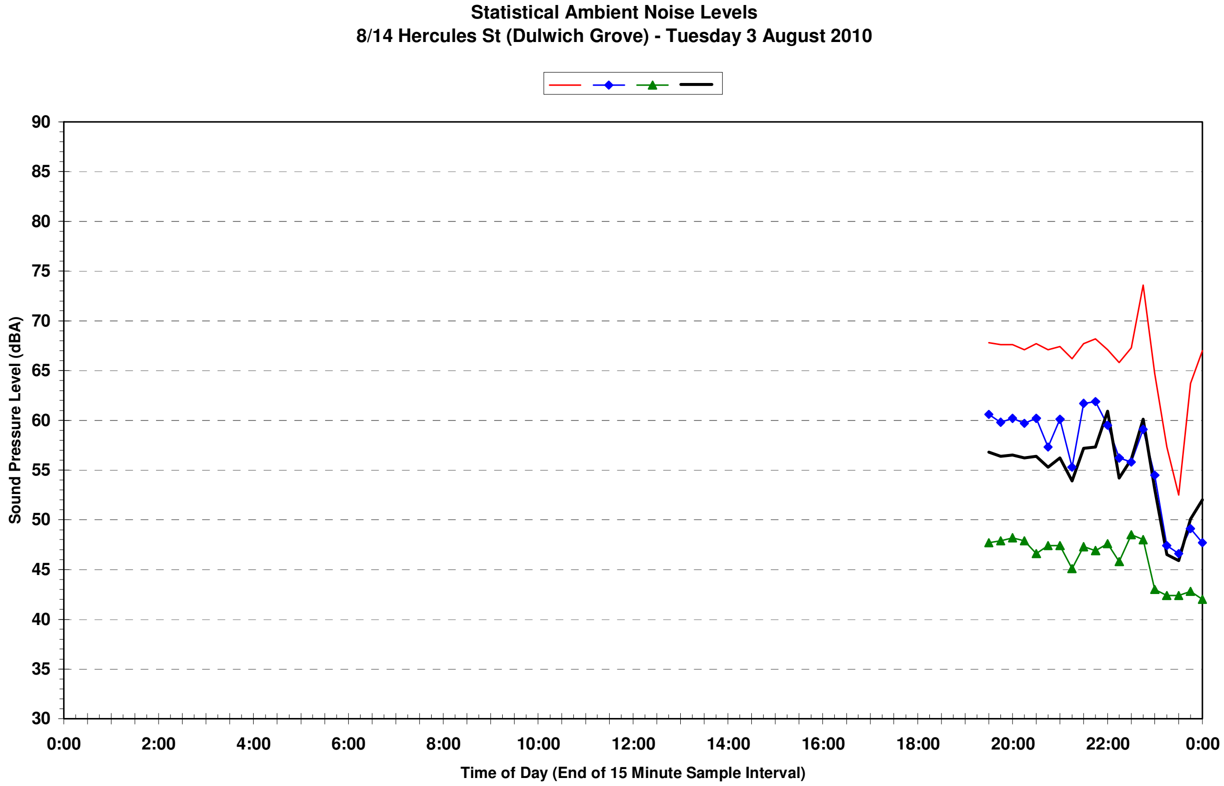


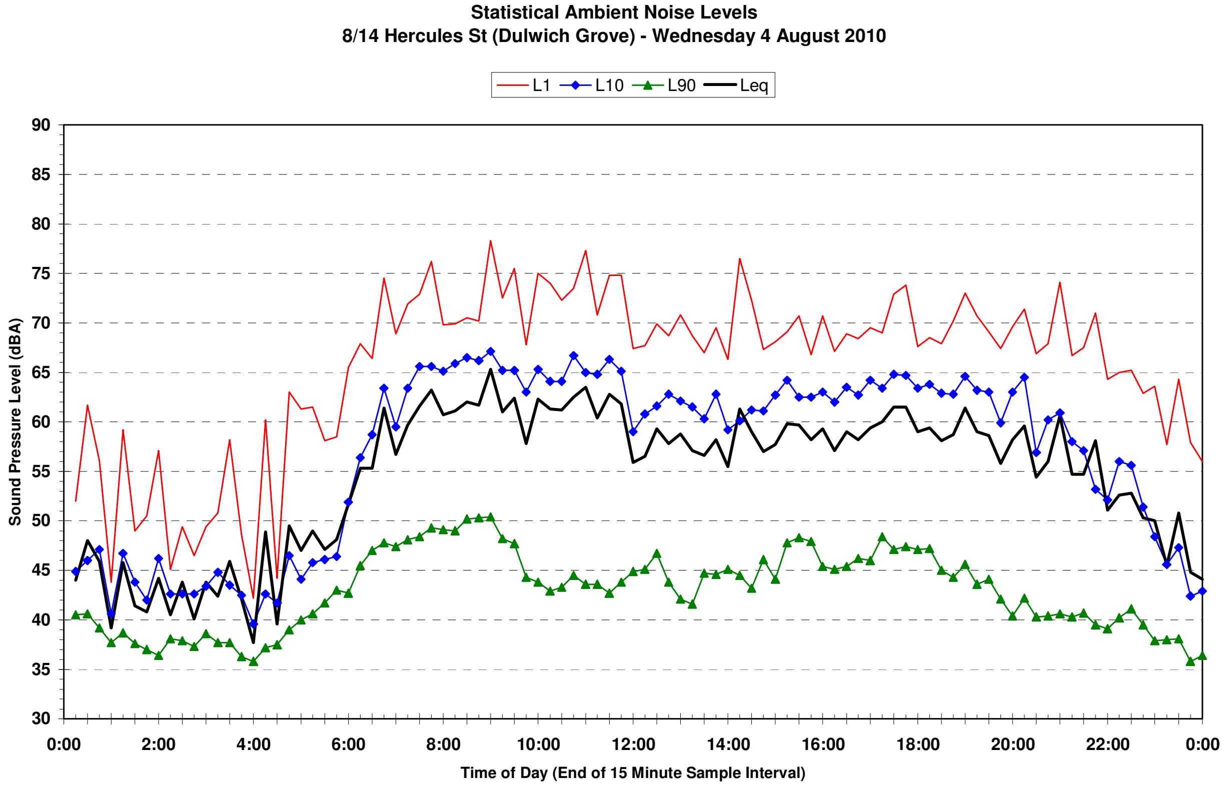
Ambient Noise Measurements

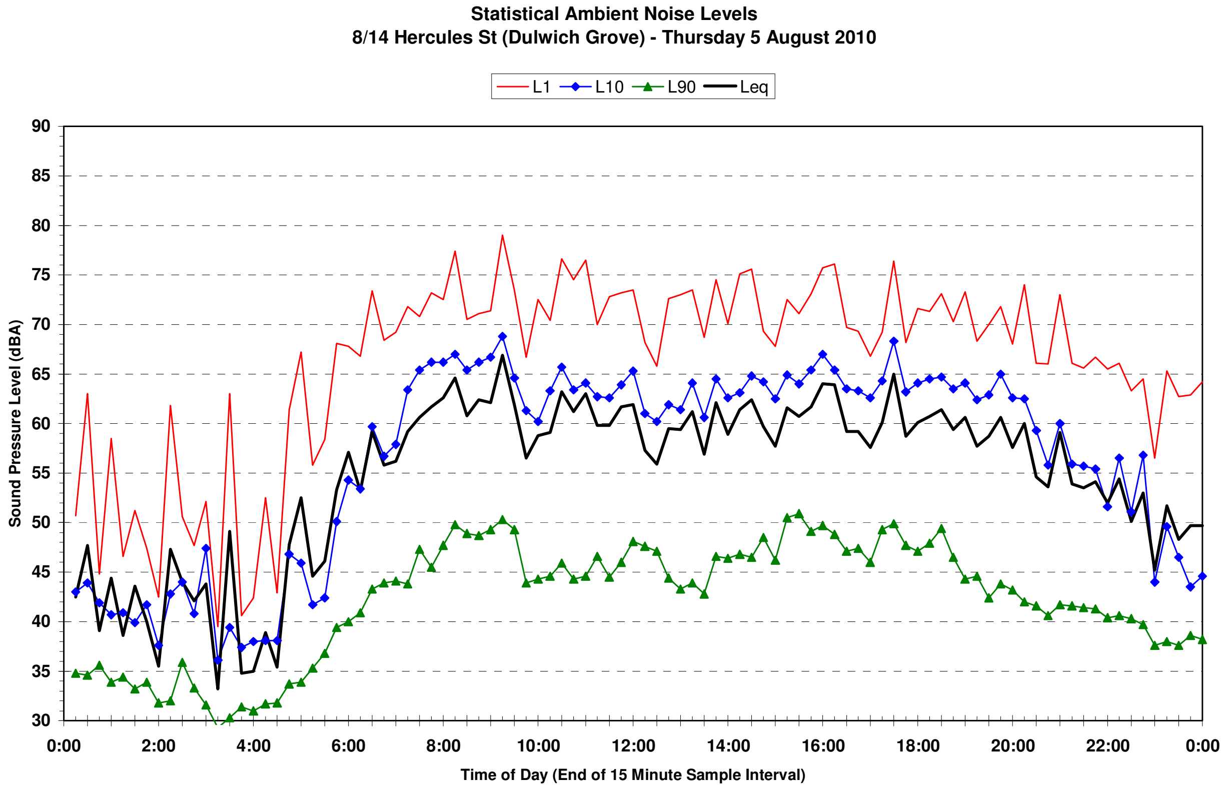




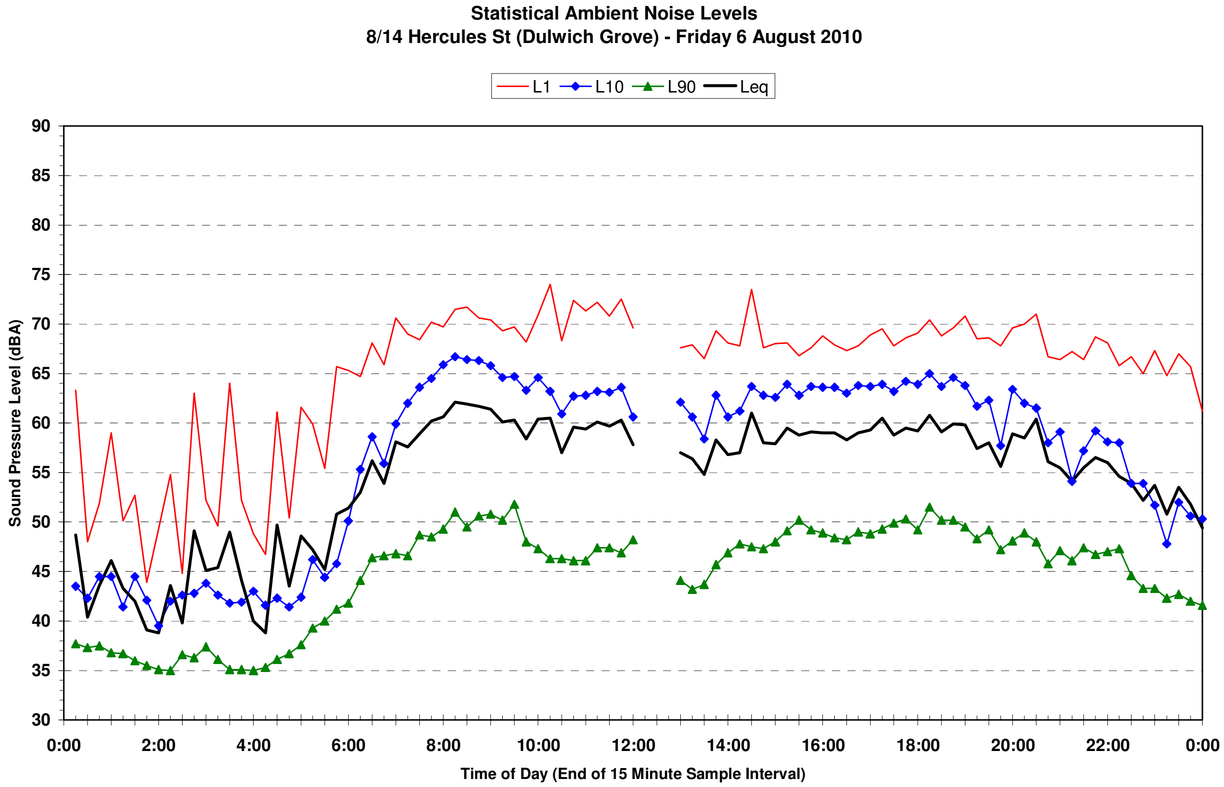
B08 – 8/14 Hercules St





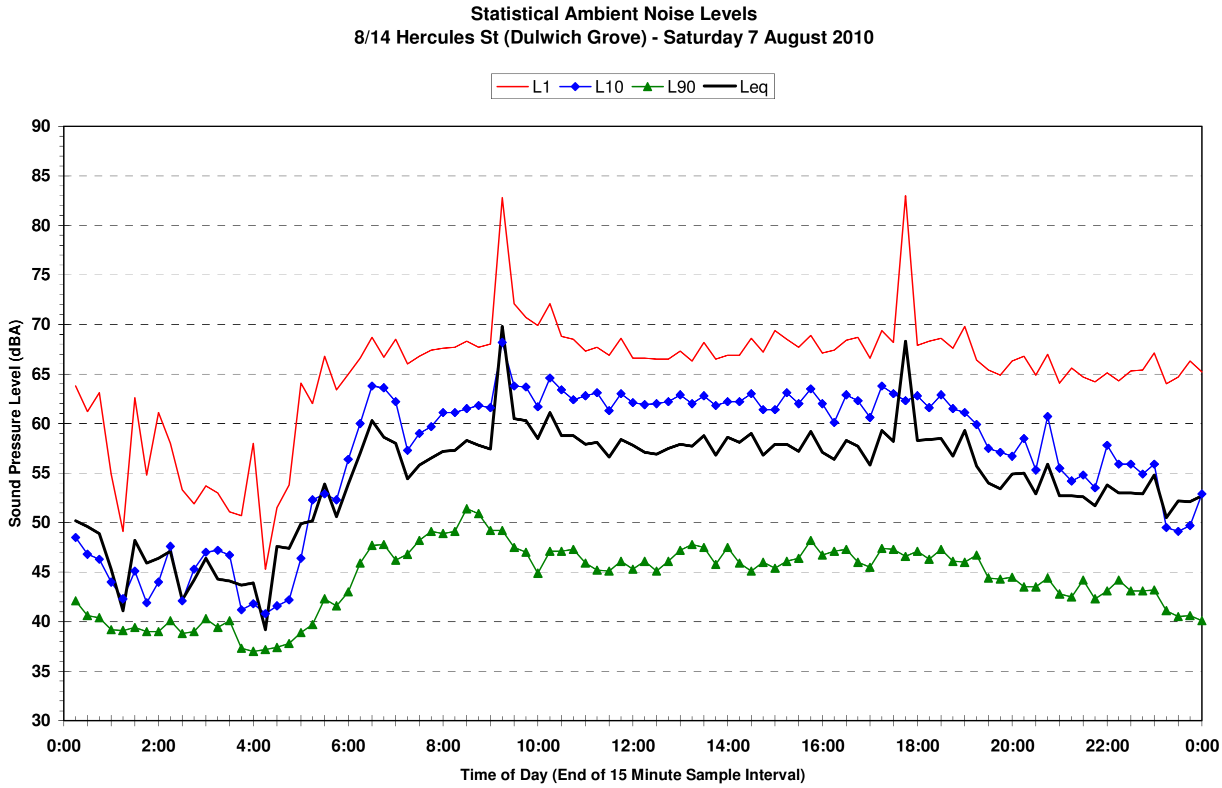


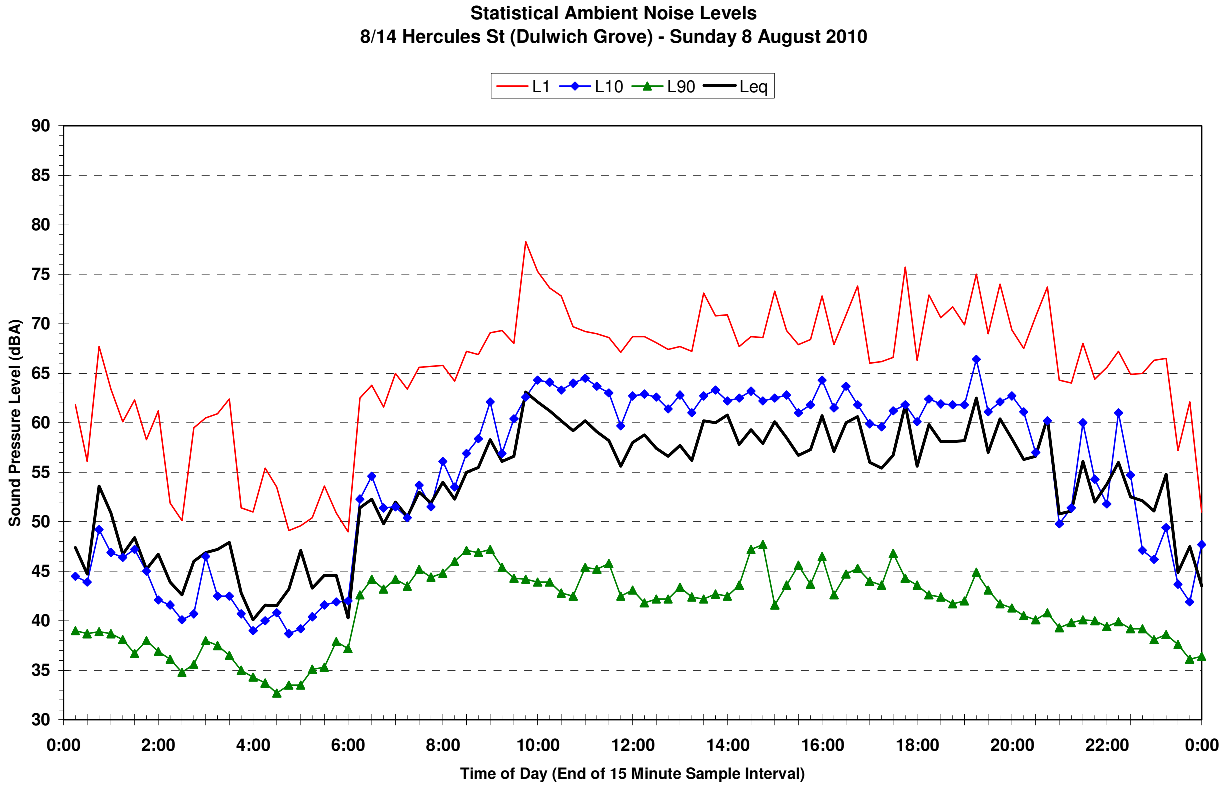
Statistical Ambient Noise Levels
8/14 Hercules St (Dulwich Grove) - Thursday 5 August 2010
L1
L10
L90
Leq
Sound Pressure Level (dBA)
90
85
80
75
70
65
60
55
50
45
40
35
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Time of Day (End of 15 Minute Sample Interval)



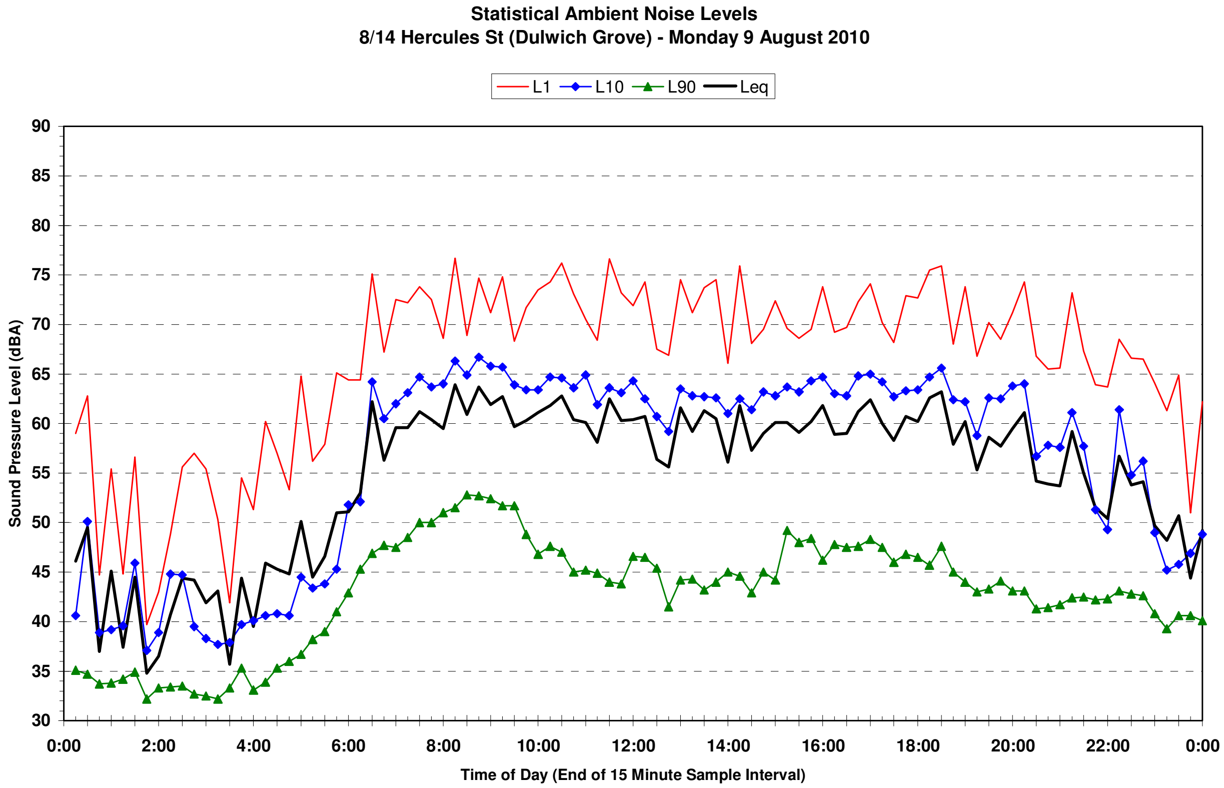
Statistical Ambient Noise Levels
8/14 Hercules St (Dulwich Grove) - Friday 6 August 2010
L1
L10
L90
Leq
Sound Pressure Level (dBA)
90
85
80
75
70
65
60
55
50
45
40
35
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Time of Day (End of 15 Minute Sample Interval)

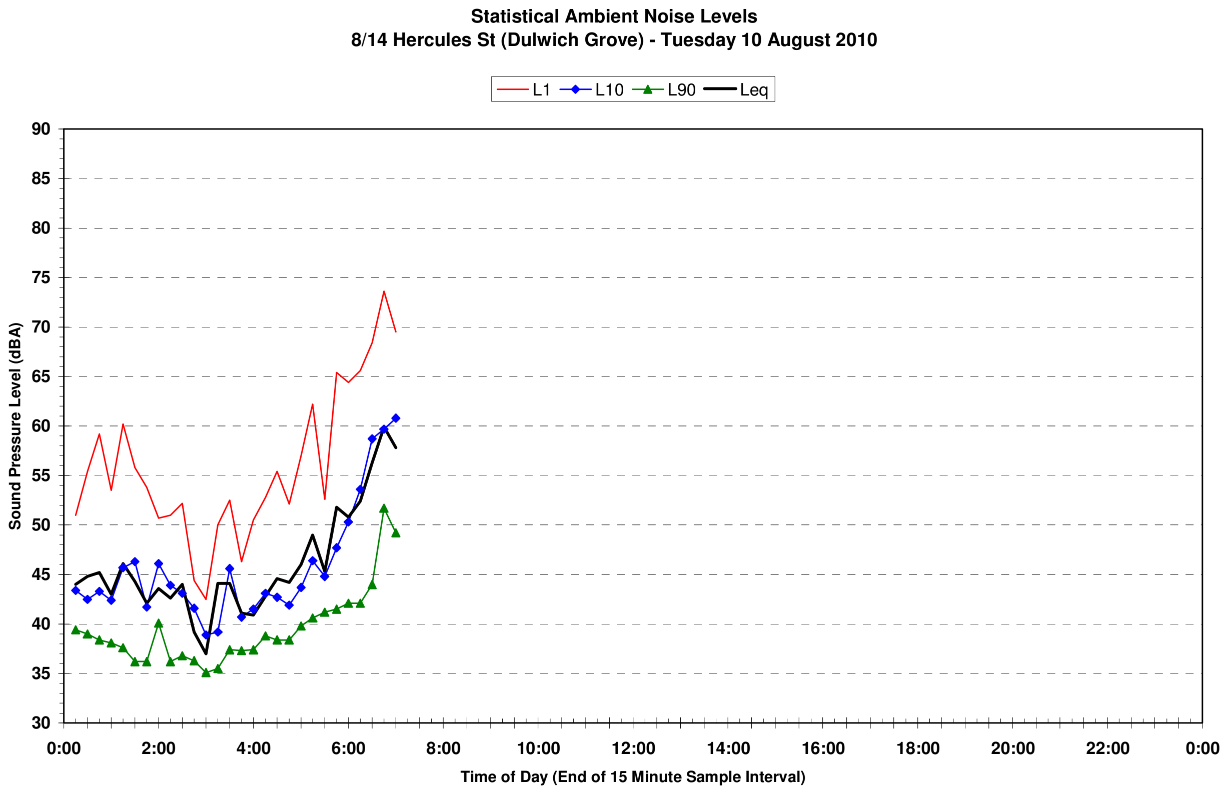
Ambient Noise Measurements



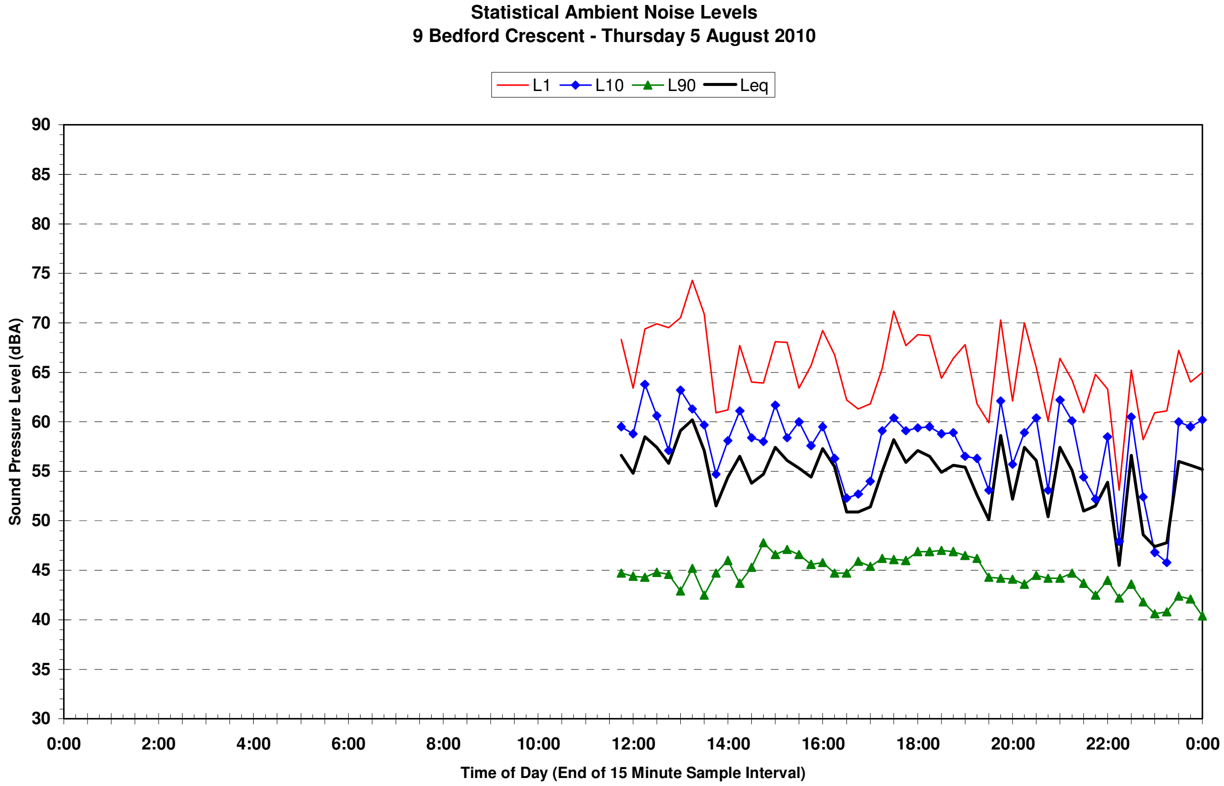


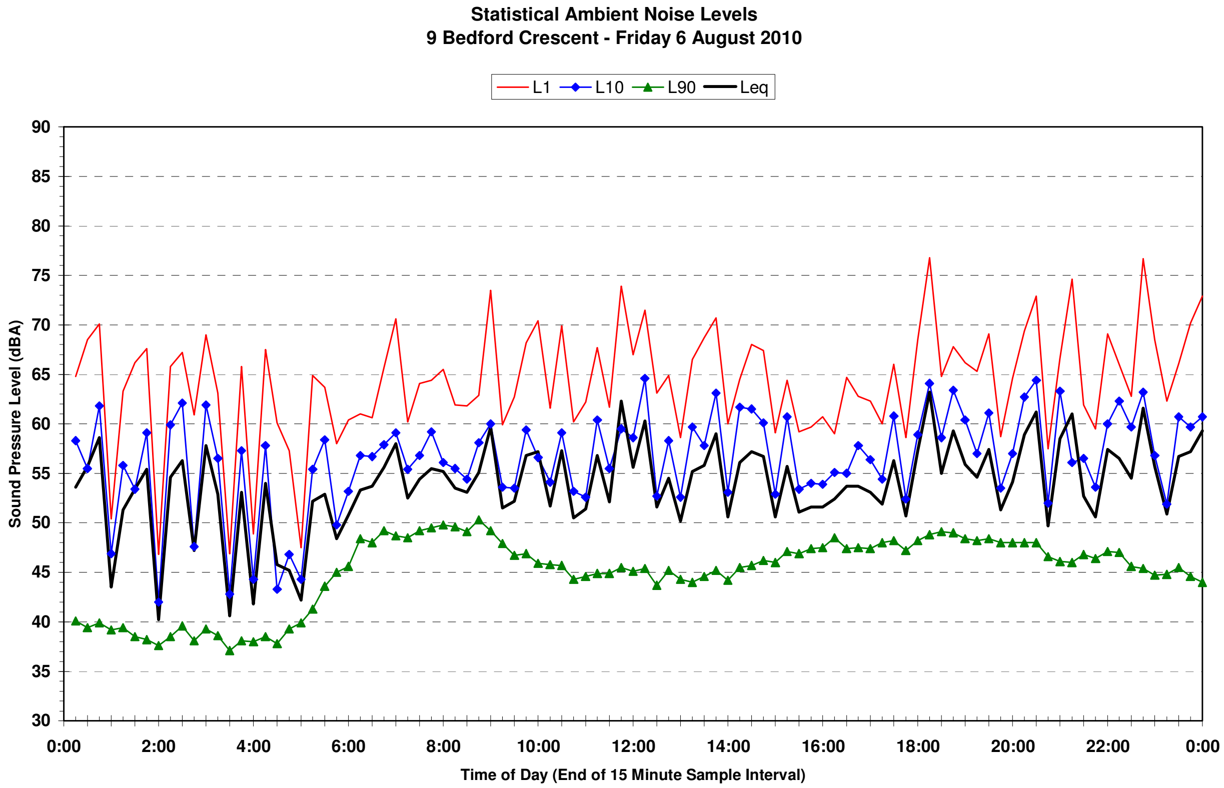
Ambient Noise Measurements





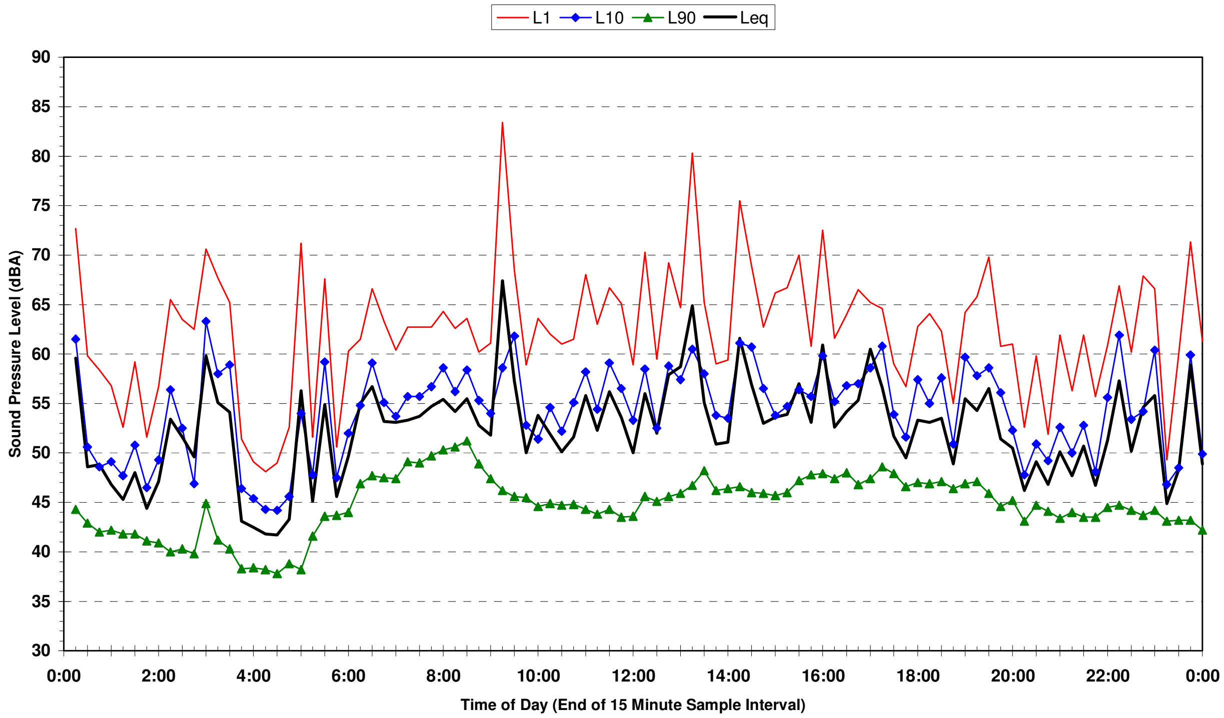
B09 – 9 Bedford Cr



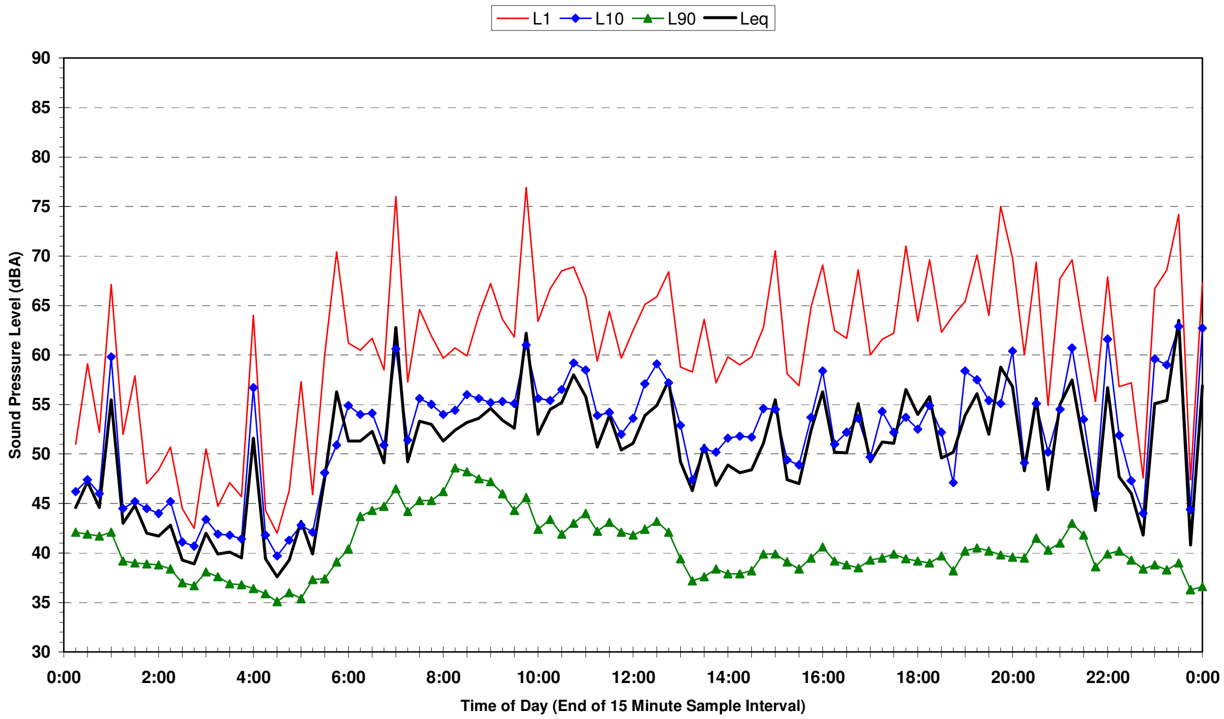


Ambient Noise Measurements

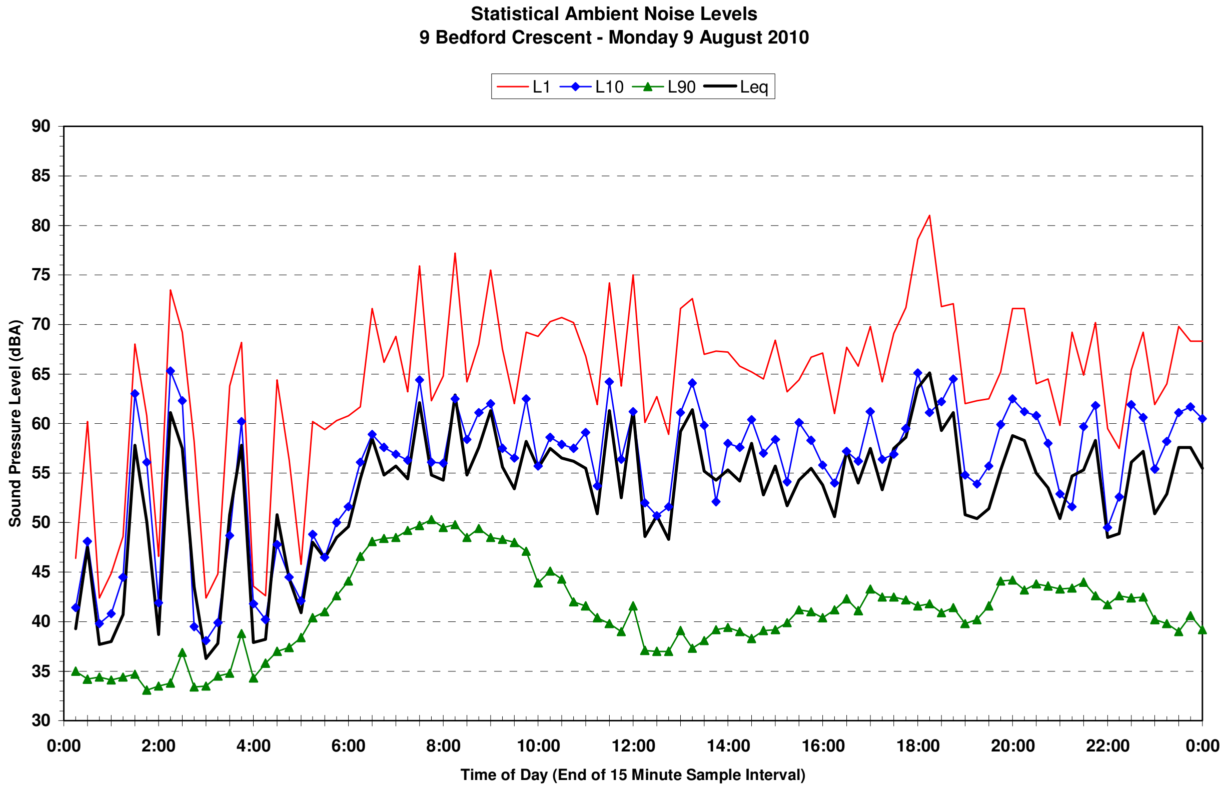
Statistical Ambient Noise Levels
9 Bedford Crescent - Saturday 7 August 2010

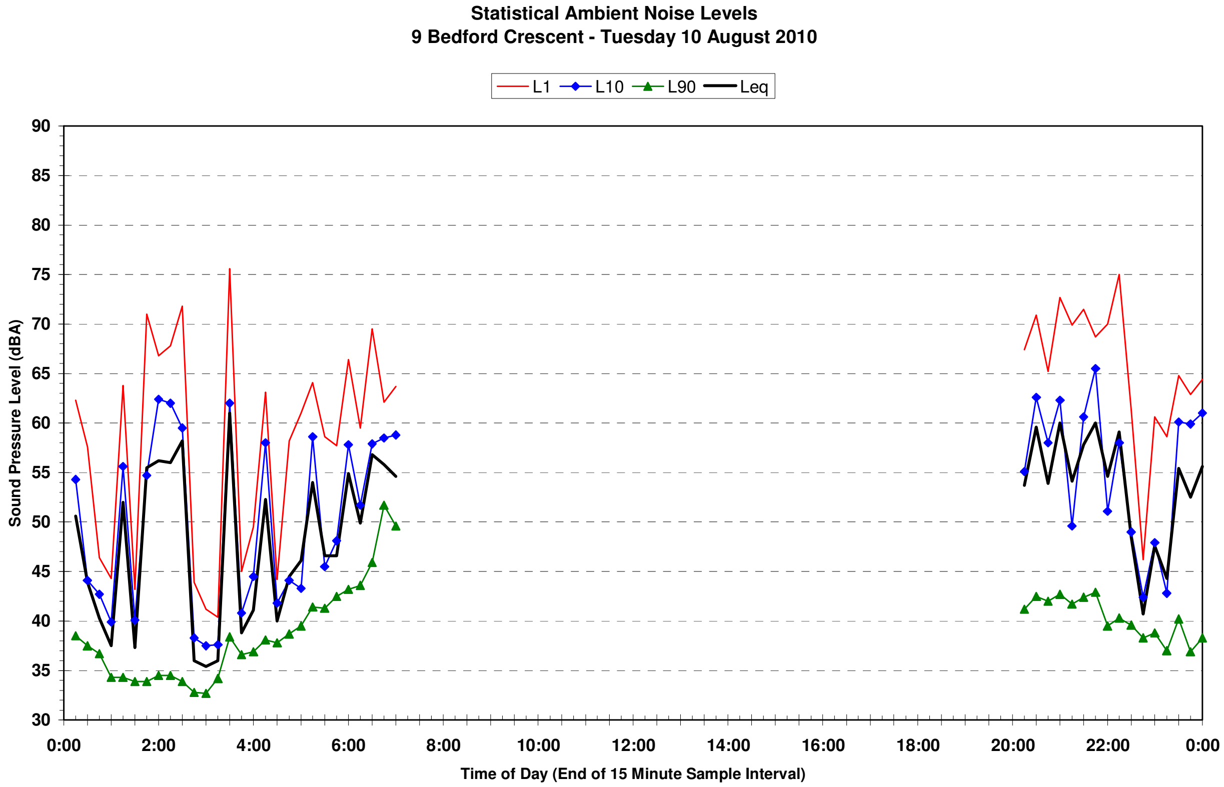


Statistical Ambient Noise Levels
9 Bedford Crescent - Sunday 8 August 2010

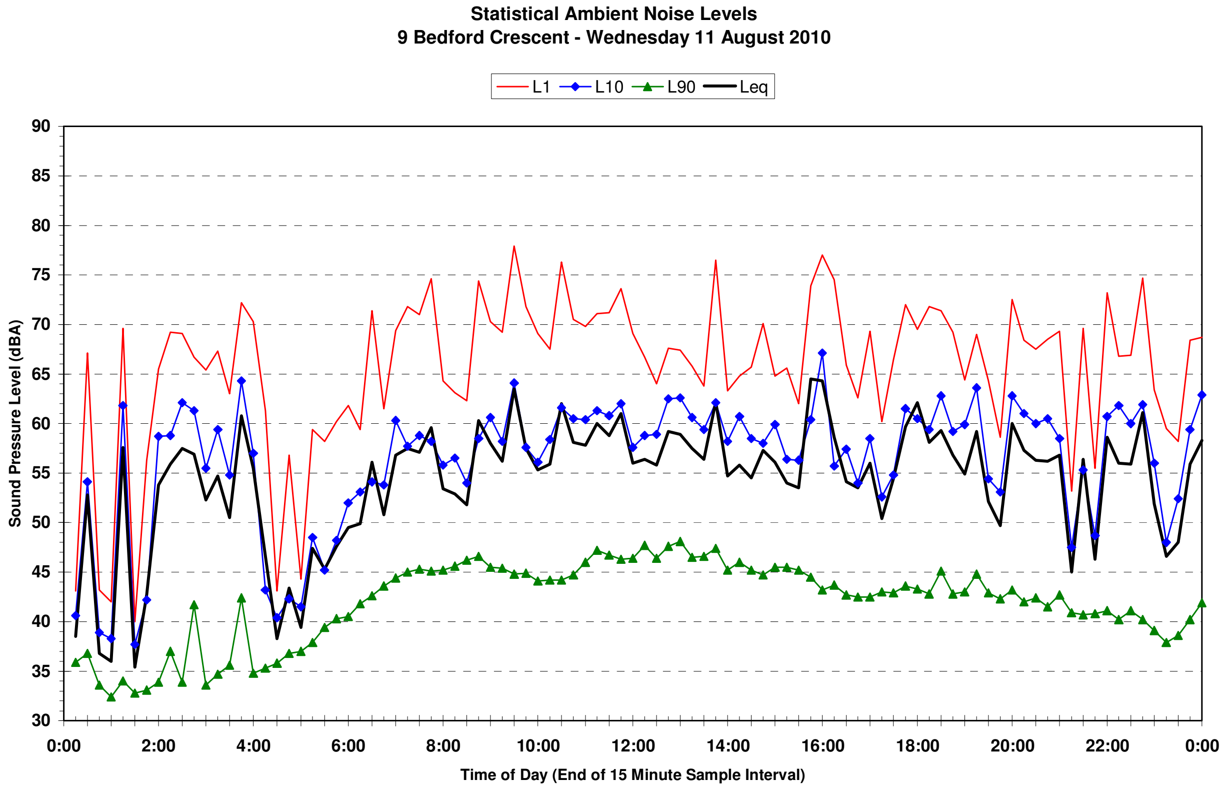


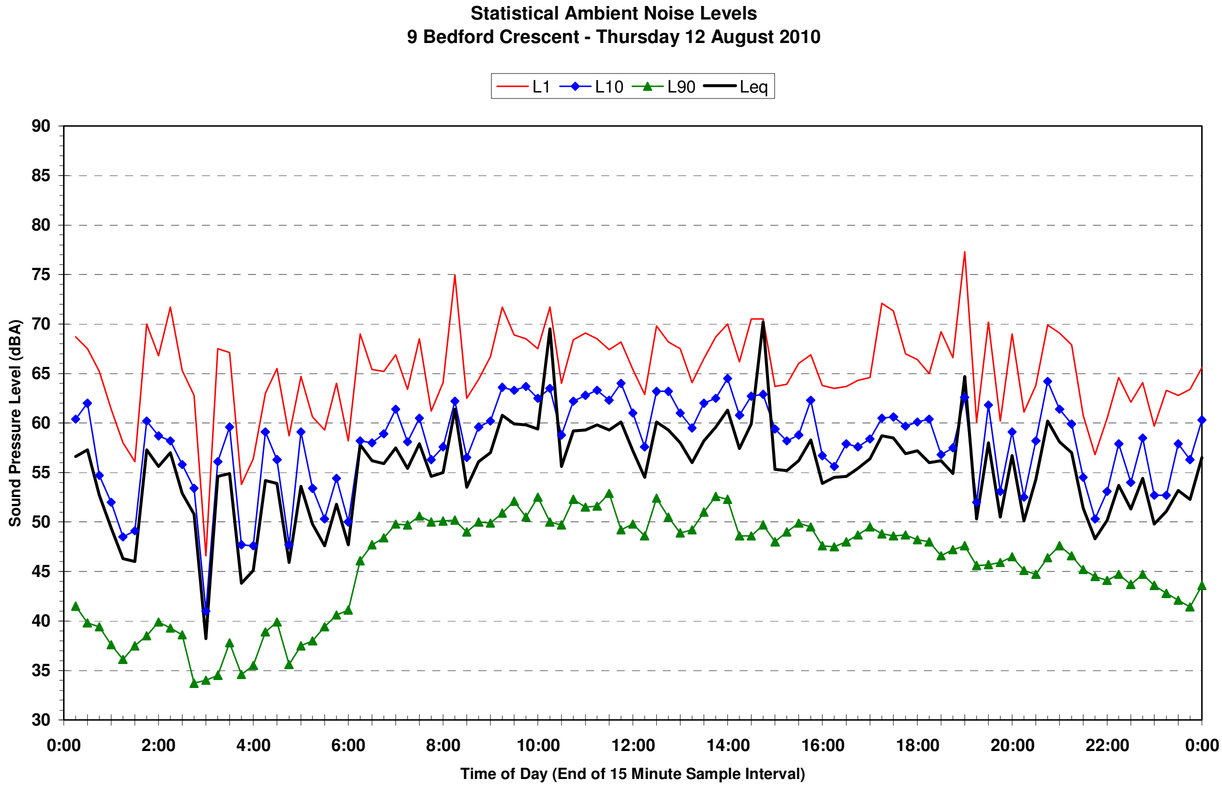
Ambient Noise Measurements

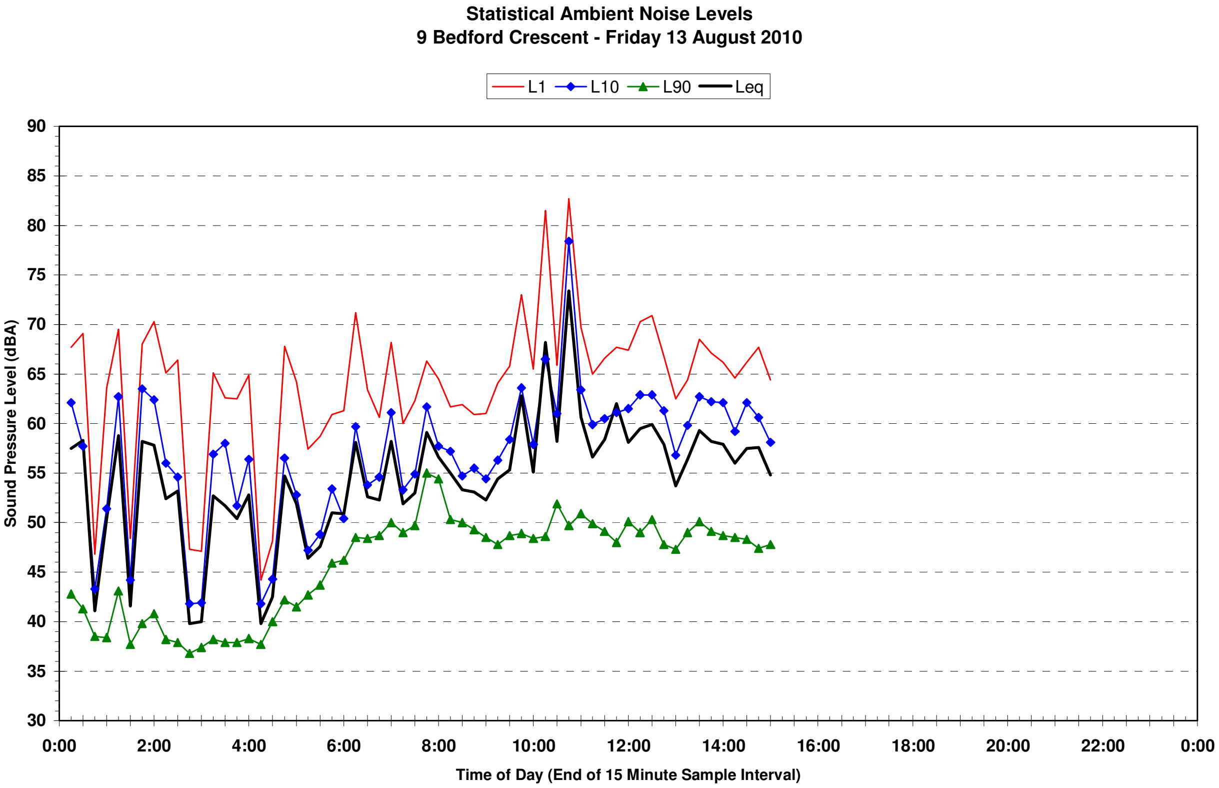




Ambient Noise Measurements






Statistical Ambient Noise Levels
9 Bedford Crescent - Friday 13 August 2010
L1
L10
L90
Leq
Sound Pressure Level (dBA)
90
85
80
75
70
65
60
55
50
45
40
35
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Time of Day (End of 15 Minute Sample Interval)