Sapphire Solar Farm

Environmental Impact Statement

Volume 3 - Appendices

Appendix G
Noise Assessment

Acoustic Consulting

Sapphire Solar Farm

Construction and Operational

Noise and Vibration Assessment Report

Prepared for Eco Logical Australia Pty Ltd
Report Reference: 17SYA0057 R01_0 SEARS Acoustic Report

About TTM

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Revision Record

No.	Author	Reviewed/Approved	Description	Date
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3.				
4.				
5.				

Executive Summary

TTM conducted a construction noise and vibration, and operational noise impact assessment for a proposed Sapphire Solar Farm project, 30 km east of Inverell, NSW for Eco Logical Australia Pty Ltd. The report is required to satisfy the NSW Department of Planning and Environment's Secretary's Environmental Assessment Requirements (SEARs) for the proposal.

Noise monitoring of existing ambient noise levels were conducted on site and construction and operational noise impact levels were predicted. Construction vibration impact was also assessed.

The assessment concluded that construction noise is expected to be audible at the identified noise sensitive receivers and there is likely to be some degree of adverse impact. A Construction Noise and Vibration Management Plan (CNVMP) is recommended to minimise the adverse impact to acceptable levels, incorporating good practice construction noise control measures and management.

The risk of vibration by the construction works onto nearby buildings showed that safe working distances for vibration causing plant are required, particularly for a vibratory roller of more than 7 tonnes.

Construction traffic on public roads has been assessed and the risk of an adverse noise impact to residential properties is considered low.

Noise generated from the operation of the solar farm showed that an adverse impact to the noise sensitive receivers is not expected.

Overall this noise assessment report has shown that noise and vibration associated with the construction and operation of the Sapphire South Solar Farm can be controlled and managed to acceptable levels.

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1 Introduction

1.1 Background

TTM Consulting has been engaged by Eco Logical Australia Pty Ltd to conduct a construction noise and vibration, and operational noise impact assessment for a proposed Sapphire Solar Farm project, 30 km east of Inverell, NSW. The report is required to satisfy the NSW Department of Planning and Environment's Secretary's Environmental Assessment Requirements (SEARs) for the proposal.

The assessment includes the following:

- Construction noise and vibration assessment:
  - Identification of construction stages and associated activities including, specialised machinery and equipment used during the works
  - Assessment in accordance with the NSW Interim Construction Noise Guideline[1] (ICNG) and relevant vibration criteria, and
  - Advice on practical and appropriate in-principle noise and vibration mitigation and management, where required.
- Operational noise impact assessment:
  - Identification of the locations of the sub-stations and inverters
  - Assessment in accordance with the NSW Noise for Industry Policy (2017)[2], and
  - Advice on practical and appropriate in-principle noise mitigation and management, where required.

1.2 Scope

The report includes the following:

- Description of the development site and proposal.
- Ambient noise measurements in accordance with the NSW Noise for Industry Policy.
- Statement of assessment criteria relating to construction noise and vibration, and environmental noise emissions.
- Assessment of potential noise impact from construction noise and vibration, and operational noise on the local community.

[1] NSW Department of Environment and Climate Change (DECC) (2009), Interim Construction Noise Guideline

[2] NSW Environment Protection Authority (2017), Noise Policy for Industry

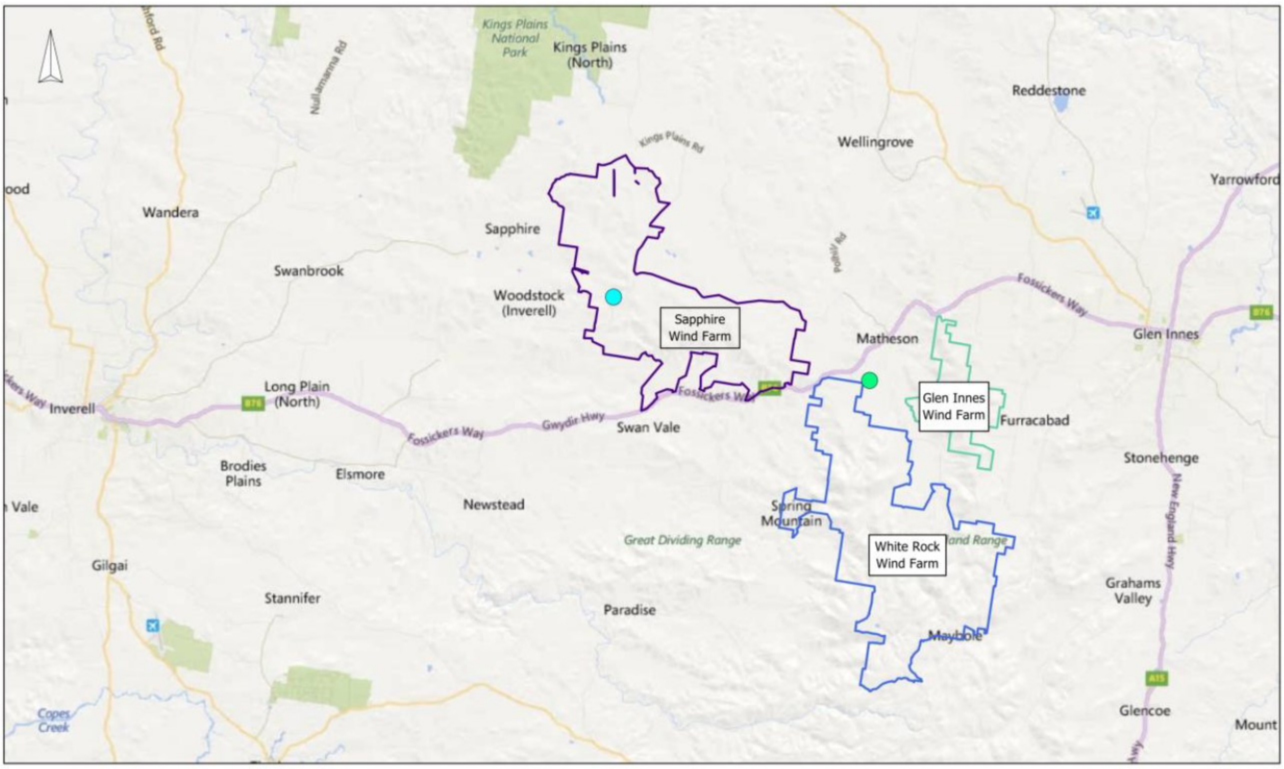
- Details of practical and appropriate in-principle noise mitigation and management measures to be incorporated to minimise any noise impact.

2 Site Description

The site is located on land, some of which include the same parcels as the Sapphire Wind Farm (SWF) project, within the Inverell Shire Local Government Area (LGA) 30km east of Inverell in northern NSW. General access to the site is from either the Gwydir Highway or Kings Plains Road with immediate access to the study area via Woodstock Road, Waterloo Road, Western Feeder Road.

The site locality is shown in Figure 1.

Figure 1: Site Locality

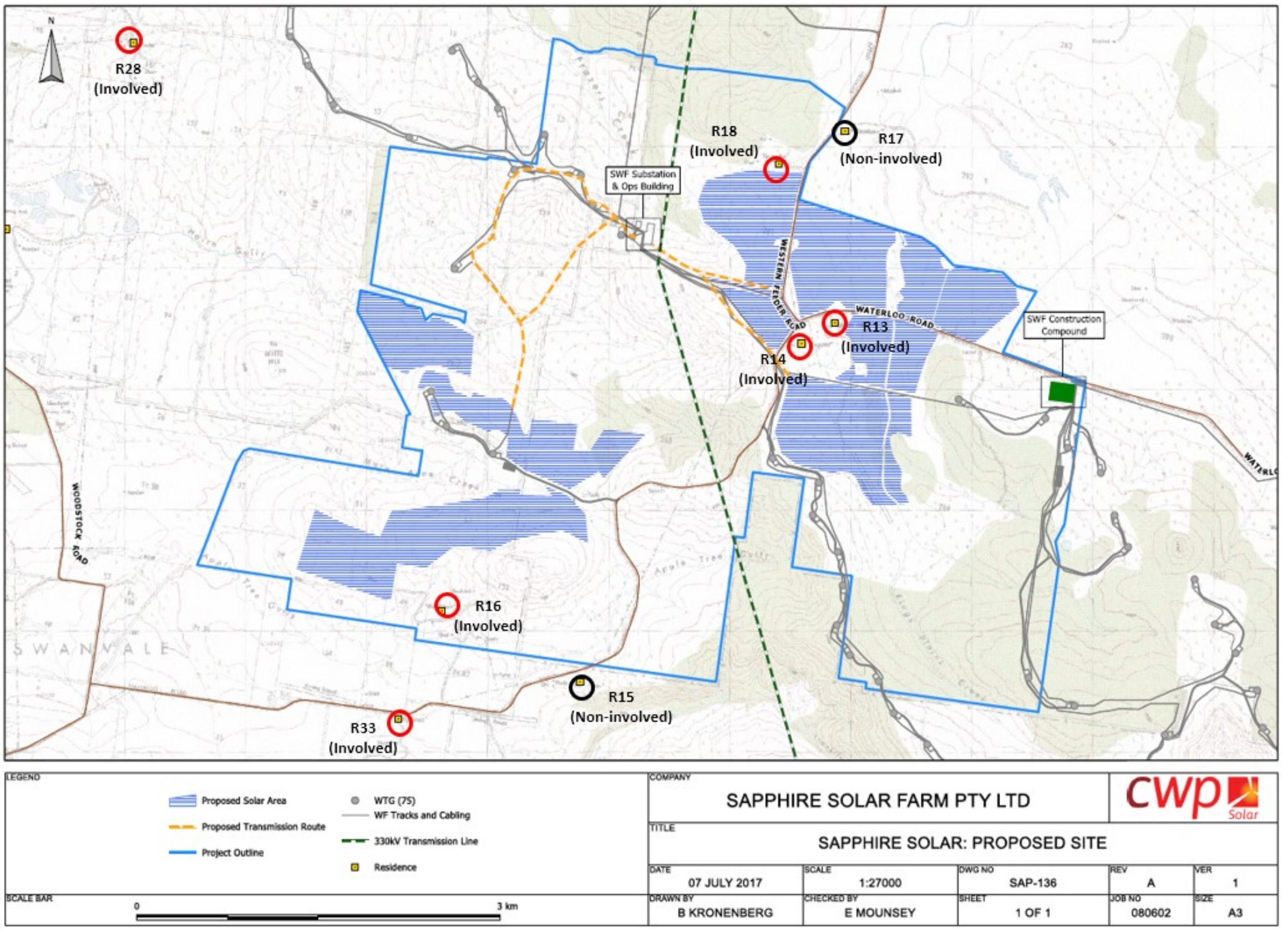


The land is currently used for grazing and/or cultivation, with some portions having previously been subject to open-cut sapphire mining and quarrying. In these areas remediation activity to restore top soil over the mined areas has concluded.

2.1 Surrounding Areas and Noise Sensitive Receivers

Surrounding land is primarily agricultural in use, with associated dwellings comprising a mix of involved and non-involved residences, totalling eight within a 2km radius of the study area. Of note, all eight residences are associated with SWF either through a host or neighbour agreement and consultation with all owners has been ongoing from inception of the proposed solar development.

Figure 2: Surrounding Areas and Noise Sensitive Receivers



2.1.1 Noise Sensitive Receivers (NSRs)

The closest residential properties (eight in total) which may be adversely impacted by noise from the construction and operation of the solar farm have been identified (Refer to Figure 2) and are as follows. Six of them are directly involved with the SSF project, while the other two are not associated with the project:

1. R18 (Involved) – Property located at approximately 60 metres from the construction site's boundary – 133 Western Feeder, Kingsland NSW 2370
2. R17 (Non-involved) – Property located at approximately 560 metres from the construction site's boundary – 176 Western Feeder, Kingsland NSW 2370

3. R13 (Involved) – Property located at approximately 80 metres from the construction site's boundary – Waterloo Rd, Woodstock NSW 2360
4. R14 (Involved) – Property located at approximately 120 metres from the construction site's boundary – 816 Waterloo Rd, Woodstock NSW 2360
5. R16 (Involved) – Property located at approximately 360 metres from the construction site's boundary – Woodstock NSW 2360
6. R15 (Non-involved) – Property located at approximately 1.2 km from the construction site's boundary – 420 Waterloo Rd, Woodstock NSW 2360
7. R33 (Involved) – Property located at approximately 1 km metres from the construction site's boundary – 260 Waterloo Rd, Woodstock NSW 2360
8. R28 (Involved) – Property located at approximately 2.8 km from the construction site's boundary – Sapphire NSW 2360

Should the derived noise limits in this report be met at the above identified NSRs with recommended noise mitigation measures, if any, compliance with the noise criteria is also expected to be met at properties located further away due to increased distance attenuation.

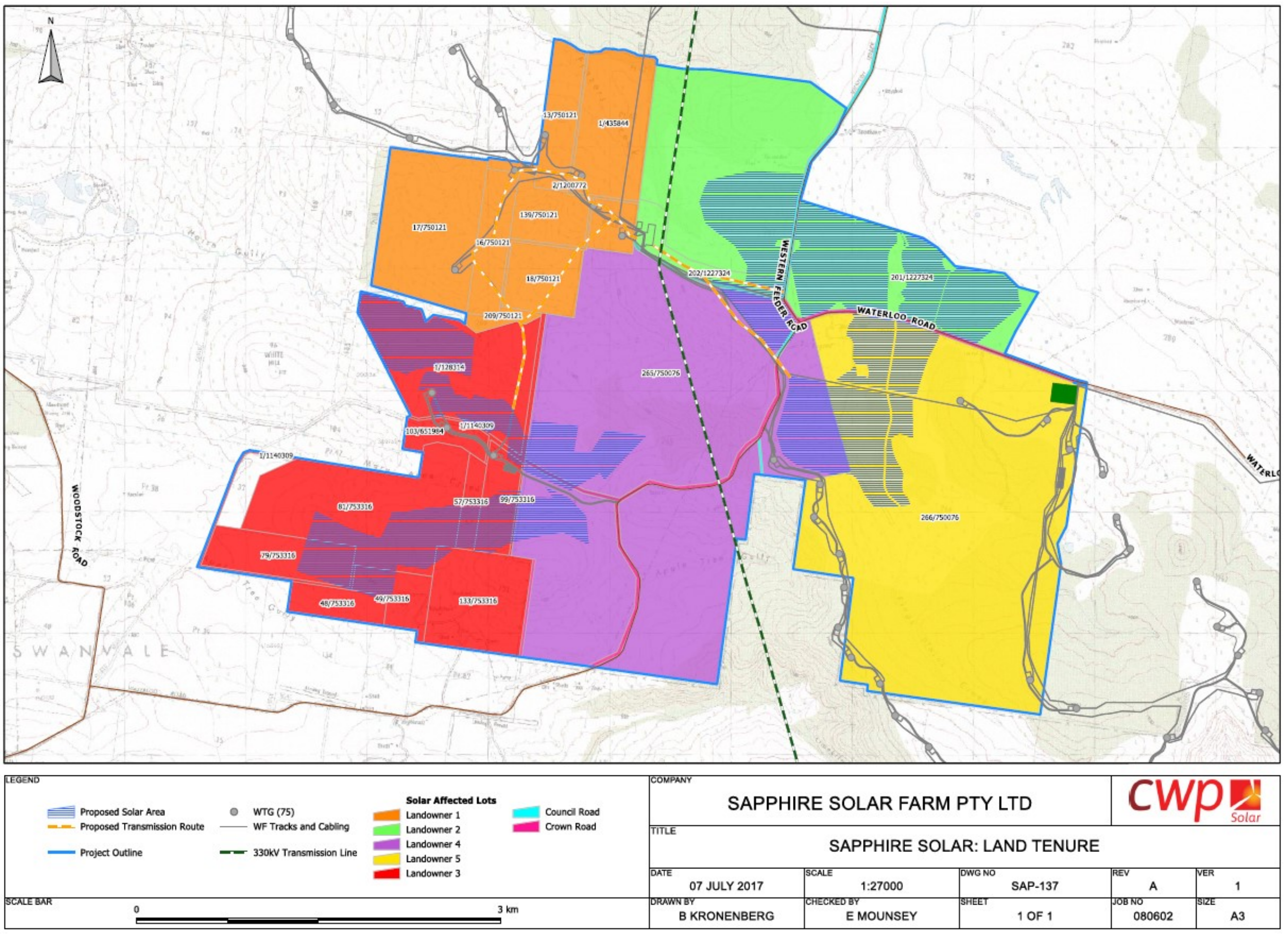
3 Proposed Development

The proposed SSF development is a ~200MW utility scale electricity generation works comprised of solar photovoltaic (PV) modules, steel racking and piled supports, electrical transformers and inverters, battery storage, electrical cabling, telecommunications equipment, security fencing, a site office, maintenance building and car park facilities.

The existence and proximity of SWF provides the opportunity to co-locate the site office and maintenance facilities and share the same point of connection to the TransGrid 330kV network through the SWF substation. This approach would minimise the overall impact of the development while maximising the use of an existing connection asset and aligns with the proposed New England Renewable Energy Hub currently being evaluated by TransGrid, the Australian Renewable Energy Agency (ARENA) and the NSW Government.

The SSF site layout along with the affected lots are shown in Figure 3.

Figure 3: SSF Site Layout



4 Noise Environment

TTM conducted a site visit at the proposed solar farm site on Tuesday, 31st October 2017. During the site visit, noise sensitive receivers (NSRs) were identified and noise measurements were conducted. Noise loggers were installed at locations representative of the NSRs to measure typical ambient noise levels at the site.

4.1 Existing acoustic environment

As observed on site, the ambient noise levels are typical of a rural area with an acoustic environment that is dominated by natural sounds, having relatively little road traffic noise from Western Feeder and Waterloo Road. The area is generally characterised by low background noise levels during all assessment periods (day, evening and night)

Both attended and unattended noise measurements were conducted on site generally in accordance with the recommendations outlined in the NSW Noise for Industry Policy.

4.2 Equipment

The following equipment was used to measure existing ambient noise levels at the site:

- Unattended ambient noise:
  - ARL Environmental Noise Logger (S/N 16-707-040)
  - Norsonic Nor140, Noise Logger (S/N 140-65-05)
- Attended measurements:
  - Rion NA-28, Type 1 Sound Level Meter (S/N 1060055)
- Calibrator:
  - Rion NC-74, Sound Calibrator (S/N 35073393)

All equipment was calibrated by a National Association of Testing Authorities (NATA) accredited laboratory. The equipment was calibrated before and after the measurement session. No significant drift from the reference signal was recorded.

4.3 Noise Monitoring

4.3.1 Unattended Ambient Noise

Unattended noise monitoring was undertaken to measure existing ambient noise levels at representative locations to the NSRs from Tuesday, 31st October to Thursday, 16th November 2017. The noise monitoring locations are shown in Figure 4.

Both unattended noise monitors were set up in practical locations to represent the typical ambient noise environment around NSRs. One noise monitor was set up at Location 1 to capture ambient noise levels at the northern boundary of the solar farm site. The other noise monitor was set up at Location 2 to capture ambient noise levels at the southern boundary. Both microphones were in a free-field position at a height of approximately 1.5 metres above ground level.

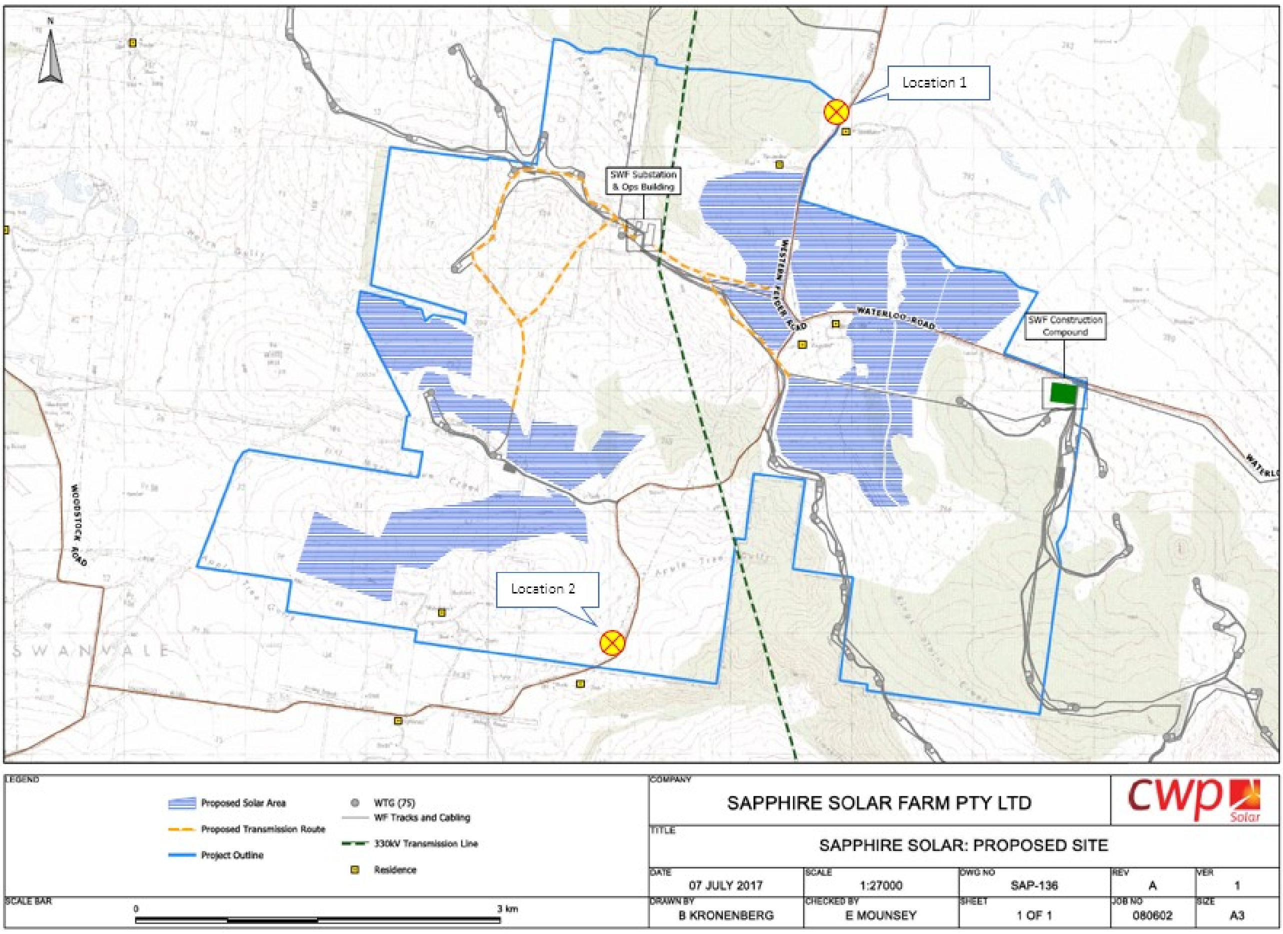
Average, maximum and statistical noise parameters were recorded by the noise monitors at 15-minute intervals using fast response.

Rain and/or high wind were recorded during the noise monitoring period at the following times:

- 31/10/2017, from 7.30am to 6.15pm
- 1/11/2017, from 9.15am to 4.45pm
- 4/11/2017, from 7.15pm to 11.30pm
- 5/11/2017, from midnight to 2.15am, and from 3.45pm to 11.30pm
- 6/11/2017, from midnight to 7.45pm
- 7/11/2017, from 5.00pm to 11.30pm, and
- 11/11/2017, the entire day.

Noise data recorded during these periods has been discarded and has not been included in the measurement summary.

Figure 4: Noise Monitoring Locations



4.3.2 Attended Noise Measurements

Attended noise measurements were also undertaken at each monitoring location. The measurements were taken using a Rion NA-28, Type 1 Sound Level Meter. The measurements are used to verify and supplement the unattended noise monitoring data.

The Sound Level Meter was secured on a tripod and its microphone was positioned next to the microphone of the noise logger. Average, maximum and statistical noise parameters were recorded for a duration of 15 minutes in fast response. The weather throughout the attended measurements was described as fine with a light breeze. The sound level meter was checked for calibration before and after the measurement and no significant drift was observed.

4.4 Results of Noise Survey

4.4.1 Ambient Noise Monitoring Results

Table 1 presents the measured ambient noise levels at Locations 1 and 2 (Refer to Figure 4). Average hourly weekday and weekend graphs are presented in Figure 5 to Figure 8 to demonstrate the variation in noise levels throughout the day. The noise monitoring results are represented graphically in Appendix B. The monitoring results were used to determine the assessment criteria for the development.

Figure 5: Location 1 – North of site – Weekday hourly average graph

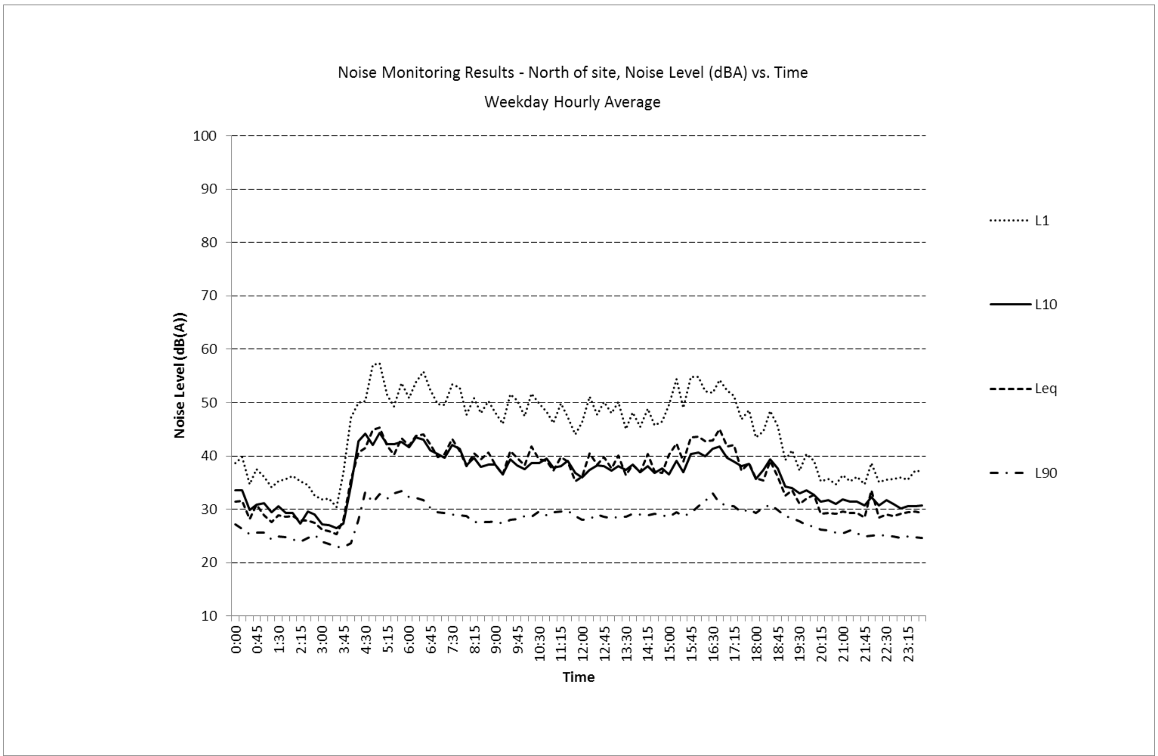


Figure 6: Location 1 – North of site – Weekend hourly average graph

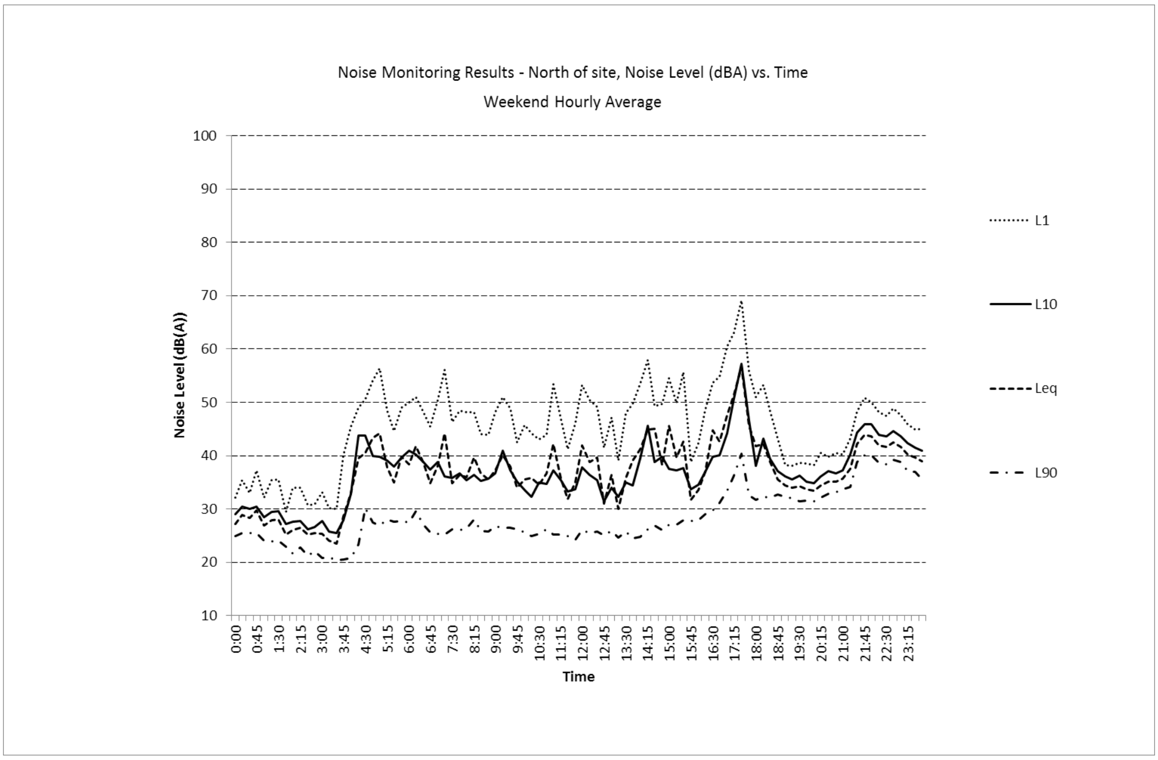


Figure 7: Location 2 – South of site – Weekday hourly average graph

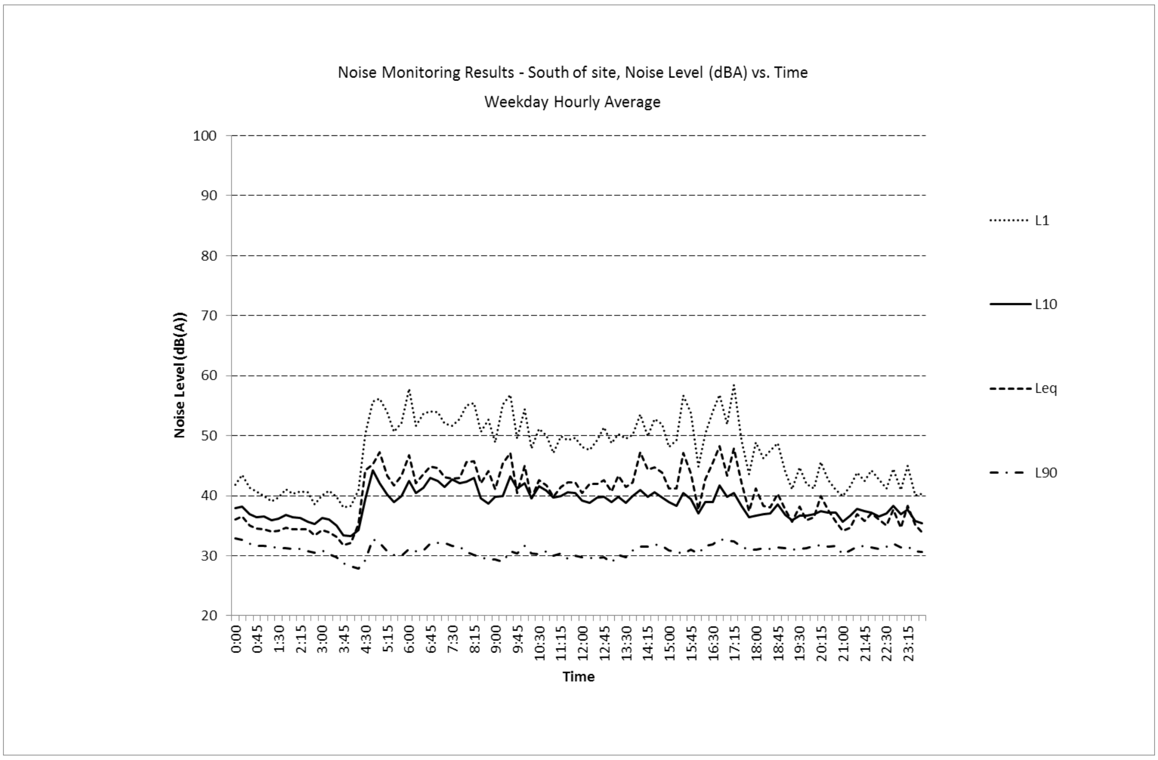


Figure 8: Location 2 – South of site – Weekend hourly average graph

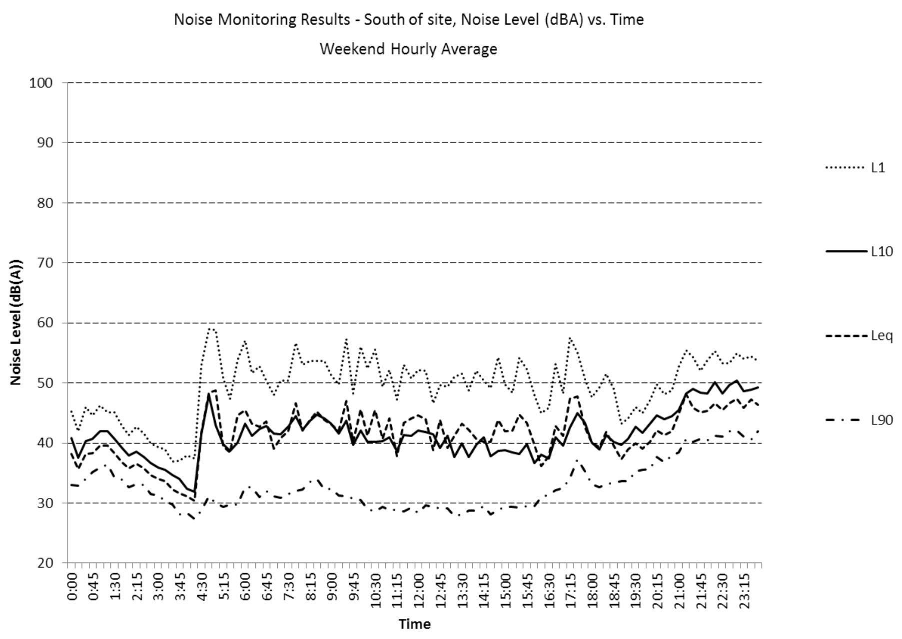


Table 1: Ambient Noise Monitoring Results

Period	Existing Noise Levels in dB(A)			
	Rating Background Noise Levels, RBL L_{90}	L_{eq}	L_{10}	L_1
Location 1 – Northern boundary				
Day	23	39	37	49
Evening	21	31	33	39
Night	21	33	33	41
Location 2 – Southern boundary				
Day	27	43	40	52
Evening	28	39	39	46
Night	27	39	39	46

Note:
- Day-time period is from 0700 to 1800 (Monday to Saturday) and 0800 to 1800 (Sundays and Public Holidays)
- Evening period is from 1800 to 2200
- Night-time period is from 2200 to 0700 (Monday to Saturday) and 2200 to 0800 (Sundays and Public Holidays)

The existing noise levels at Location 1 are slightly lower than the noise levels at Location 2. This could be mainly due to the noise from the activities of the Sapphire Wind Farm which is closer to Location 2 than Location 1.

The measured noise levels generally drops throughout the day, except for the L_{90} parameter, which are similar throughout the day at both measurement locations.

4.4.2 Attended Measurements

The results of the attended noise measurements are summarised in Table 2, have been compared with the corresponding measured unattended noise measurement at that time to confirm the validity of the measurements. The attended measurements were conducted at approximately 10 metres away from the noise loggers, closer to the roads.

Table 2: Summary of Attended Noise Measurements

Meas. Location (Refer to Figure 4)	Approx. Start Date/Time	Meas. Type	Measured Noise Levels in dB(A)*					Comments
			L_{90}	L_{eq}	L_{10}	L_{1}	L_{max}	
Location 1 (Northern)	31/10/2017 10:14	Unattended	29	44	38	49	70	Noise environment dominated by natural sounds. A couple of vehicle pass-bys were also observed.
		Attended	**33**	**44**	**45**	**54**	**73**	
Location 2 (Southern)	31/10/2017 11:10	Unattended	38	42	44	48	58	Noise environment dominated by natural sounds. Noise from residents' car in the driveway was also captured.
		Attended	**38**	**46**	**48**	**53**	**63**	

The attended measurements are slightly higher to the unattended measurements. The slight increase is due to the attended measurements being taken closer to the road which recorded higher levels of car pass-bys. Also, the attended measurements captured noise from the operator of the equipment.

The attended noise measurements show a snap-shot sample of the ambient noise environment in the area. The sample measurements have similar patterns to the unattended measurements, although within ±5 dB difference in the presented statistical parameters. As such, the attended measurements confirm the validity of the unattended noise survey for the purpose of the noise impact assessment.

5 Noise Criteria

The main guidelines, standards and other policy documents relevant to the construction and operational noise impact assessment include:

- NSW Department of Environment and Climate Change (DECC) (2009), Interim Construction Noise Guideline, and
- NSW Environment Protection Authority (2017), NSW Noise Policy for Industry.

5.1 DECC Interim Construction Noise Guideline (ICNG)

The DECC Interim Construction Noise Guideline (ICNG) provides guidelines for the assessment and management of noise from construction works. The type and duration (greater than 4 weeks) of construction activities for the proposed development mean that it is considered a major construction project. Therefore, the quantitative approach has been adopted for the construction noise assessment.

5.1.1 ICNG Noise Management Levels

The ICNG suggests the following standard hours for construction activities where noise is audible at residential premises:

- Monday to Friday, 7am to 6pm
- Saturday, 8am to 1pm, and
- No construction work is to take place on Sundays or public holidays.

Time restrictions on construction works are the primary management tool of the ICNG. The construction working hours of the proposed development are expected to be in line with the above standard hours.

The guideline also provides noise management levels for residential premises for both the recommended, and outside standard hours of construction. The noise management levels recommended for residential premises have been extracted from the ICNG and are summarised in Table 3.

Table 3: Residential – ICNG noise management levels

Time of day	Management level, $L_{Aeq\ (15\ min)}$ *	How to apply
Recommended standard hours: Monday to Friday 7am to 6pm Saturday 8am to 1pm No work on Sundays or public holidays	Noise affected RBL + 10 dB	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured $L_{Aeq\ (15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: a. times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences b. if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5 dB	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community. • For guidance on negotiating agreements see section 7.2.2 of the ICNG.
Note: * Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5m above ground level. If the property boundary is more than 30m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30m of the residence. Noise levels may be higher at upper floors of the noise affected residence.		

5.2 NSW Noise Policy for Industry

The policy sets out the procedure to determine the project noise trigger levels relevant to assess noise from industrial developments. The project noise trigger level applies to existing noise-sensitive receivers.

The project noise trigger level provides a benchmark or objective for assessing a proposal or site. It is not intended for use as a mandatory requirement. The project noise trigger level is a level that, if exceeded, would indicate a potential noise impact on the community, and so ‘trigger’ a management response; for example, further investigation of mitigation measures.

The project noise trigger level is the lower (that is, the more stringent) value of the project intrusiveness noise level and project amenity noise level determined in Sections 2.3 and 2.4 of the policy.

5.2.1 Project Intrusiveness Noise Level

The Noise Policy for Industry states:

> *The intrusiveness of an industrial noise source may generally be considered acceptable if the level of noise from the source (represented by the L_{Aeq} descriptor), measured over a 15-minute period, does*

not exceed the background noise level by more than 5 dB when beyond a minimum threshold. This intrusiveness noise level seeks to limit the degree of change a new noise source introduces to an existing environment.

The intrusiveness noise level is determined as follows:

$$L_{Aeq,\ 15min} \leq \text{Rating Background Noise Level} + 5\ \text{dB}$$

5.2.1.1 Minimum Rating Background Noise Level and Project Intrusive Noise Levels

The rating background noise level (RBL) is the overall single-figure background level representing each assessment period (day/evening/night) over the whole monitoring period (as opposed to over each 24-hour period used for the assessment background level). The rating background noise level is the level used for assessment purposes.

For the assessment, the lowest measured RBLs are used to derive the intrusive noise levels. Referring to Table 1, the lowest measured RBLs are at Location 1.

Regardless of the measured RBLs, minimum RBLs apply in this policy, which result in minimum intrusiveness noise levels. The project intrusiveness noise levels have been derived in Table 4.

Table 4: Minimum assumed RBLs and project intrusiveness noise levels.

Time of day	Measured RBLs at Location 1, in dB(A) (Refer to Table 1)	Minimum RBLs, in dB(A)	Project intrusiveness noise levels, in $L_{Aeq,15min}$ dB(A)
Day	23	35	40
Evening	21	30	35
Night	21	30	35

The measured RBLs are lower than the minimum recommended RBLs in the NSW Noise for Industry Policy. The project intrusiveness noise levels have therefore been derived based on the minimum RBLs.

5.2.2 Amenity noise levels and Project Amenity Noise Levels

To limit continuing increases in noise levels from application of the intrusiveness level alone, the ambient noise level within an area from all industrial noise sources combined should remain below the recommended amenity noise levels specified in Table 2.2 of the Noise Policy for Industry where feasible and reasonable. The recommended amenity noise levels will protect against noise impacts such as speech interference, community annoyance and some sleep disturbance. The noise amenity area is defined as residential rural and the relevant noise amenity levels are given in Table 5.

Table 5: Amenity noise levels

Receiver/ Noise amenity area	Assessment period	Recommended amenity noise level, L_{eq} dB(A)
Residential Rural	Day	50
	Evening	45
	Night	40
Note: - Day-time period is from 0700 to 1800 (Monday to Saturday) and 0800 to 1800 (Sundays and Public Holidays) - Evening period is from 1800 to 2200 - Night-time period is from 2200 to 0700 (Monday to Saturday) and 2200 to 0800h (Sundays and Public Holidays)		

The recommended amenity noise levels represent the objective for total industrial noise at a receiver location, whereas the project amenity noise level represents the objective for noise from a single industrial development at a receiver location.

To ensure that industrial noise levels (existing plus new) remain within the recommended amenity noise levels for an area, a project amenity noise level applies for each new source of industrial noise as follows:

Project amenity noise level for industrial developments = Recommended amenity noise level minus 5 dB(A)

5.2.3 Project Noise Trigger Level

The project noise trigger level (PNTL) has been determined in Table 6 and are the most stringent of the intrusiveness and amenity noise criteria.

Table 6: NSW Noise Policy for Industry Evaluated criteria

Assessment period	Project Intrusiveness Noise Level $L_{eq,15min}$ dB(A)*	Project Amenity Noise Level L_{eq} dB(A)	Project Noise Trigger Level L_{eq} dB(A)
Day	40	45	**40**
Evening	35	40	**35**
Night	35	35	**35**
Note: - Day-time period is from 0700 to 1800 (Monday to Saturday) and 0800 to 1800 (Sundays and Public Holidays) - Evening period is from 1800 to 2200 - Night-time period is from 2200 to 0700 (Monday to Saturday) and 2200 to 0800h (Sundays and Public Holidays) * Based on minimum intrusive noise levels in Table 4.			

Table 6 shows that the PNTLs are set by the project intrusiveness noise level for all assessment periods.

By meeting the PNTLs at the identified NSRs, all other properties located further away from the development site are expected to comply with the noise requirements of this policy.

5.3 Noise-enhancing Weather Conditions

Certain meteorological/weather conditions may increase noise levels by focusing sound-wave propagation paths at a single point. Such refraction of sound waves will occur during temperature inversions (atmospheric conditions where temperatures increase with height above ground level), and where there is a wind gradient (that is, wind velocities increasing with height) with wind direction from the source to the receiver.

A range of meteorological conditions have been considered in the construction and operational noise impact assessment of the solar farm, to account for all conditions.

The standard meteorological conditions and noise-enhancing meteorological conditions as defined in the NSW Noise for Industry Policy, which have been considered in this assessment are summarised in Table 7.

Table 7: Standard and noise-enhancing meteorological conditions

Meteorological conditions	Meteorological parameters
Standard meteorological conditions	Day/evening/night: stability categories A–D with wind speed up to 0.5 m/s at 10 m AGL.
Noise-enhancing meteorological conditions	Daytime/evening: stability categories A–D with light winds (up to 3 m/s at 10 m AGL). Night-time: stability categories A–D with light winds (up to 3 m/s at 10 m AGL) and/or stability category F with winds up to 2 m/s at 10 m AGL.

5.4 NSW Road Noise Policy

The NSW Road Noise Policy sets out noise assessment criteria for residential land uses affected by additional traffic on existing roads generated by land use developments. The criteria will be used as a guide to assess additional road traffic noise on Western Feeder Road and Waterloo Road due to the construction activities associated with the SSF. The criteria are summarised in Table 8.

Table 8: NSW Road Noise Policy noise assessment criteria

Road type	Period	Assessment criteria, in dB(A)
Local roads (Western Feeder Road and Waterloo Road)	Day (7am - 10pm)	55 dB(A) $L_{eq,1\ hour}$ (external)
	Night (10pm - 7am)	50 dB(A) $L_{eq,1\ hour}$ (external)

6 Vibration Criteria

6.1 Building Damage

The likelihood of structural or even cosmetic damage to buildings located around the construction site is considered highly unlikely given the machinery and equipment proposed to be used in the construction activities. However, for the sake of completeness a building damage vibration criterion has been provided below.

There is little reliable data on the threshold of vibration-induced damage in buildings. Although vibrations induced in buildings by ground-borne excitation are often noticeable, there is little evidence that cosmetic damage[3] is actually produced. The lack of data is one of the reasons that there is variation between International Standards.

Vibration will be felt by the occupants of a dwelling at levels far lower than those at which damage is likely to occur. Therefore, for the purposes of the project, it is recommended to set a building damage vibration criterion that is conservative. In doing so, in the unlikely event that the criterion is exceeded, the works can be stopped and any vibration damage can be established. If no damage is observed and the resident's fears have been allayed, the construction works can resume.

Construction vibration levels are to be measured on or close to the foundations of the closest building to where the vibration causing work is taking place. A recommended conservative vibration criterion for building damage is provided in Table 9.

Table 9: Recommended conservation vibration criterion – Building damage

Criteria	Vibration Limit, Peak Particle Velocity (PPV), mm/s	Comments
Structural/Cosmetic Damage	5	Set as an initial limit, to be monitored during construction for excavation, use of hydraulic hammers and compaction plant.

6.2 Human Comfort

Vibration criteria for human comfort are given by the Office of Environment and Heritage (OEH) "Assessing Vibration" guideline[4]. The criteria are for guidance and represent non-mandatory goals for new developments.

The human comfort vibration criterion is significantly below the building damage vibration criterion, and therefore achieving the human comfort condition generally results in the building damage condition being met.

[3] Building Research Establishment (1995), 'Damage to Structures from Ground-borne Vibration', BRE Digest

[4] NSW Department of Environment and Conservation (2006) – *Assessing Vibration: a technical guideline*

For intermittent vibration sources, such as from the hydraulic hammer and other construction plant, the concept of a "vibration dose value" (VDV) has been adopted. For residences, the acceptable VDV range is as follows:

- Preferred value: 0.2 $m/s^{1.75}$; and
- Maximum value: 0.4 $m/s^{1.75}$.

The OEH's vibration guidance is generally based on British Standard *BS6472*[5]. *BS6472* and its Australian equivalent, Australian Standard *AS2670.2*[6] give a series of rating curves to assess human exposure to vibration and provide further guidance on acceptable vibration levels.

Table 2 of AS2670.2 recommends day-time continuous or intermittent human comfort vibration limits for residential receivers that should not be exceeded. The human comfort vibration limits for the day-time period are summarised in Table 10.

Table 10: Human comfort vibration levels equivalent to Curve 4 given in *AS2670.2*

Criteria (Day-time period)	Vibration Limit, rms in mm/s		Comments
	Continuous or intermittent	Transient vibration with several occurrences per day	
Human comfort in residences	0.2 – 0.4	3 – 9*	To be monitored and reported should a complaint be received.
Note: *AS2670 suggests that for transient vibration people may not elicit an adverse reaction to vibration levels 30 to 90 times to the threshold of perception (0.1 mm/s).			

[5] British Standard BS6472.2 (1992) Guide to evaluation of human exposure to vibration in buildings (1 to 80 Hz)

[6] Australian Standard AS2670.2 (1990) – Evaluation of human exposure to whole-body vibration. Part 2: Continuous and shock-induced vibration in buildings (1 to 80 Hz)

7 Construction Noise Assessment

7.1 Construction Process

Construction will include all pre-operation activities associated with the project other than survey, acquisitions, fencing, investigative drilling or excavation, or other preparatory activities that have minimal environmental impact such as site mobilisation, minor adjustments to services/utilities, establishing temporary construction sites or minor clearing. Construction would typically comprise of the following activities:

7.1.1 Site Preparation and Substation Construction Phase

Significant earthworks and piling activities will be required prior to installing PV modules. Site preparation is required to ensure the land is flat. The land is largely clear of trees and dense vegetation. Site entrances will be opened and site gates secured in position. Fencing will be upgraded or installed around the site perimeter. The site will be cleared of internal fences, timber or rock debris as required. Trees within the development footprint where clearing has been approved will be removed.

It is possible that the Essential Energy low voltage 11 kV distribution lines crossing the site will need to be relocated to avoid impacting the layout. This will be carried out at this stage if required and undertaken in close cooperation with Essential Energy and residents supplied by these connections.

Site facilities and construction laydown areas will be established within the development footprint and construction vehicles and equipment will be mobilised to the site. Site access tracks will be staked and established through scraping, grading and compacting. Some tracks may require road base to create an all-weather (unsealed) surface. Extensive track construction is planned.

Typically, construction of the site substation will also commence at this phase. However, owing to the colocation of SSF with the wind farm, only minor works are required which will incur limited new impacts.

During construction, additional infrastructure will be established including site offices and amenities, vehicle parking and turning areas, equipment laydown and storage areas, safety fencing, and temporary power.

Site preparation and substation construction phase will require the use of plant such as bulldozers, water trucks, graders, flatbed trucks, skid steers, front end loaders, roller compactors, trenchers, backhoes, gravel trucks, cranes and aerial lifts.

7.1.2 Installation

Following site preparation, the supporting structures and the solar modules will be installed. The site will be surveyed and locations of all the equipment will be pegged. Top soil will be left intact wherever possible. The circular hollow sections or flanged sectioned steel piles which support the racking system will be driven into the ground pneumatically or alternatively holes will be bored and the piles will be grouted in position. Percussion piling machines or excavator equipped with rotating auger will be used.

Piles may be cut off to height and the steel racking assembly will be attached in accordance with the manufacturers proprietary system. Solar PV modules are then installed on the racking and secured in position to withstand wind loading. Once the modules have been installed the DC collection cables are laid on the structure and terminated to the modules. If a tracking system is being used, the rotating mechanism and servo motors will be installed on the support structure.

This phase will require the use of equipment including pile drivers, augers, forklifts, welders, oxy acetylene, trenchers, excavators, pickup trucks, water trucks, flatbed trucks and cranes.

7.1.3 Inverter and Transformer Assemblies, and Electrical Collection System

Cable trenches will be excavated and AC and DC cables will be laid as the PV modules are installed. Trenches will be backfilled with excavated material and cables will be terminated to the modules. Foundations for the inverter assemblies will be constructed as either concrete slabs on the ground or piles. The inverter and transformer assemblies will be placed on the foundations and the cables will be terminated to them. Testing and quality assurance will be carried out as connections are made.

7.1.4 Commissioning

Once all the inverter assemblies and electrical collection system has been installed, commissioning of equipment can commence. Commissioning will include terminations, testing, calibration and troubleshooting. The inverters, transformers, collection system, solar PV array, substation and storage system (if any) will be tested prior to commencement of commercial operations to ensure any system issues are rectified. Commissioning will involve site crews and TransGrid personnel. Upon completion of successful testing, the solar farm can be connected to the TransGrid network and it will be ready to export electricity.

This phase of the construction process will require skid steers, pile drivers, trenchers, backhoes, cranes, aerial lifts, flatbed and concrete trucks (light vehicles only) on site.

7.1.5 Post-construction – Maintenance

The solar PV modules may be periodically washed to remove excess dirt, dust or other matter (i.e. bird droppings) which can prevent sunlight from effectively reaching the solar cells and subsequently reducing the electricity production output. The frequency of any washing will depend on monitoring the actual performance of the farm.

If required washing will be carried out manually or mechanically. Clean water would be transported to site by water trucks that would then be driven down the rows between the strings of modules and personnel or mechanical devices would use spray equipment to clean the surface of modules.

7.1.6 Post-construction – Upgrading, Repowering and/or Decommissioning

Upgrading or repowering of the PV modules and ancillary equipment maybe required throughout the operational life of the project. This will be a commercial decision based on the relative economics of solar PV generation compared to alternatives at the time.

Upgrading and repowering would involve removal of any obsolete equipment such as modules and inverters and disposing of these off-site in accordance with good practice, including recycling wherever possible. The technology available at that time would be installed using the existing structures and infrastructure to the extent possible and the farm would be recommissioned.

If the decision at the time is to decommission the farm the procedure would be to initially disconnect the solar farm from the TransGrid network. The interconnecting cable and substation equipment would be removed and disposed of off-site, reusing and recycling wherever possible. Foundations would be broken up and removed off site. The substation compound fencing would be removed and area would be graded and seeded.

Modules and the racking system would be removed and it could be expected that a significant amount of the support structure could be reused or recycled off-site. Piles will be lifted out of the ground and recycled wherever possible. In general, cables are likely to be worth removing and recycling. However, underground cables which are more than 300 mm below ground level may be left buried to avoid excessive ground disturbance. The site control room and facilities would be lifted off their foundations and transported off site on flatbed trucks. Finally, the surface of the site would be ripped and returned to agricultural use.

7.2 Plant and Equipment Noise Source Levels

For each construction process, the expected plant and machinery information to be used are summarised in Table 11. The table also includes an estimated percentage of use per day, which reflects the transient and changing nature of the construction noise activities, dependent upon site-conditions, timelines, delays and other unexpected occurrences, as well as, the source sound levels for each of the items of plant and equipment.

Table 11: Summary of Construction Process and Associated Equipment

Construction Process	Task	Equipment	% Use per day	Sound Power Level, dB(A)	Reference*
Site Preparation and Substation Construction Phase	Site Clearing, Site Facilities and Construction laydown areas, Site Access Tracks and Construction of site substation	Hydraulic Hammer Rig 4t hammer, Power rating 186kW	75	115	Ref. No. 2, Table 3 in DEFRA
		Dozer 20t, Power Rating 142kW	75	109	Ref. No. 1, Table 2 in DEFRA[7]
		Water Trucks	75	107	AS 2436
		Graders	75	110	AS 2436
		Flatbed Trucks (>20t)	75	107	AS 2436
		Skid Steers	75	105	AS 2436
		Front End Loaders	75	113	AS 2436
		Roller Compactors	75	107	Ref. No. 37, Table 2 in DEFRA

[7] Department for Environment Food and Rural Affairs, DEFRA – Update of Noise Database for Prediction of Noise on Construction and Open Sites - 2005

Construction Process	Task	Equipment	% Use per day	Sound Power Level, dB(A)	Reference*
		Tracked Excavator 16t, 72kW	50	104	Ref. No. 5, Table 2 in DEFRA
		Tracked Excavator (Idling) 16t, Power rating 72kW	25	91	Ref. No. 6, Table 2 in DEFRA
		Wheeled Backhoe Loader 8t, Power rating 62kW	50	96	Ref. No. 8, Table 2 in DEFRA
		Wheeled Backhoe Loader (Idling) 8t, Power rating 62kW	25	83	Ref. No. 9, Table 2 in DEFRA
		Gravel Trucks	75	108	Ref. No. 34, Table 2 in DEFRA
		Mobile crane	50	104	AS 2436
		Lifting Platform	75	95	Ref. No. 57, Table 4 in DEFRA
Installation	Supporting structures and Solar PV Modules Installation	Hydraulic Hammer Rig 4t hammer, Power rating 186kW	75	115	Ref. No. 2, Table 3 in DEFRA
		Backhoe with auger	75	106	AS 2436
		Forklifts	75	106	AS 2436
		Welders	75	105	AS 2436
		Tracked Excavator 16t, 72kW	50	104	Ref. No. 5, Table 2 in DEFRA
		Tracked Excavator (Idling) 16t, Power rating 72kW	25	91	Ref. No. 6, Table 2 in DEFRA
		Wheeled Backhoe Loader 8t, Power rating 62kW	50	96	Ref. No. 8, Table 2 in DEFRA
		Wheeled Backhoe Loader (Idling) 8t, Power rating 62kW	25	83	Ref. No. 9, Table 2 in DEFRA
		Pickup truck (>20t)	50	107	AS 2436
		Water Bowser	75	107	Ref. No. 37, Table 6 in DEFRA
		Flatbed truck (>20t)	50	107	AS 2436
		Wheeled Loader, 170kW	75	104	Ref. No. 28, Table 2 in DEFRA
		Mobile crane	50	104	AS 2436
Inverter and Transformer Assemblies, and Electrical Collection System	Trenching	Tracked Excavator 16t, 72kW	50	104	Ref. No. 5, Table 2 in DEFRA
		Tracked Excavator (Idling) 16t, Power rating 72kW	25	91	Ref. No. 6, Table 2 in DEFRA
		Wheeled Backhoe Loader 8t, Power rating 62kW	50	96	Ref. No. 8, Table 2 in DEFRA

Construction Process	Task	Equipment	% Use per day	Sound Power Level, dB(A)	Reference*
		Wheeled Backhoe Loader (Idling) 8t, Power rating 62kW	25	83	Ref. No. 9, Table 2 in DEFRA
		Pickup truck (>20t)	75	107	AS 2436
		Water truck	75	107	AS 2436
		Flatbed truck (>20t)	75	107	AS 2436
		Water Pump	75	93	Ref. No. 45, Table 2 in DEFRA
		Concrete Pump + Cement Mixer Truck (Discharging)	50	95	Ref. No. 24, Table 4 in DEFRA
		Hydraulic Hammer Rig 4t hammer, Power rating 186kW	75	115	Ref. No. 2, Table 3 in DEFRA
		Lifting Platform	75	95	Ref. No. 57, Table 4 in DEFRA
		Tipper Truck	75	108	Ref. No. 34, Table 2 in DEFRA
		Diesel generator	80	99	AS 2436
Commissioning	-	Tracked Excavator 16t, 72kW	50	104	Ref. No. 5, Table 2 in DEFRA
		Tracked Excavator (Idling) 16t, Power rating 72kW	25	91	Ref. No. 6, Table 2 in DEFRA
		Wheeled Backhoe Loader 8t, Power rating 62kW	50	96	Ref. No. 8, Table 2 in DEFRA
		Wheeled Backhoe Loader (Idling) 8t, Power rating 62kW	25	83	Ref. No. 9, Table 2 in DEFRA
		Pickup truck (light vehicle)	75	97	TTM Database
		Flatbed truck (light vehicle)	75	97	TTM Database
		Concrete Pump + Cement Mixer Truck (Discharging)	50	95	Ref. No. 24, Table 4 in DEFRA
		Hydraulic Hammer Rig 4t hammer, Power rating 186kW	75	115	Ref. No. 2, Table 3 in DEFRA
		Lifting Platform	75	95	Ref. No. 57, Table 4 in DEFRA
		Mobile crane	50	104	AS 2436
Post-construction – Maintenance: Solar module washing	Water spraying	Water Truck	50	107	AS 2436
		Water Pump	50	93	Ref. No. 45, Table 2 in DEFRA
	Mechanical method	Truck	50	107	AS 2436
		Pump	50	93	Ref. No. 45, Table 2 in DEFRA

Construction Process	Task	Equipment	% Use per day	Sound Power Level, dB(A)	Reference*
Upgrading, Repowering and/or Decommissioning	Upgrading, Repowering	Forklifts	50	106	AS 2436
		Welders	50	105	AS 2436
		Pickup truck (>20t)	50	107	AS 2436
		Water Bowser	50	107	Ref. No. 37, Table 6 in DEFRA
		Flatbed truck (>20t)	50	107	AS 2436
		Wheeled Loader, 170kW	50	104	Ref. No. 28, Table 2 in DEFRA
		Mobile crane	50	104	AS 2436
	Decommissioning	Flatbed truck (>20t)	50	107	AS 2436
		Wheeled Loader, 170kW	50	104	Ref. No. 28, Table 2 in DEFRA
		Mobile crane	50	104	AS 2436

Note: *

DEFRA – Department for Environment Food and Rural Affairs (DEFRA), 2005. Update of noise database for prediction of noise on construction and open sites. Noise levels are given as a sound pressure level at 10 metres from the source. The sound pressure levels have been converted to sound power levels in the table.

AS 2436:2010. Guide to noise and vibration control on construction, demolition and maintenance sites.

7.3 Assessment Methodology

The noise impact of construction activities for each applicable construction phase has been predicted for a worst-case scenario. The noise prediction has been based on the following:

- Plant and equipment source sound power level information given in Table 11
- Distance attenuation, and
- Atmospheric, meteorological and ground noise attenuation using the CONCAWE[8] method, where applicable.

The worst-case scenario represents the use of all the plant and equipment for each activity at the same time at one single point. This scenario represents an unrealistic scenario, but does represent the maximum possible impact of construction noise for a short duration before the work moves to another location.

Noise predictions have been made using the CONCAWE prediction method. CONCAWE is a noise prediction method developed for assessing environmental noise propagation, drawn from both acoustic theory and extensive field noise measurements. The CONCAWE predictions consider atmospheric, meteorological and ground attenuation.

[8] CONCAWE – the propagation of noise from petroleum and petrochemical complexes to neighbouring communities. Report no.4/81, 1981

A worst-case scenario has been modelled to conservatively predict the propagation of noise from source to receiver. The worst-case scenario includes the effects of temperature inversions and favourable winds onto the noise, which is equivalent to CONCAWE Category 6.

A neutral meteorological condition has also been predicted, where the resulting noise levels are neither elevated or reduced. This condition is equivalent to CONCAWE Category 4.

For the construction noise assessment, noise levels have been predicted at the approximate boundaries of the identified NSRs. The predicted noise levels have then been compared to the following noise targets:

1. ICNG noise management level of **33 dB(A)** Day-time for R13, R14, R17, R18 and R28
2. ICNG noise management level of **37 dB(A)** Day-time for R15, R16 and R33, and
3. ICNG highly noise affected limit of **75 dB(A)** at all NSRs.

7.4 Predicted Construction Noise Levels

The predicted noise levels for each noise significant construction phase are provided in the tables below. Exceedances of the ICNG noise management level are shown in bold and red.

Table 12: Predicted construction noise levels from Site Preparation and Substation Construction Phase

Construction Stage – Site Preparation and Substation Construction Phase								
NSR Reference	R18	R17	R13	R14	R16	R15	R33	R28
Predicted noise level dB(A) worst-case Met. Cat 6	73	50	70	67	56	40	42	26
Predicted noise level dB(A) neutral-case Met. Cat 4	73	45	70	65	51	34	37	20
ICNG noise management level (Day)	*33*	*33*	*33*	*33*	*37*	*37*	*37*	*33*
Meets Target worst-case Met. Cat 6 ✓/✗	✗	✗	✗	✗	✗	✗	✗	✓
Meets Target neutral-case Met. Cat 4 ✓/✗	✗	✗	✗	✗	✗	✓	✓	✓

Table 13: Predicted construction noise levels from Installation

Construction Stage – Installation								
NSR Reference	R18	R17	R13	R14	R16	R15	R33	R28
Predicted noise level dB(A) worst-case Met. Cat 6	73	50	70	67	56	40	43	27
Predicted noise level dB(A) neutral-case Met. Cat 4	73	45	70	65	51	35	37	21
ICNG noise management level (Day)	*33*	*33*	*33*	*33*	*37*	*37*	*37*	*33*
Meets Target worst-case Met. Cat 6 ✓/✗	✗	✗	✗	✗	✗	✗	✗	✓
Meets Target neutral-case Met. Cat 4 ✓/✗	✗	✗	✗	✗	✗	✓	✓	✓

Table 14: Predicted construction noise levels from Inverter and Transformer Assemblies, and Electrical Collection System

Construction Stage – Inverter and Transformer Assemblies, and Electrical Collection System								
NSR Reference	R18	R17	R13	R14	R16	R15	R33	R28
Predicted noise level dB(A) worst-case Met. Cat 6	73	50	70	67	55	40	42	26
Predicted noise level dB(A) neutral-case Met. Cat 4	73	45	70	65	51	34	37	20
ICNG noise management level (Day)	*33*	*33*	*33*	*33*	*37*	*37*	*37*	*33*
Meets Target worst-case Met. Cat 6 ✓/✗	✗	✗	✗	✗	✗	✗	✗	✓
Meets Target neutral-case Met. Cat 4 ✓/✗	✗	✗	✗	✗	✗	✓	✓	✓

Table 15: Predicted construction noise levels from Commissioning

Construction Stage – Installation								
NSR Reference	R18	R17	R13	R14	R16	R15	R33	R28
Predicted noise level dB(A) worst-case Met. Cat 6	72	50	70	66	55	40	42	26
Predicted noise level dB(A) neutral-case Met. Cat 4	72	44	70	64	50	34	37	20
ICNG noise management level (Day)	*33*	*33*	*33*	*33*	*37*	*37*	*37*	*33*
Meets Target worst-case Met. Cat 6 ✓/✗	✗	✗	✗	✗	✗	✗	✗	✓
Meets Target neutral-case Met. Cat 4 ✓/✗	✗	✗	✗	✗	✗	✓	✓	✓

Table 16: Predicted operational noise levels for Maintenance

Post Construction – Maintenance								
NSR Reference	R1	R2	R3	R4	R5	R6	R7	R8
Predicted noise level dB(A) worst-case Met. Cat 6	60	37	57	55	43	27	30	14
Predicted noise level dB(A) neutral-case Met. Cat 4	60	32	57	52	38	22	24	8
Project Noise Target Levels (PNTLs) – Day	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*
Meets Target worst-case Met. Cat 6 ✓/✗	✗	✓	✗	✗	✗	✓	✓	✓
Meets Target neutral-case Met. Cat 4 ✓/✗	✗	✓	✗	✗	✓	✓	✓	✓

Table 17: Predicted operational noise levels for Upgrading, Repowering

Post Construction – Upgrading, Repowering								
NSR Reference	R1	R2	R3	R4	R5	R6	R7	R8
Predicted noise level dB(A) worst-case Met. Cat 6	68	45	65	62	50	35	37	22
Predicted noise level dB(A) neutral-case Met. Cat 4	68	40	65	60	46	29	32	16
Project Noise Target Levels (PNTLs) – Day	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*
Meets Target worst-case Met. Cat 6 ✓/✗	✗	✗	✗	✗	✗	✓	✓	✓
Meets Target neutral-case Met. Cat 4 ✓/✗	✗	✓	✗	✗	✗	✓	✓	✓

Table 18: Predicted operational noise levels for Decommissioning

Operation Process – Decommissioning								
NSR Reference	R1	R2	R3	R4	R5	R6	R7	R8
Predicted noise level dB(A) worst-case Met. Cat 6	63	40	60	57	46	31	33	17
Predicted noise level dB(A) neutral-case Met. Cat 4	63	35	60	55	41	25	28	12
Project Noise Target Levels (PNTLs) – Day	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*
Meets Target worst-case Met. Cat 6 ✓/✗	✗	✓	✗	✗	✗	✓	✓	✓
Meets Target neutral-case Met. Cat 4 ✓/✗	✗	✓	✗	✗	✗	✓	✓	✓

7.5 Discussion of Results

The predicted construction noise levels shown in the tables above show that noise generated from construction activities will impact the noise sensitive receivers R13, R14, R15, R16, R17, R18 and R33.

R18 is the most noise affected NSR and the closest receiver at approximately 60 metres from the nearest boundary of the construction site. The ICNG noise management level of **33 dB(A)** is exceeded by up to 40 dB under the worst-case meteorological category (Met. Cat 6) at R18. However, the ICNG highly noise affected limit of **75 dB(A)** is not exceeded at any of the NSRs.

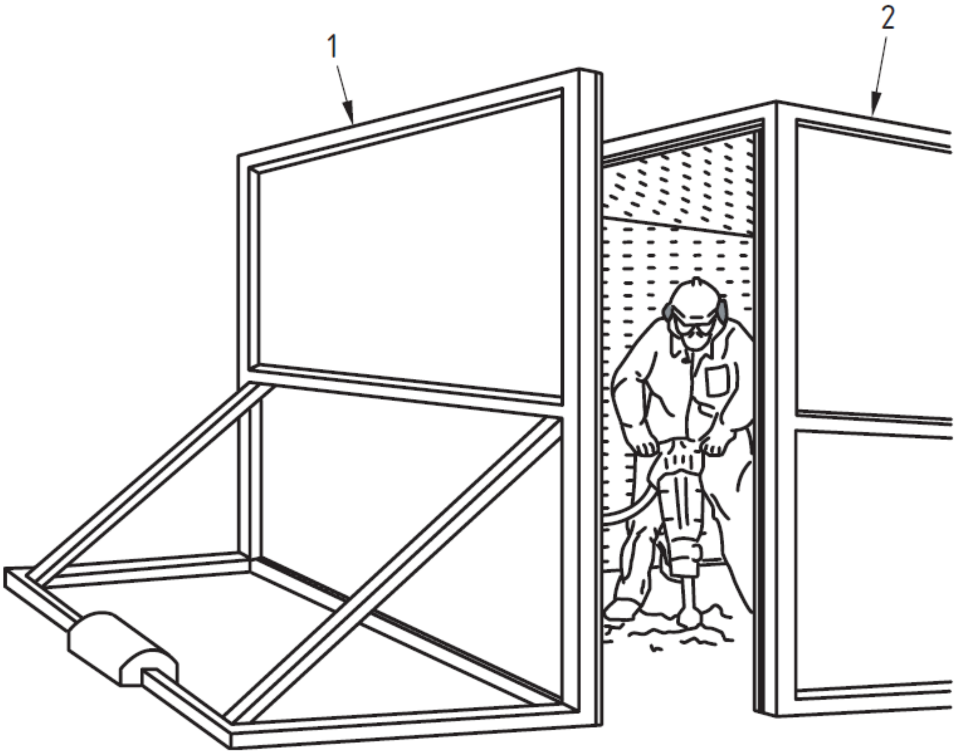
It should be noted that the prediction method has assumed that all plant and equipment are operating simultaneously (adjusted for the percentage daily use) at the construction site's boundary, to represent maximum noise impact. This is an unlikely scenario in practice, and even if it did occur, it would be only for a short duration before the work moves on to another area of the site further away from the NSRs. Plant and equipment will also be scattered across the site conducting different work at different times which will further alleviate the noise impact on the NSRs.

However, construction noise is expected to be audible at R13, R14, R15, R16, R17, R18 and R33 and there is likely to be some degree of adverse impact, as is typical with construction projects in close proximity to people. However, by incorporating noise control measures, the noise impact to noise sensitive areas can be significantly reduced. Construction noise from the proposed development can be managed through a Construction Noise and Vibration Management Plan (CNVMP) to minimise the adverse impact to acceptable levels.

7.6 Construction Noise Control Measures and Management

The opportunities for practical physical noise control are few given the transient and constantly moving nature of the construction work. Concerns from residents can be alleviated by implementing some noise mitigation measures. In cases where multiple noise complaints are received, mobile noise barriers/enclosures during certain construction work, such as around stationary work activities and plant, can be used to mitigate construction noise. Examples of mobile enclosure and demountable noise barriers are shown in Figure 9 and Figure 10 respectively.

Figure 9: Illustration of a mobile enclosure and barrier



Key

1 Acoustic screen 2 m wide and 2.7 m high

2 Acoustic shed 2 m square and 2.7 m high

Figure 10: Photos demountable noise barriers

In other circumstances, management measures should be employed to minimise the construction noise impact onto residential premises. These can include:

- Informing and consulting residents and interested parties, as far as practicable, regarding impending or current events that may cause high levels of noise and how long they are expected to take. This may take the form of letter-drops, or community notices
- Provide a complaints telephone number prominently displayed where the works are taking place and on any letter-drops or community notices
- Respite hours agreed with residents when noisy works will not take place if necessary
- Investigate complaints when received to establish the cause, and where possible implement a corrective action such as, provide a respite period or other practical measure
- Minimising the operating noise of machinery brought on to the site
- Where appropriate, obtaining acoustic test certificates for machinery brought on to the site
- Undertake noise monitoring at the start of a new noisy activity so noise levels can be investigated should a complaint be received
- If there is excessive noise from any process, that process will be stopped and if possible that noise attenuated to acceptable levels. Where there is no alternative the process will be rescheduled to non-sensitive hours
- Ensuring that plant is not left idling when not in use
- Ensuring that plant is well maintained and in good working order and not causing unnecessary noise, such as damaged mufflers on plant, and
- All access hatches for plant to be kept closed.

8 Construction Vibration Assessment

The risk of vibration caused by the construction works onto nearby buildings is considered highly unlikely due to the type of activities taking place and the high levels of vibration required to cause damage.

It is recommended to set a conservative building damage vibration criterion so that in the unlikely event that the criterion is exceeded, the construction works can be stopped and the vibration damage established. If no damage is observed and after the resident's fears have been allayed, the works can resume. The recommended vibration criterion for building damage is set at **5mm/s PPV.**

The greatest risk of vibration causing an adverse impact to the residents is by causing discomfort or fear of damage to their premises.

For reference, the safe working distances for vibration causing plant which may be used during the construction activities have been taken from the *Transport Infrastructure Development Corporation Construction Noise Strategy (Rail Projects) 2007* and are summarised in Table 19.

Table 19: Recommended safe working distances

Plant Item	Rating/Description	Safe Working Distance, in metres	
		Cosmetic Damage (BS7385[9])	Human Response (AS2670)
Vibratory Roller	<50kN (1-2t)	5	15 to 20
Vibratory Roller	<100kN (2-4t)	6	20
Vibratory Roller	<200kN (4-6t)	12	40
Vibratory Roller	<300kN (7-13t)	15	100
Small Hydraulic Hammer	300kg – 5 to 12t excavator	2	7
Medium Hydraulic Hammer	900kg – 12 to 18t excavator	7	23
Vibratory Pile Driver	Sheet piles	22	73

8.1 Discussion and Recommendations

R18 and R13 are the only residences within 100 metres of the construction site at approximately 60 metres and 80 metres respectively. An exceedance of the human comfort criteria is most likely to be caused at R18 and R13 if a 7-13t vibratory roller is used during construction works.

To minimise any risk of exceedances of the human comfort criteria, it is recommended to use a vibratory roller of less than 7 tonnes at distances of less than 100 metres from R18 and R13. A smaller vibratory roller to suit the required buffer distance as given in Table 19, is preferable.

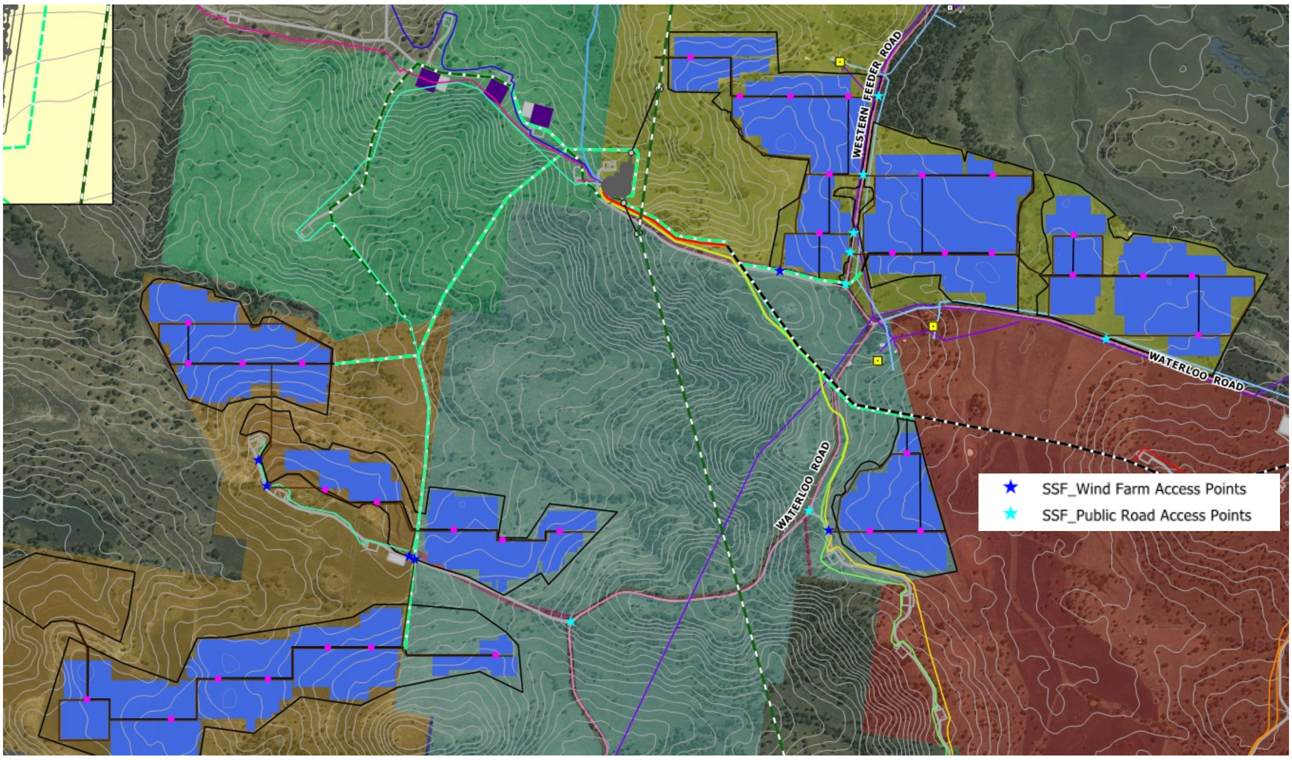
However, cosmetic damage to the residences is not expected from the construction works.

[9] BS 7385 -2: 1993 Guide to damage levels from ground borne vibration

9 Construction Traffic Noise Assessment

The site will be accessed directly off Waterloo and Western Feeder roads. Permanent access locations are illustrated in Figure 11. During construction, access may be required through existing gate entrances to the site to accommodate an efficient workflow.

Figure 11: Access Locations



Waterloo Road joins the Gwydir Highway, a Roads and Maritime Services (RMS) Classified State Road southeast of the project boundary. The intersection between the Gwydir Highway and Waterloo Road has been upgraded to accommodate over-dimensional equipment for SWF, and it is not expected that further upgrades would be required for the Proposed Development.

Staffing arrangements during construction will depend on the staging of the development. The construction phase is expected to last 12-18 months with an estimated peak staff of 100.

Furthermore, deliveries will depend on the day-to-day operational requirements. Heavy vehicle movements into the site are estimated to be up to 30 vehicles per day at the start of the construction activities. As the construction phase progresses the number of heavy vehicles will reduce.

Overall traffic movements during construction will be up to 100 light vehicles and 30 heavy vehicles daily.

9.1 Construction Traffic Noise Predictions

The construction traffic noise impact has been predicted to the residences and compared to the NSW Road Noise Policy criteria given in Table 8. The assessment considers the following:

- Noise sources:
  - Heavy Vehicle (HV) pass-by noise level of **86 dB(A) L_{eq}** measured at 15 metres from the road
  - Light Vehicle (LV) pass-by noise level of **71 dB(A) L_{eq}** measured at 15 metres from the road
- Average of five HVs and 17 LVs pass-bys per hour.

Construction traffic noise has been predicted to the closest residences to the roads, which are R13, R14, R17 and R18. The results are summarised in

Table 20: Construction Traffic Noise Predictions

Residence Ref. (Refer to Figure 2	Approx. distance of Residence to nearest road, in metres	Predicted noise levels $L_{eq,1hour}$, in dB(A)	Compliance with NSW Road Noise Policy criteria of 55 dB(A) $L_{eq,1hour}$?
R13	90	47	✓
R14	110	45	✓
R17	70	49	✓
R18	225	39	✓

The results show that compliance with the NSW Road Noise Policy criteria is achieved at the closest residences. Other residences located further away from the roads are also expected to achieve compliance due to additional distance attenuation.

However, considering the highest noise impact of a truck with articulated trailer, the approximate maximum pass-by noise level is **81 dB L_{Amax}** at 10m (Source: DEFRA database, Table 2, Ref. No. 33 Articulated Dump Truck). This translates to a predicted noise level, incident at the façade of the residences at R13, R14, R17 and R18, of **53-64 dB L_{Amax}**. At 500 metres and 1 kilometre away from the truck, a pass-by noise level of **47 dB L_{Amax}** and **41 dB L_{Amax}** is predicted respectively.

Construction traffic noise will still be audible and noticeable due to the very low background noise levels in the area (23-27 dB(A) L_{90}). However, due to the very short duration of the pass-bys, the risk of an adverse noise impact being caused to residents is considered low.

10 Operational Noise Assessment

This section of the report addresses the operational noise impact of the proposed development onto noise sensitive receivers. The assessment includes:

- Prediction of noise emissions from the operation activities of the solar farm
- Comparison of predicted noise emissions to noise criteria derived from the NSW Noise Policy for Industry, and,
- Provide noise mitigation measures, if any, to ensure compliance with the criteria.

10.1 General Operation

The farm will operate independently and four to six permanent employees will be stationed on-site. The farm will be monitored remotely from an off-site location and apart from a routine maintenance program, operators will only visit the farm when responding to any performance issues (i.e. where actual output measured by the monitoring system deviates from generation forecasts and other key performance metrics).

Activities at the farm that will be part of a routine maintenance program will generally be limited to:

- Equipment, cabling, substation and communications system inspection and maintenance
- Fence, access road and control room management
- Vegetation (fuel load), weed and pest management
- Possible solar PV module washing on an as-needed basis
- Security monitoring, and
- Communicating with customers, transmission and distribution network operators, Australian Energy Market Operator (AEMO), Council, neighbours and other stakeholders.

Noise impact from general operation is expected to be negligible.

10.2 Noise Impact of Inverters

The assessment involves predicting minimum buffer distances for the inverters to meet the NSW Noise for Industry criteria. The predicted buffer distances consider the following:

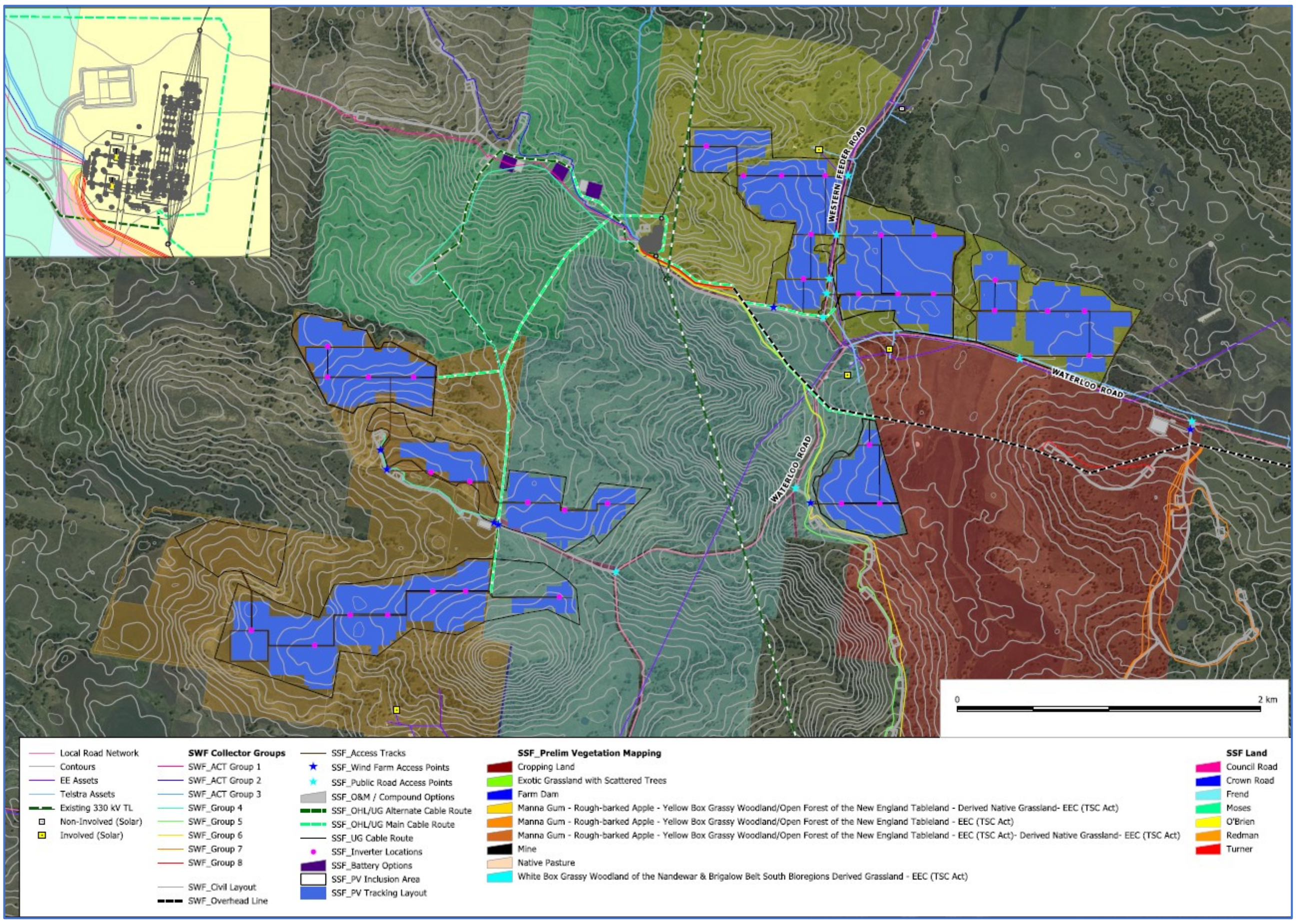
- Source sound levels of the inverters
- Distance attenuation, and

- Atmospheric, meteorological and ground attenuation using the CONCAWE[10] method for distances between the source and receiver greater than 100m.

Further, we have made the following assumption in our calculations:

- The source sound levels used in the calculations are as follows:
    - **Inverters** – Sound power level **94 L_{WA}**
- There are approximately 31 inverters spread over the solar farm site, as shown in Figure 12.

Figure 12: Location of inverters



- Similarly to the construction noise assessment, a worst-case meteorological scenario has been modelled using CONCAWE Met Category 6 (worst-case) for the substations, and also with Category 4 (zero meteorological influence - neutral/average case) for the inverters given their closer proximity to the noise sensitive receivers.

[10] CONCAWE – the propagation of noise from petroleum and petrochemical complexes to neighbouring communities. Report no.4/81, 1981

10.3 Results and discussion

Operational noise levels have been predicted at various distances from the inverters to show the impact of buffer distances with respect to the criterion. For distances greater than 100 metres, in addition to distance attenuation the CONCAWE environmental prediction methods for atmospheric, meteorological (category 6 – greatest increase in noise) and ground attenuation has been applied to the prediction.

In addition to using the worst-case meteorological category 6 for the prediction of noise levels from the inverters at the various buffer distances, a neutral/average case (meteorological category 4) where there is no impact on noise levels has been used for comparison. This may help in setting suitable minimum buffer distances.

Table 21: Predicted inverter noise levels at various buffer distances versus criterion

Plant Type	Source noise level, dB(A)	Distance from plant, m	Predicted noise level dB(A) Met Category 6 (worst-case)	Predicted noise level dB(A) Met Category 4 (neutral/average case)	Compliance with noise criteria of 40 dB L_{Aeq}?	
					Met Category 6	Met Category 4
Inverter	94 dB L_{WA}	50	52	52	✘	✘
		100	45	45	✘	✘
		200	38	35	✓	✓

Table 21 shows that when assuming the worst-case meteorological category 6 in the noise prediction for the inverters, the noise criterion is met by 2 dB at approximately 200 metres. When the neutral/average case meteorological category 4 is used, where there is assumed to be no meteorological influence on noise propagation the criterion is also met at 200 metres by 5 dB.

The inverters are generally 200-250 metres away from each other, minimising the risk of cumulative noise impact of multiple inverters at the noise sensitive receivers. The closest noise sensitive receiver is more than 200 metres from its closest inverter. Therefore, compliance is expected to be achieved at all noise sensitive receivers.

It is concluded that noise from the operation of the solar farm is not expected to adversely impact the noise sensitive receivers.

The above predictions and recommendations for buffer distances are contingent of the noise source level data for the inverters being accurate. Should the assumed noise levels presented above change significantly, the buffer distances should be reviewed accordingly.

11 Conclusion

TTM has carried out construction noise and vibration and operational noise assessments for the proposed Sapphire South Solar Farm project.

TTM predicted construction noise levels from the various phases of construction at the nearest identified noise sensitive receivers (NSRs), using a worst-case scenario of all plant and equipment associated with each respective stage of the construction process. The predictions show that construction noise is expected to be audible at the NSRs and there is likely to be some degree of adverse impact. A Construction Noise and Vibration Management Plan (CNVMP) is recommended to minimise the adverse impact to acceptable levels, incorporating good practice construction noise control measures and management.

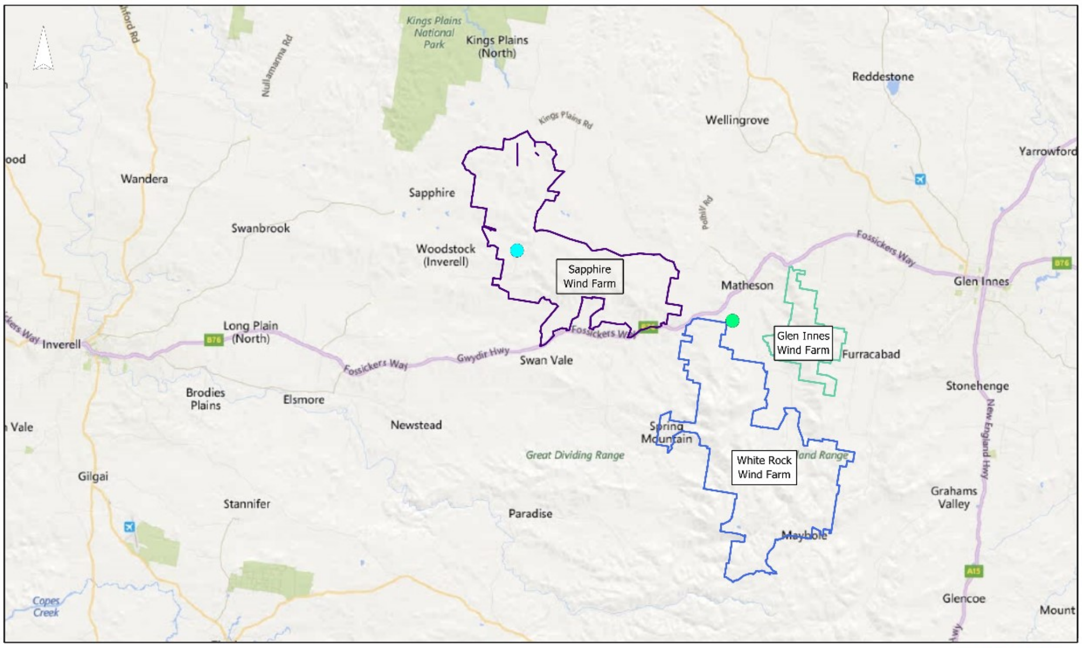
TTM also assessed the risk of vibration by the construction works onto nearby buildings. Safe working distances for vibration causing plant have been provided. The assessment concluded cosmetic damage to the residences is not expected from the construction works. However, to minimise the risk of exceeding the human response criterion, a vibratory roller of less than 7 tonnes is recommended to be used within 100 metres of R18 and R13.

Construction traffic on public roads has been assessed and the risk of an adverse noise impact to residential properties is considered low.

Noise generated from the operation of the solar farm has also been assessed and are not expected to adversely impact the noise sensitive receivers.

Overall this noise assessment report has shown that noise and vibration associated with the construction and operation of the Sapphire South Solar Farm can be controlled and managed to acceptable levels.

Appendix A Relevant Development Plans

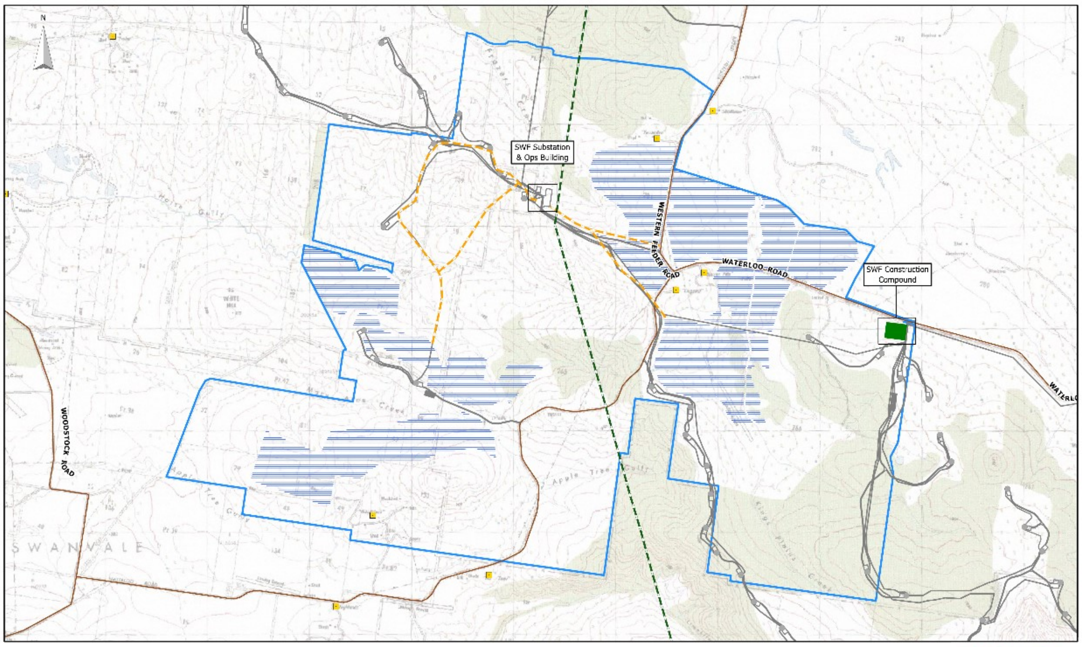


LEGEND

Sapphire Solar Farm
White Rock Solar Farm
Glen Innes Wind Farm
Sapphire Wind Farm
White Rock Stage 1

SCALE BAR 0 10 km

COMPANY	SAPPHIRE SOLAR FARM PTY LTD				
TITLE	SAPPHIRE SOLAR: LOCAL CONTEXT				
DATE 07 JULY 2017	SCALE 1:210000	DWG NO SAP-135	REV A	VER 1	
DRAWN BY B KRONENBERG	CHECKED BY E MOUNSEY	SHEET 1 OF 1	JOB NO 080602	SIZE A3	

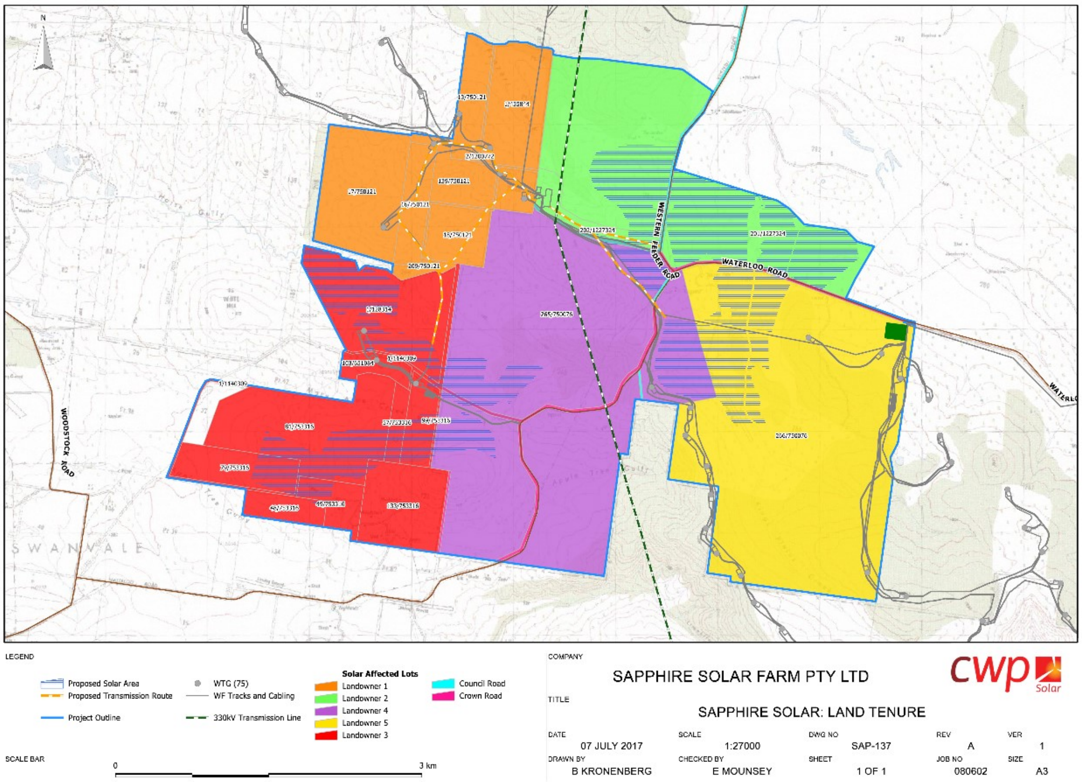


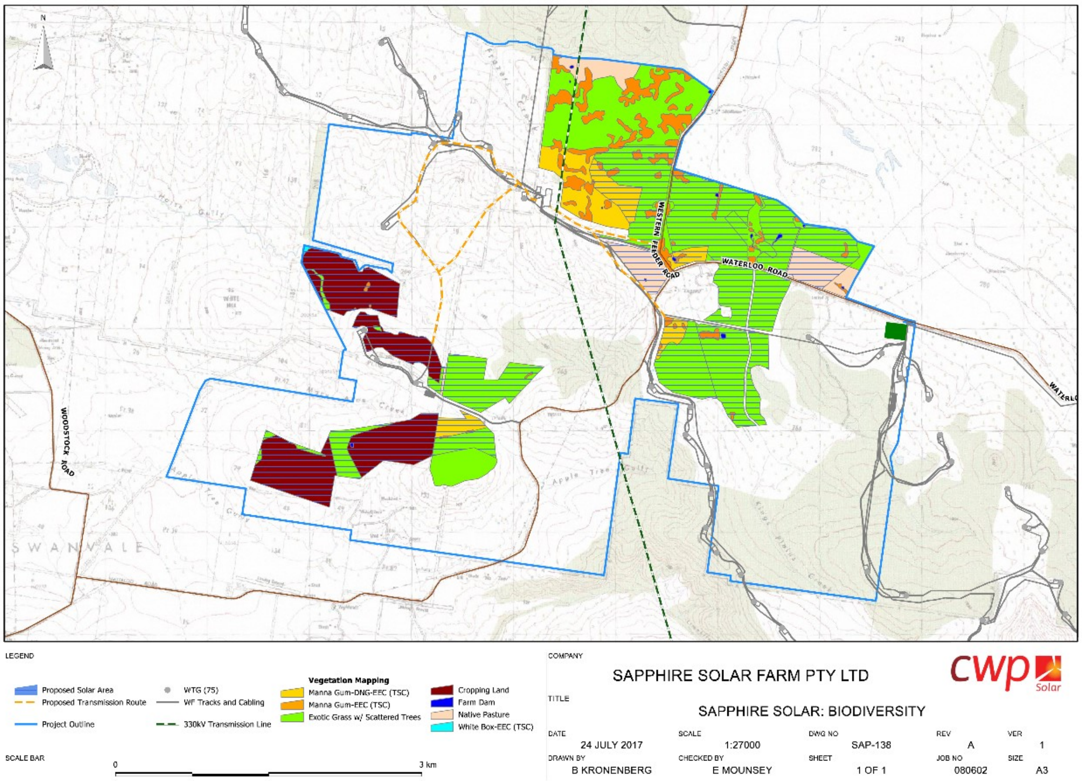
LEGEND

Proposed Solar Area
Proposed Transmission Route
Project Outline
WTG (75)
WF Tracks and Cabling
330kV Transmission Line
Residence

SCALE BAR 0 3 km

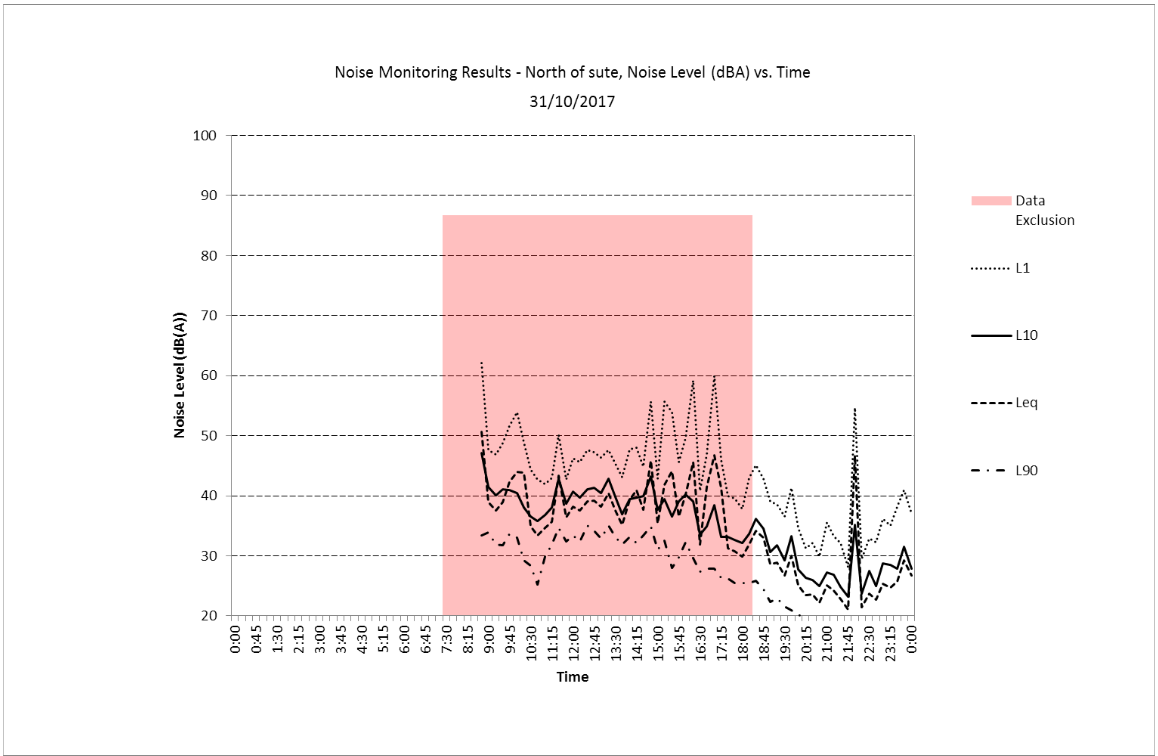
COMPANY	SAPPHIRE SOLAR FARM PTY LTD				
TITLE	SAPPHIRE SOLAR: PROPOSED SITE				
DATE 07 JULY 2017	SCALE 1:27000	DWG NO SAP-136	REV A	VER 1	
DRAWN BY B KRONENBERG	CHECKED BY E MOUNSEY	SHEET 1 OF 1	JOB NO 080602	SIZE A3	

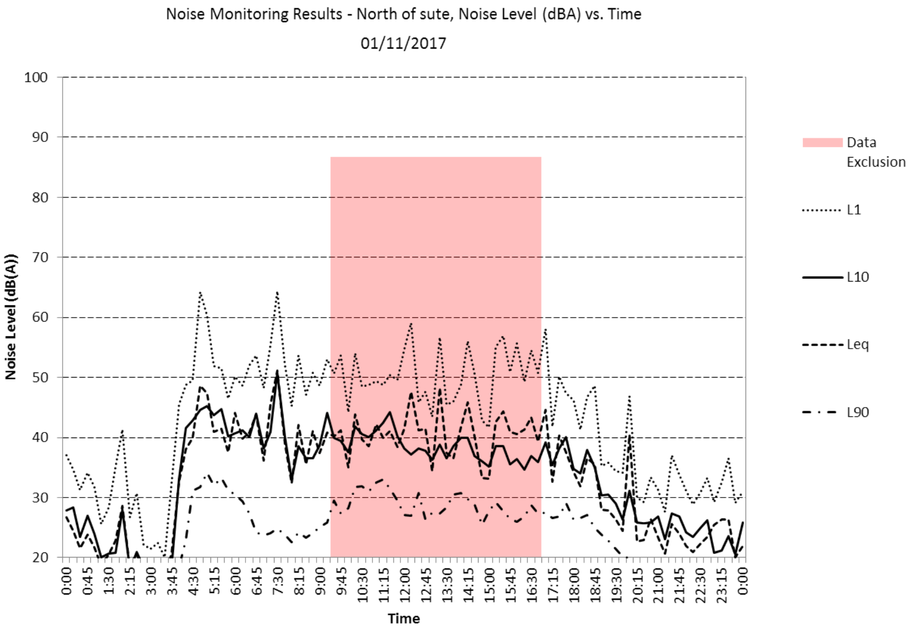

WESTERN FEEDER ROAD
WATERLOO ROAD
WOODSTOCK ROAD
SWANVALE
LEGEND
Proposed Solar Area
Proposed Transmission Route
Project Outline
WTG (75)
WF Tracks and Cabling
330kV Transmission Line
Solar Affected Lots
Landowner 1
Landowner 2
Landowner 4
Landowner 5
Landowner 3
Council Road
Crown Road
SCALE BAR
0
3 km
COMPANY
SAPPHIRE SOLAR FARM PTY LTD
TITLE
SAPPHIRE SOLAR: LAND TENURE
DATE
07 JULY 2017
SCALE
1:27000
DWG NO
SAP-137
REV
A
VER
1
DRAWN BY
B KRONENBERG
CHECKED BY
E MOUNSEY
SHEET
1 OF 1
JOB NO
080602
SIZE
A3
cwp Solar

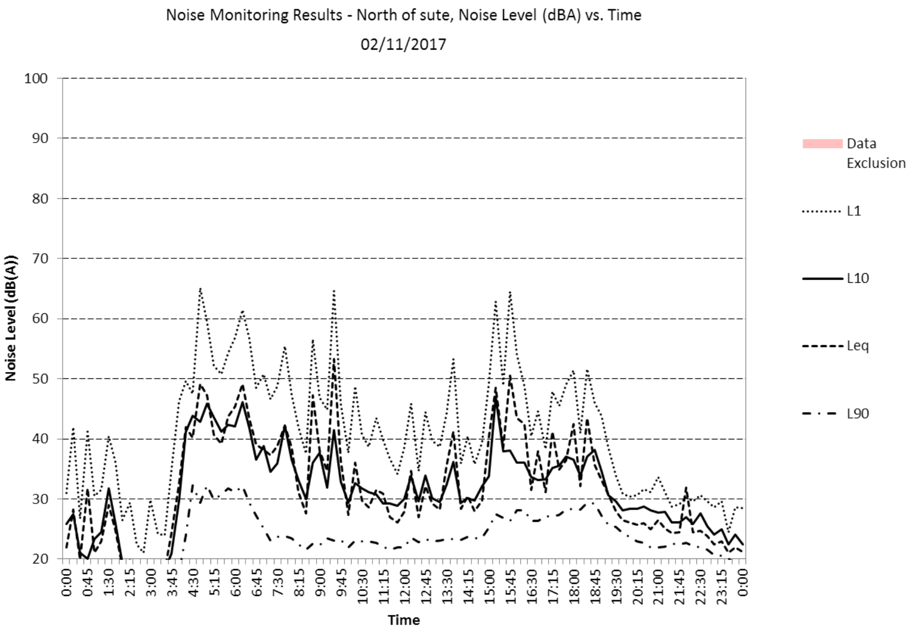

WESTERN FEEDER ROAD
WATERLOO ROAD
WOODSTOCK ROAD
SWANVALE
LEGEND
Proposed Solar Area
Proposed Transmission Route
Project Outline
WTG (75)
WF Tracks and Cabling
330kV Transmission Line
Vegetation Mapping
Manna Gum-DNG-EEC (TSC)
Manna Gum-EEC (TSC)
Exotic Grass w/ Scattered Trees
Cropping Land
Farm Dam
Native Pasture
White Box-EEC (TSC)
SCALE BAR
0
3 km
COMPANY
SAPPHIRE SOLAR FARM PTY LTD
TITLE
SAPPHIRE SOLAR: BIODIVERSITY
DATE
24 JULY 2017
SCALE
1:27000
DWG NO
SAP-138
REV
A
VER
1
DRAWN BY
B KRONENBERG
CHECKED BY
E MOUNSEY
SHEET
1 OF 1
JOB NO
080602
SIZE
A3
cwp Solar

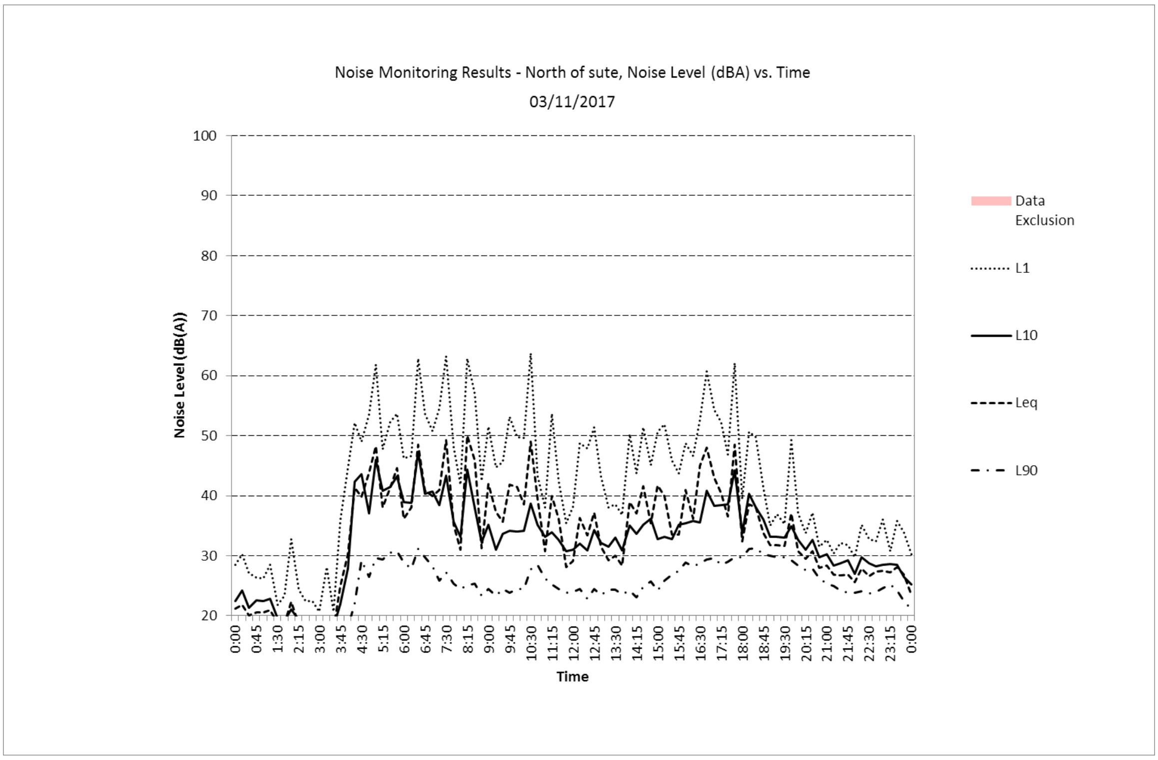
Appendix B Unattended Noise Monitoring Graphs

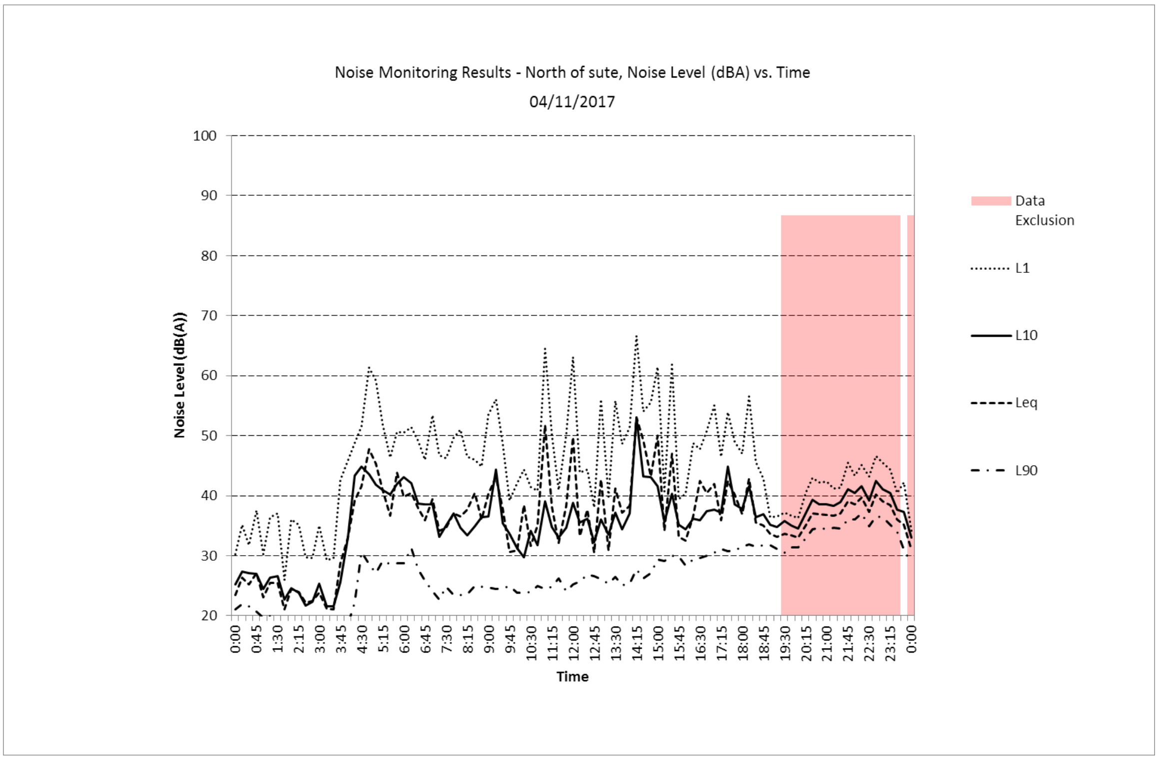
Location 1 – North of site

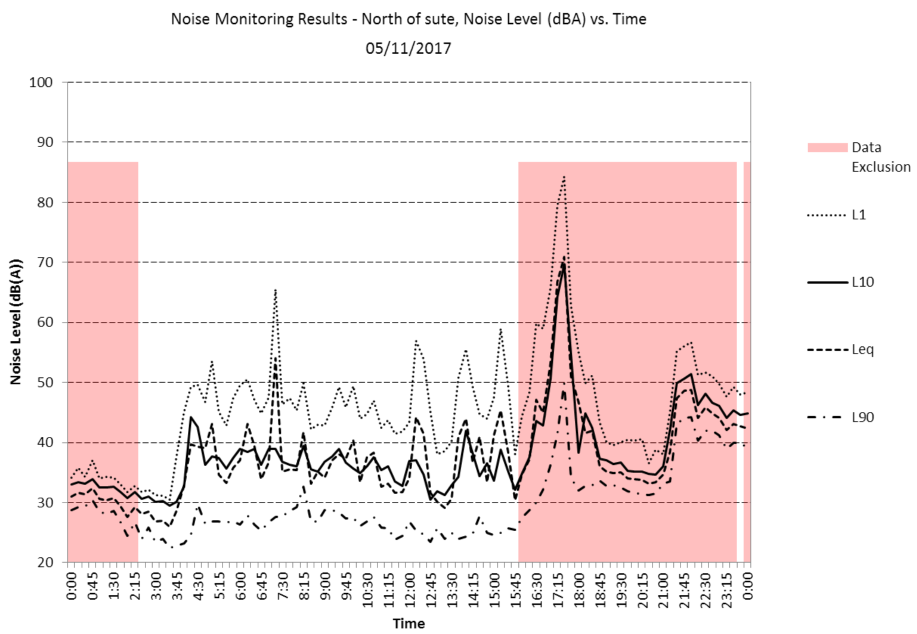



Noise Monitoring Results - North of sute, Noise Level (dBA) vs. Time
01/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90

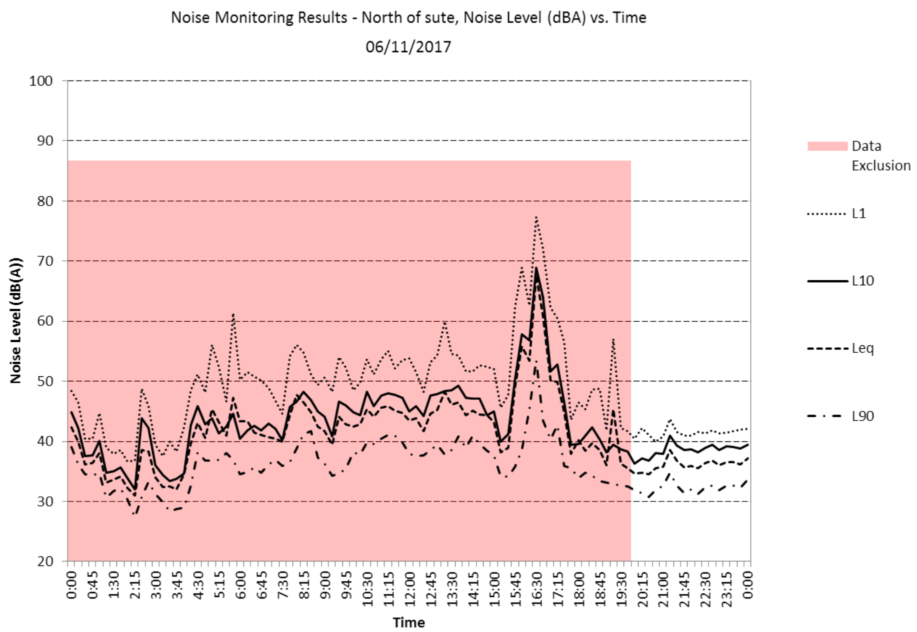

Noise Monitoring Results - North of sute, Noise Level (dBA) vs. Time
02/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90


Noise Monitoring Results - North of sute, Noise Level (dBA) vs. Time
03/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90

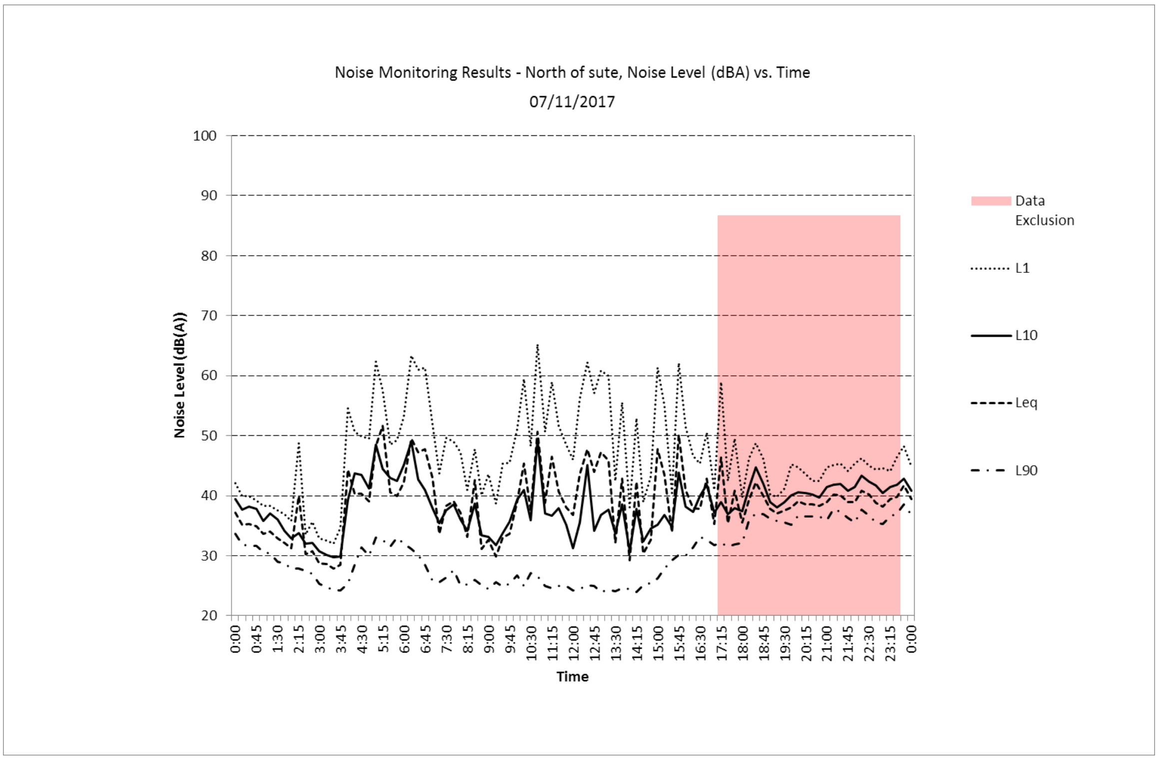

Noise Monitoring Results - North of sute, Noise Level (dBA) vs. Time
04/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90



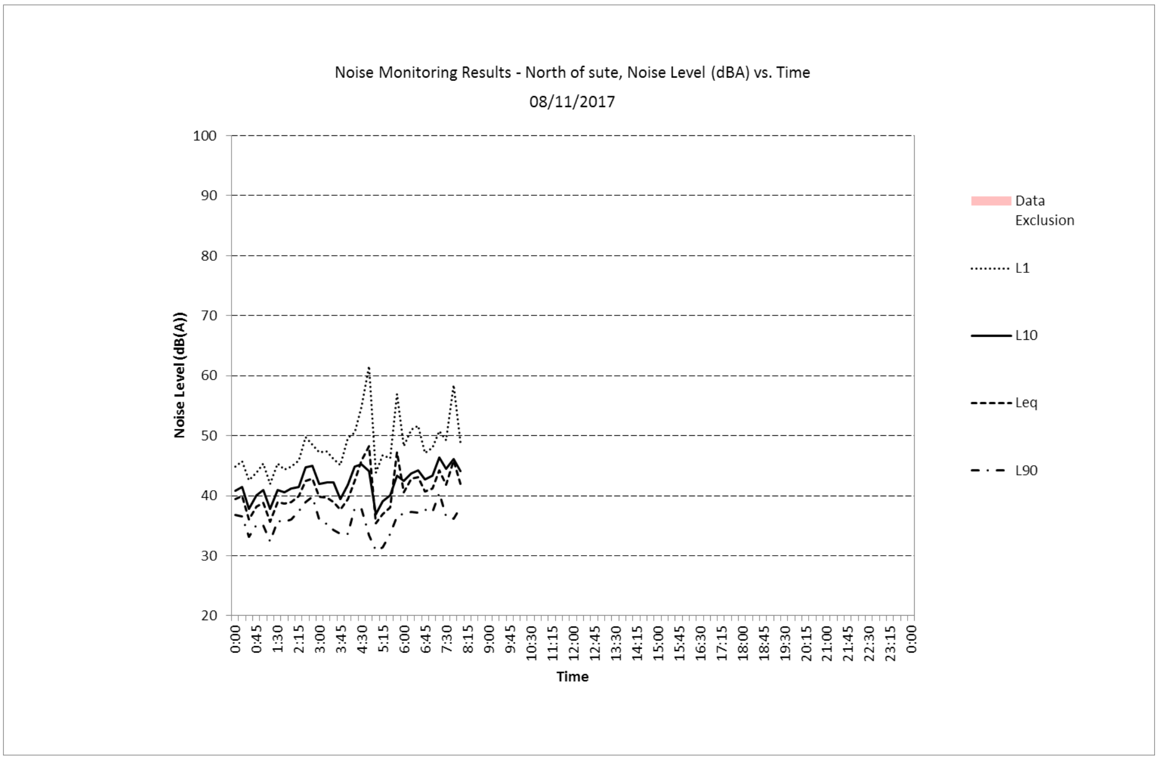
Noise Monitoring Results - North of sute, Noise Level (dBA) vs. Time
05/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90



Noise Monitoring Results - North of sute, Noise Level (dBA) vs. Time
06/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90

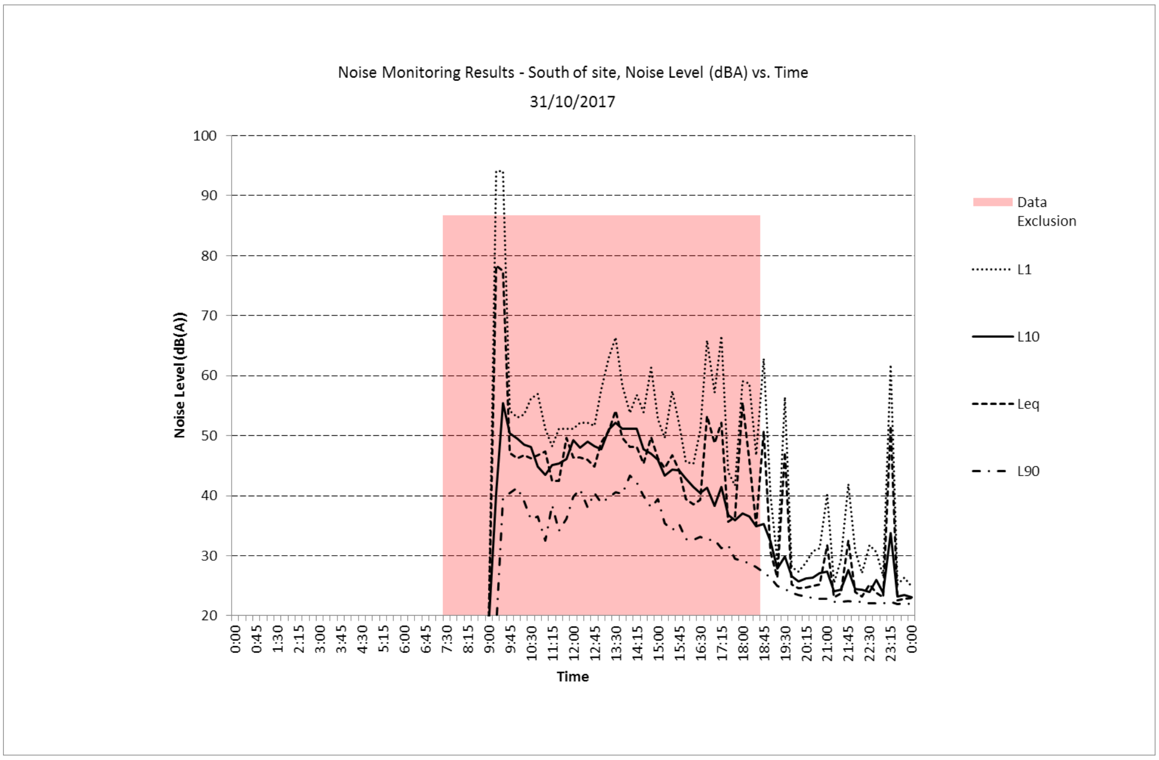


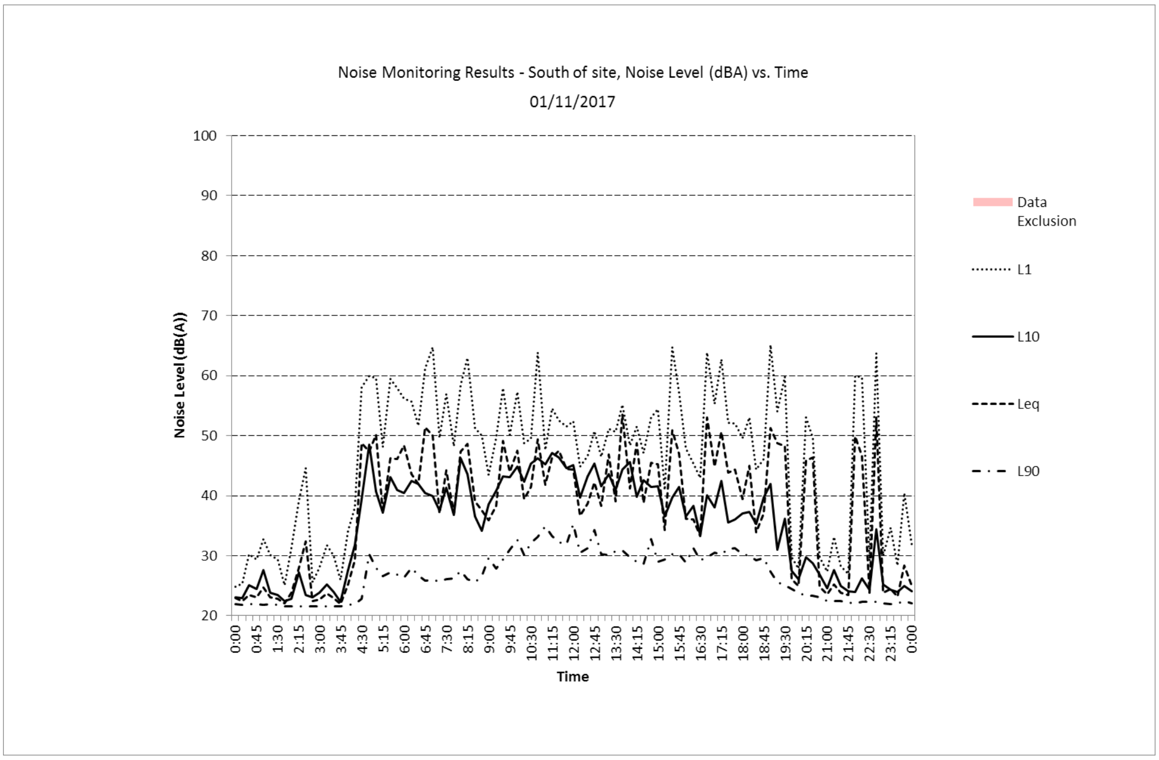
Noise Monitoring Results - North of sute, Noise Level (dBA) vs. Time
07/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90

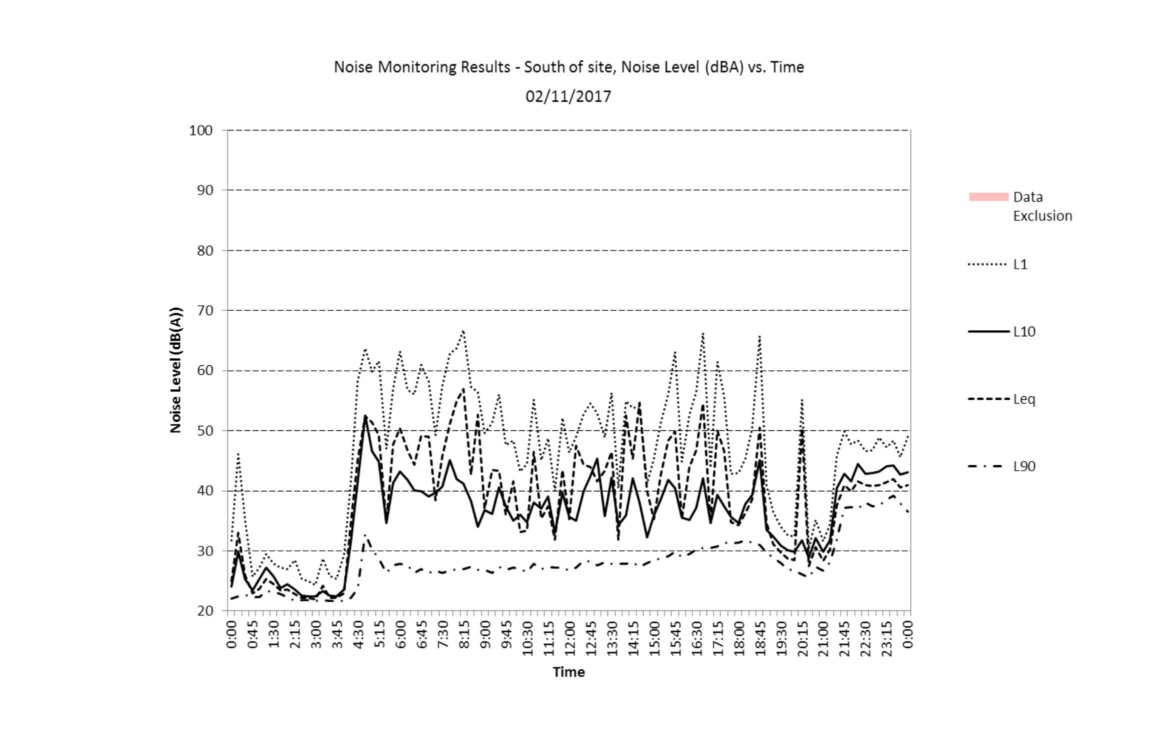


Noise Monitoring Results - North of sute, Noise Level (dBA) vs. Time
08/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90

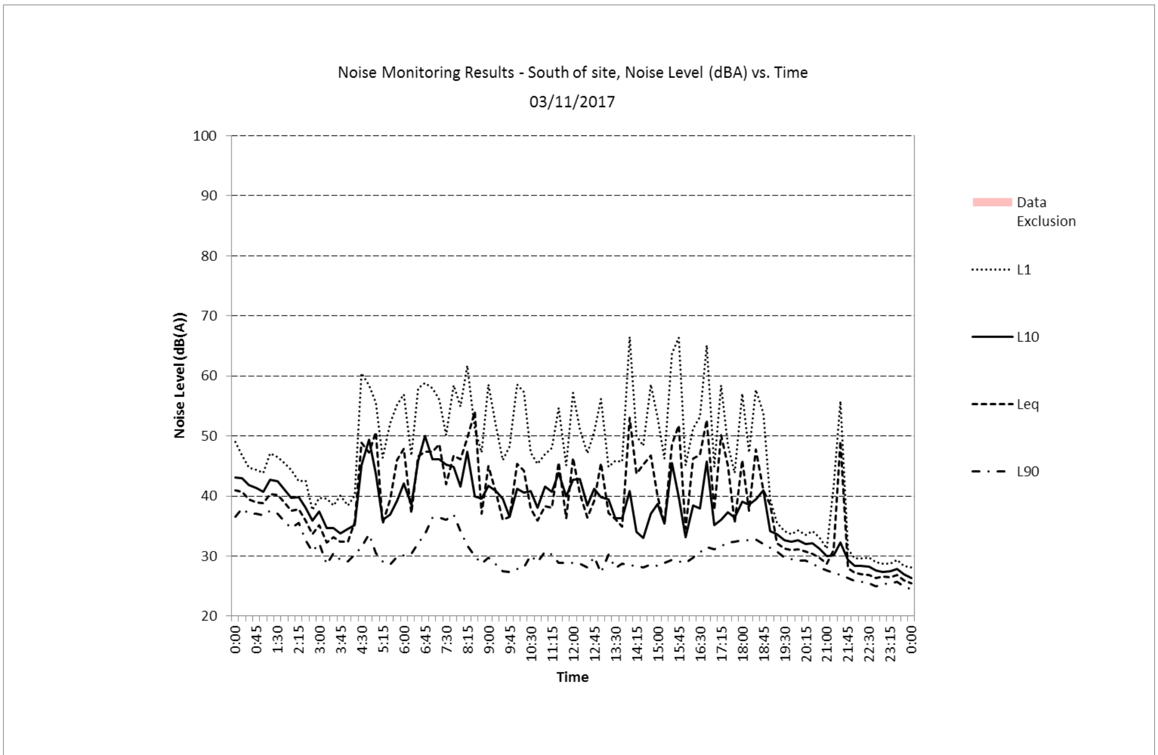
Location 2 – South of site



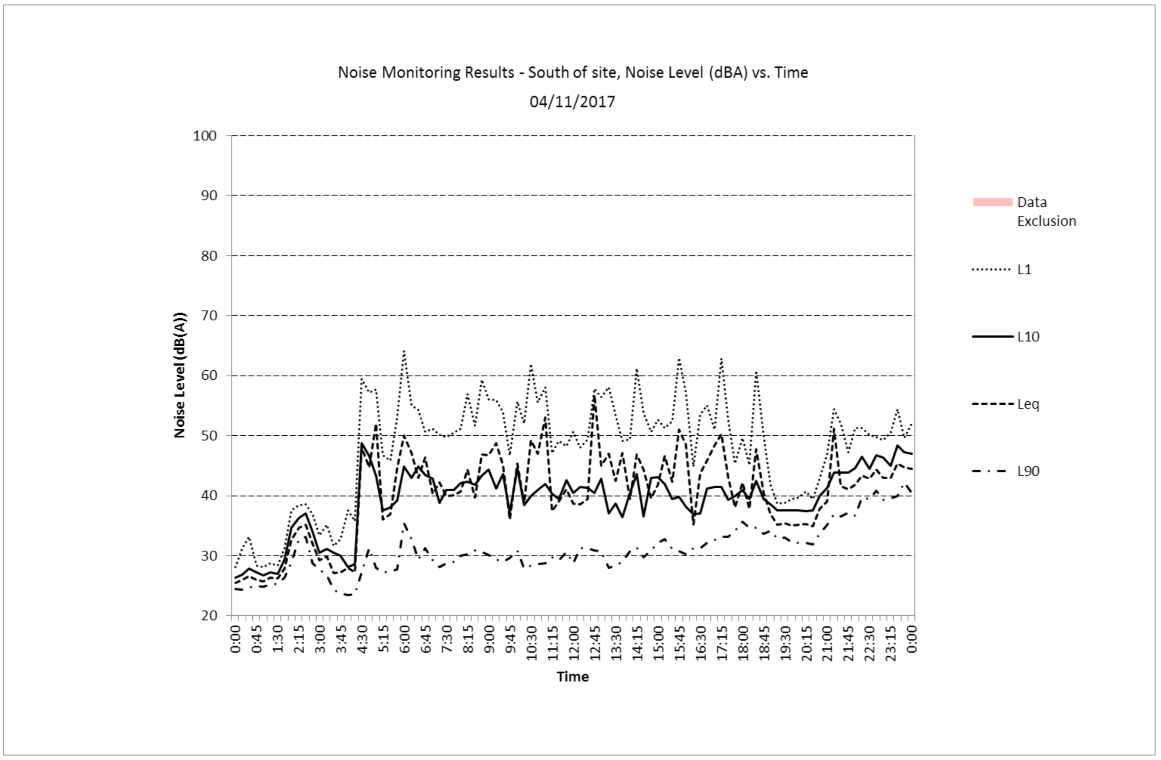


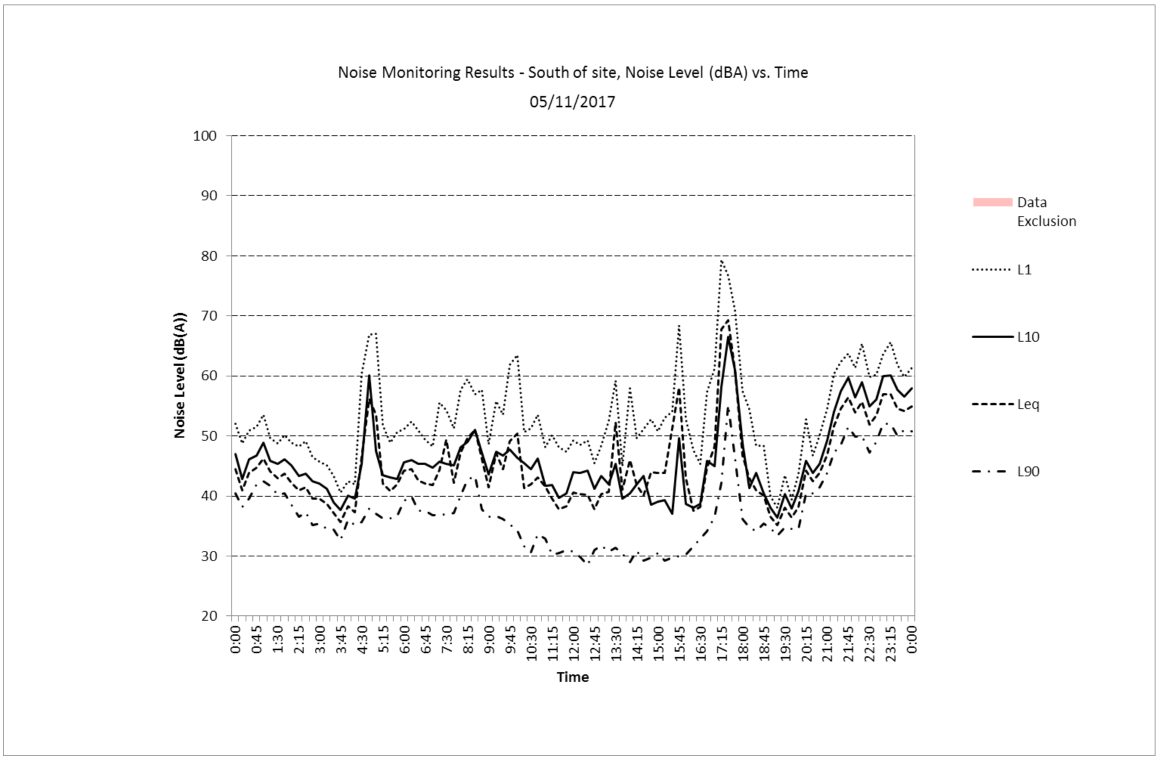


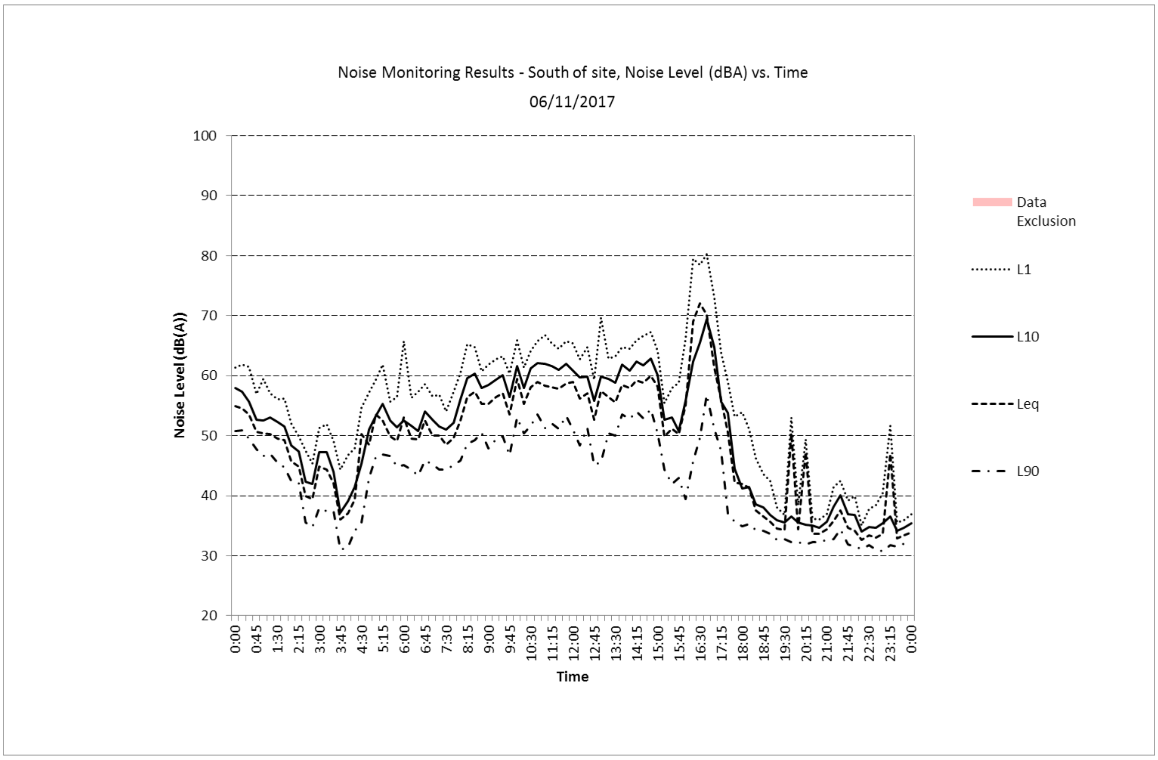
Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
02/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90

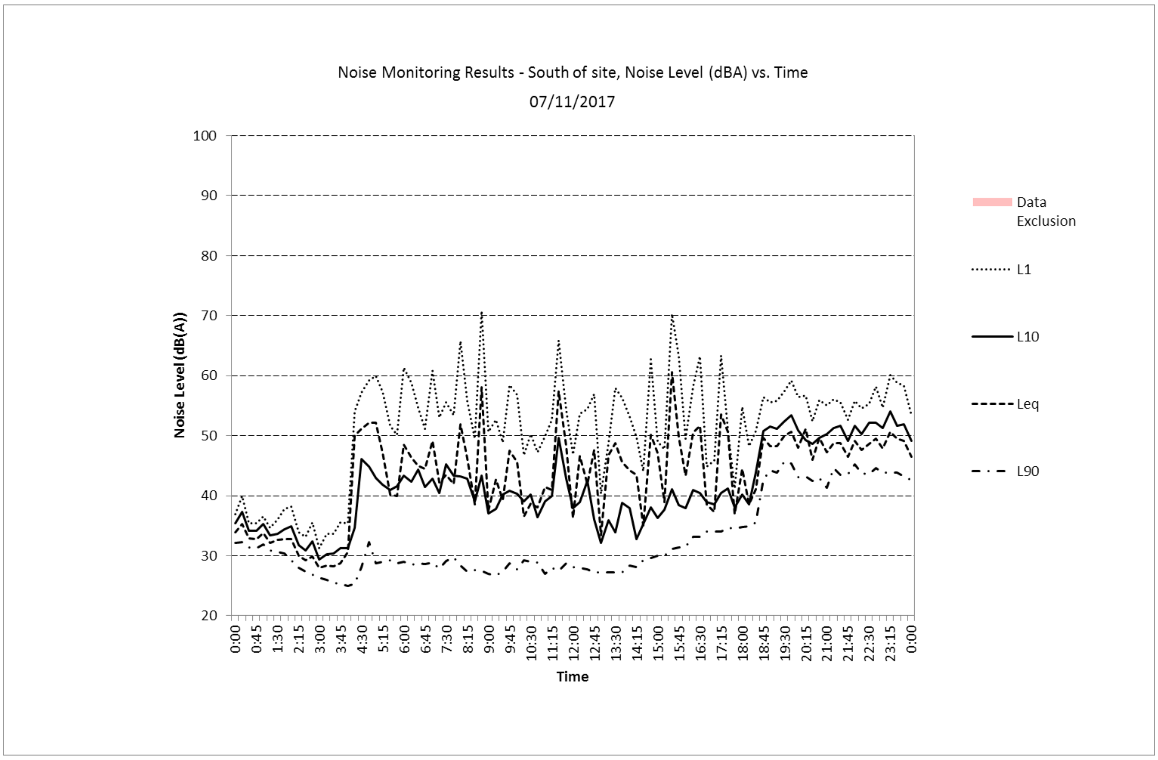


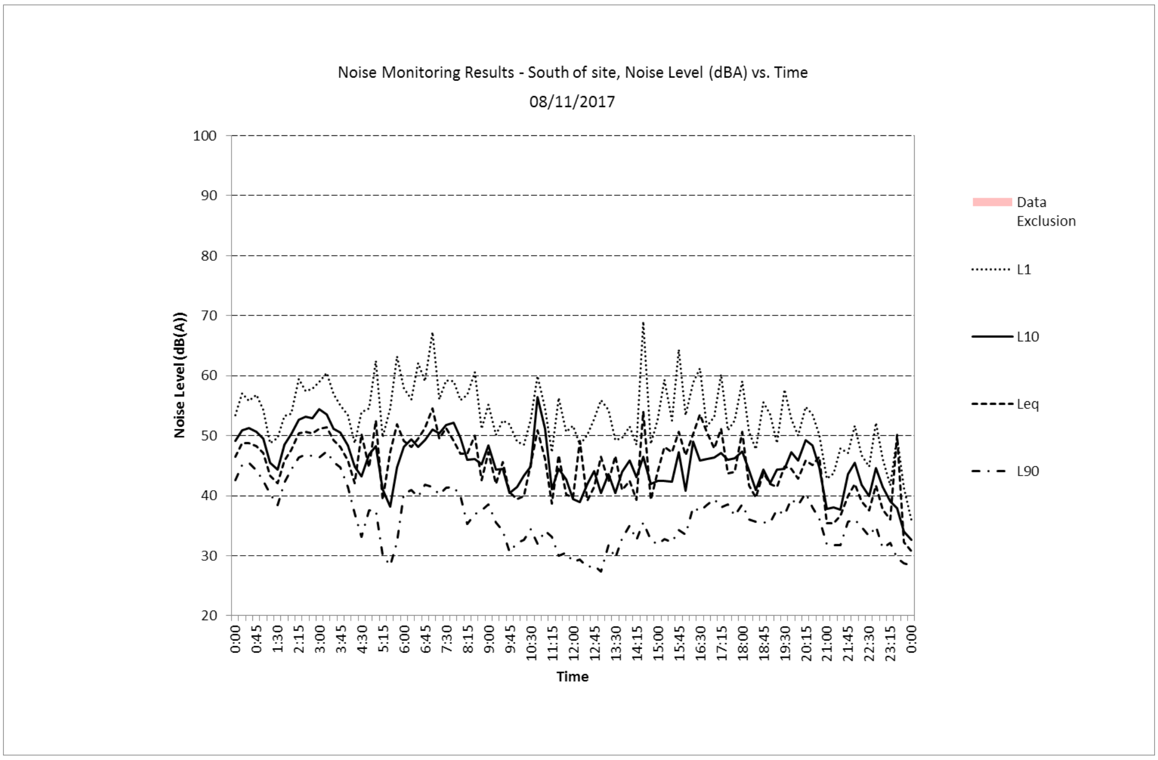
Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
03/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90

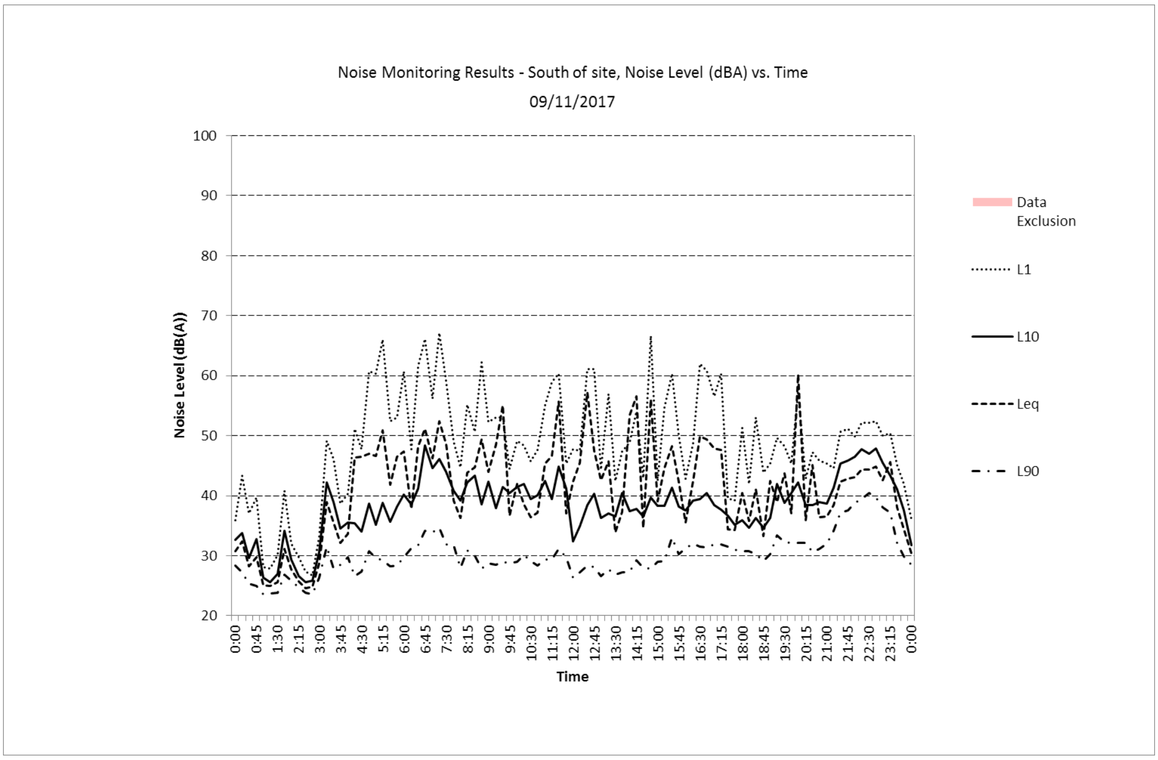

Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
04/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90


Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
05/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90


Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
06/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90


Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
07/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90


Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
08/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90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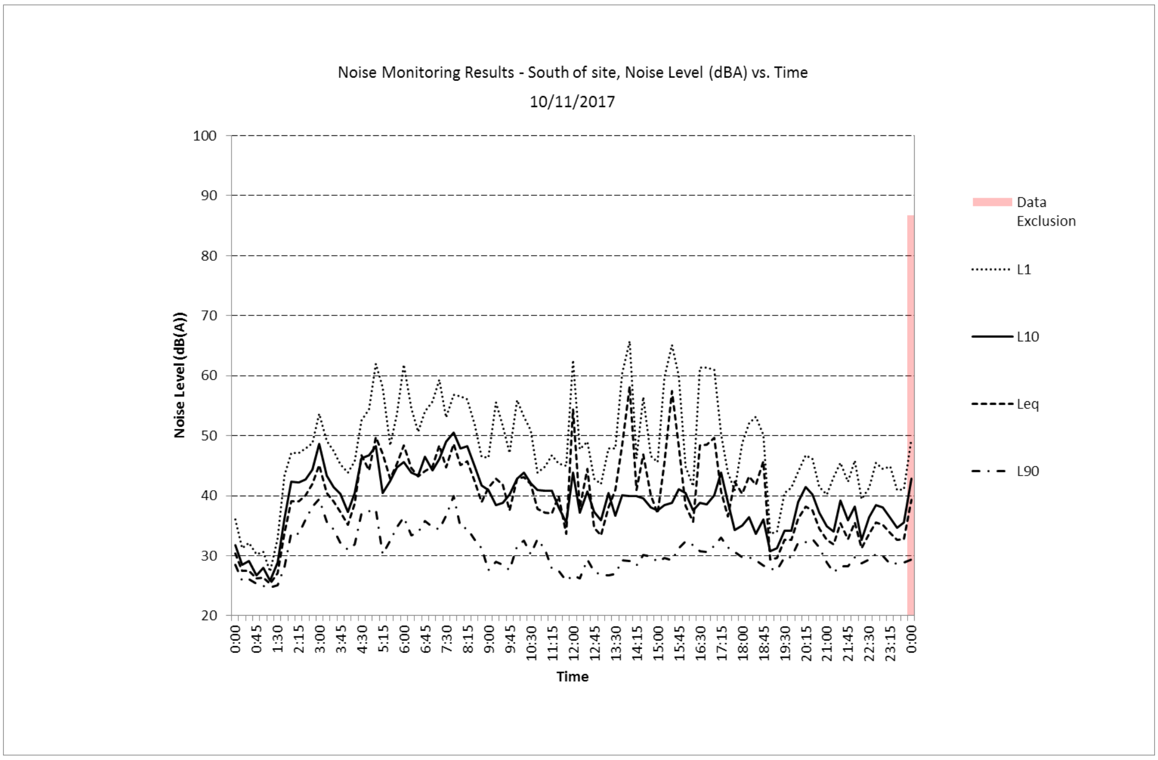
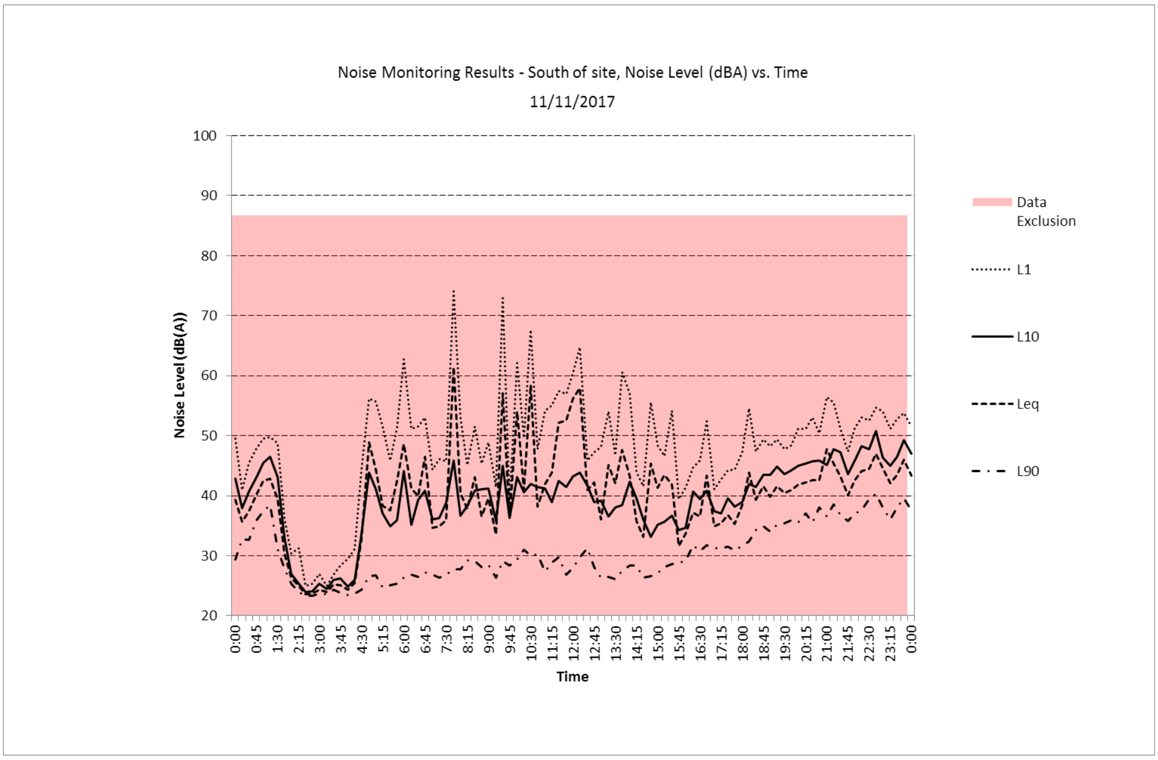
09/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90


Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
10/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90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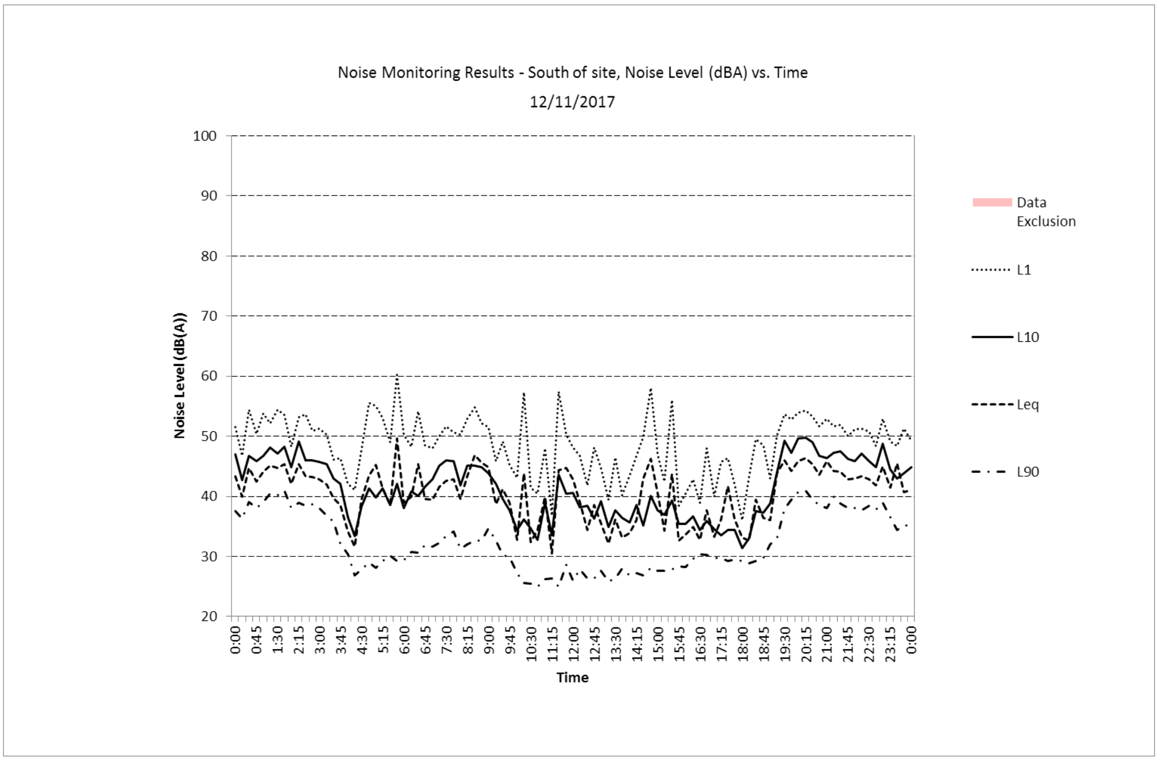
11/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90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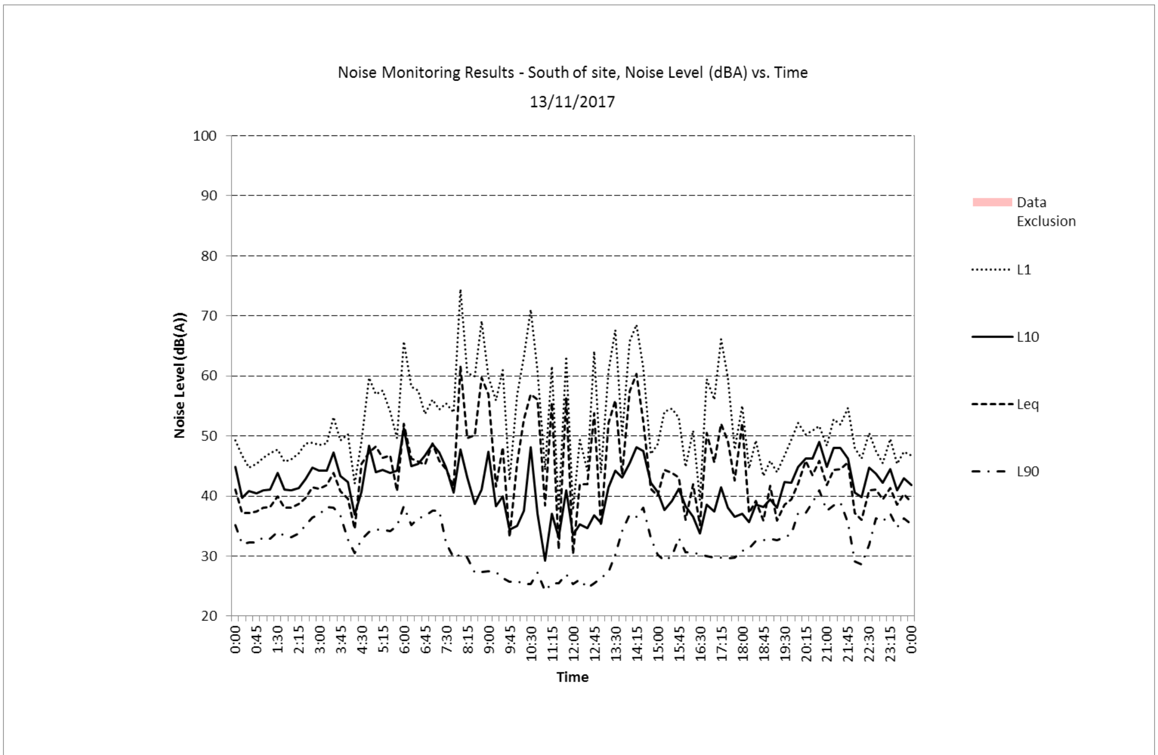
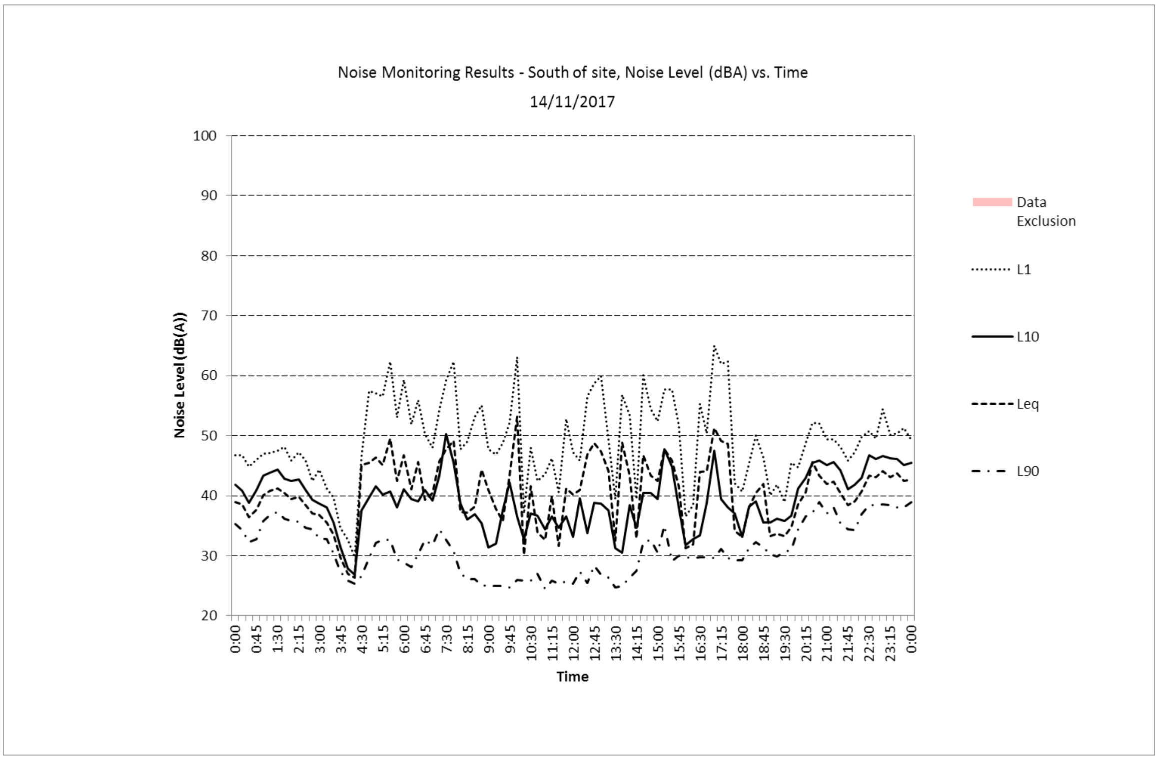
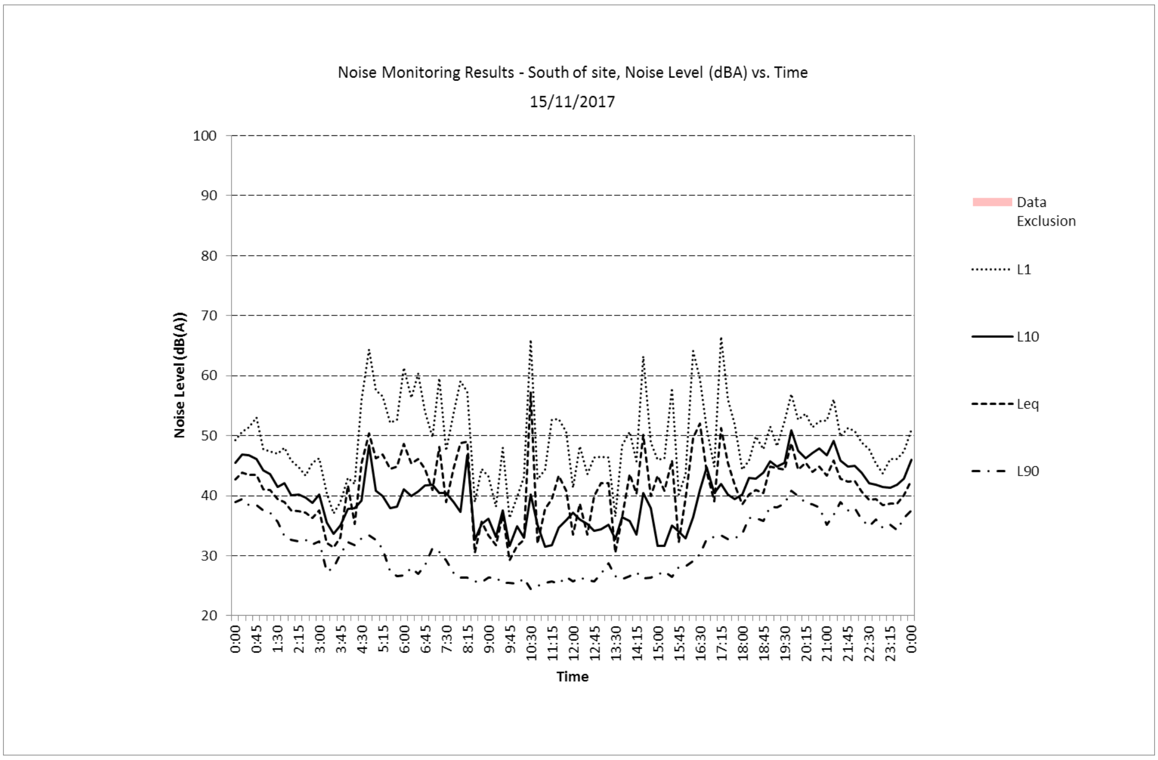
12/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90

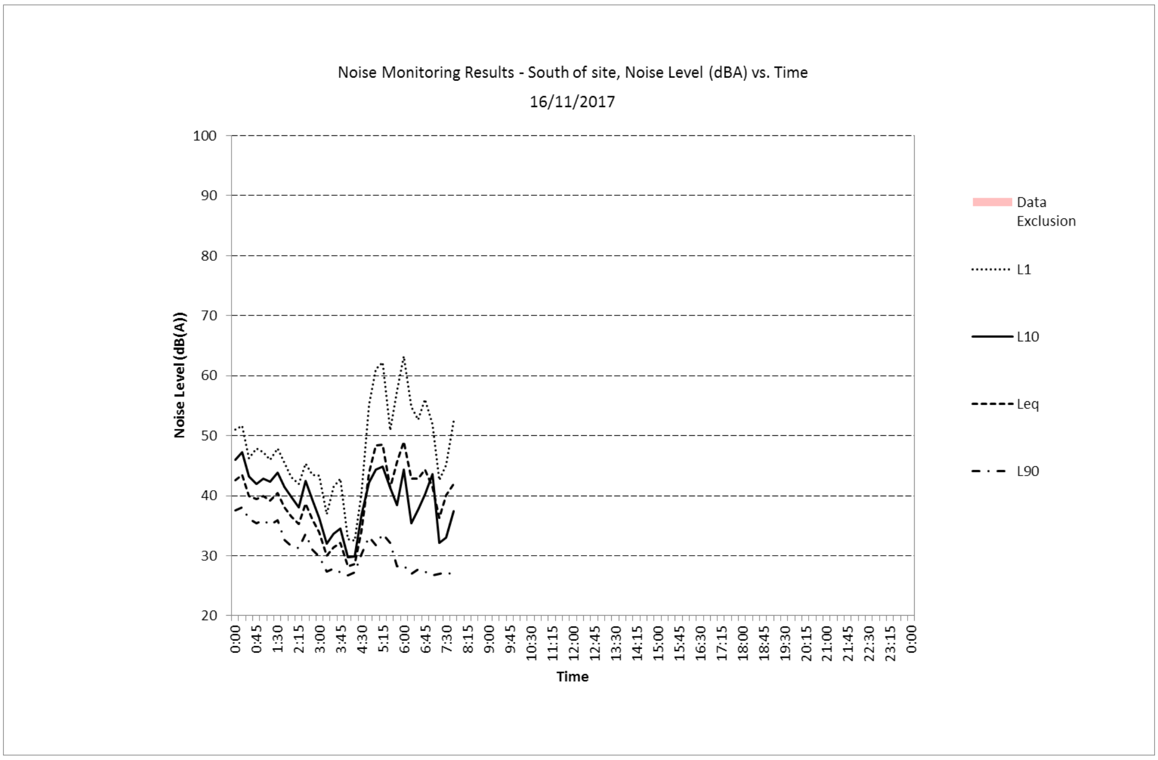

Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
13/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90



Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
14/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90



Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
15/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90



Noise Monitoring Results - South of site, Noise Level (dBA) vs. Time
16/11/2017
Noise Level (dB(A))
Time
Data Exclusion
L1
L10
Leq
L90

Appendix C Glossary

GLOSSARY

In this acoustic report unless the context of the subject matter otherwise indicates or requires, a term has the following meaning:

TERM	DEFINITION
ABL	The Assessment Background Level is the single figure background level representing each assessment period (daytime, evening and night-time (for each day). It is determined by calculating the 10th percentile (lowest 10th percent) background level (L_{A90}) for each period.
Adverse Weather	Weather effects that increases noise (i.e. wind and temperature inversion) that occurs at a site for a significant period of time (i.e. wind occurring more than 30% of the time in any assessment period in any season and / or temperature inversion occurring more than 30% of the nights in winter).
Ambient Noise	The all-encompassing noise associated within a given environment. It is the composite of sounds from many sources both near and far.
Assessment Period	The period in a day over which assessments are made: day (0700 to 1800h), evening (1800 to 2200h) or night (2200 to 0700h) or actual operating period if only a part of a period(s).
A – Weighting Filter	A-weighting is the most commonly used of a family of curves defined in the International standard IEC 61672:2003 and various national standards relating to the measurement of sound pressure level. A-weighting is applied to instrument-measured sound levels in effort to account for the relative loudness perceived by the human ear, as the ear is less sensitive to low audio frequencies.

Background Noise	The underlying level of noise present in the ambient noise, excluding the noise source under investigation, when extraneous noise is excluded. Usually described using the L90 measurement parameter.
C – Weighting Filter	The C-weighting approximates the sensitivity of human hearing at industrial noise levels (above about 85 dB(A)). The C-weighted sound level (i.e., measured with the C-weighting) is more sensitive to sounds at low frequencies than the A-weighted sound level and is sometimes used to assess the low-frequency content of complex sound environments and entertainment noise.
Decibel	The ratio of sound pressures which we can hear is a ratio of 106 (one million:one). For convenience, therefore, a logarithmic measurement scale is used. The resulting parameter is called the 'sound pressure level' (Lp) and the associated measurement unit is the decibel (dB). As the decibel is a logarithmic ratio, the laws of logarithmic addition and subtraction apply.
dB(A)	The unit generally used for measuring environmental, traffic or industrial noise is the A-weighted sound pressure level in decibels, denoted dB(A). An A-weighting network can be built into a sound level measuring instrument such that sound levels in dB(A) can be read directly from a sound level meter. The weighting is based on the frequency response of the human ear and has been found to correlate well with human subjective reactions to various sounds. It is worth noting that an increase or decrease of approximately 10 dB corresponds to a subjective doubling or halving of the loudness of a noise, and a change of 2 to 3 dB is subjectively barely perceptible.
Equivalent Continuous Sound Level (L_{eq})	Another index for assessment for overall noise exposure is the equivalent continuous sound level, L_{eq}. This is a notional steady level which would, over a given period of time, deliver the same sound energy as the actual time-varying sound over the same period, similar to the average. Hence fluctuating levels can be described in terms of a single figure level.
Extraneous Noise	Noise resulting from activities that are not typical of the area. Atypical activities may include construction, and traffic generated during holiday periods and during special events such as concert or sporting events.
Fast Time Weighting	125 ms integration time while the signal level is increasing and decreasing.
Frequency	The rate of repetition of a sound wave. The subjective equivalent in music is pitch. The unit of frequency is the Hertz (Hz), which is identical to cycles per second. A thousand hertz is often denoted kHz, e.g. 2 kHz = 2000 Hz. Human hearing ranges approximately from 20 Hz to 20 kHz. For design purposes, the octave bands between 63 Hz to 8 kHz are generally used. The most commonly used frequency bands are octave bands, in which the mid frequency of each band is twice that of the band below it. For more detailed analysis, each octave band may be split into three one-third octave bands or in some cases, narrow frequency bands.
L_{Aeq}	See equivalent continuous sound level definition above. This is the A-weighted energy average of the varying noise over the sample period and is equivalent to the level of a constant noise which contains the same energy as the varying noise environmental. This measure is also a common measure of environmental noise and road traffic noise.
$L_{Aieq,T}$	Equivalent continuous A-weighted sound pressure level over the measurement period T with impulse time weighting.

$L_{Ceq,T}$	The equivalent continuous C-weighted sound pressure level (integrated level) that, over the measurement period T, has the same mean square sound pressure (referenced to 20 µPa) as the fluctuating sound(s) under consideration.
$L_{C, Peak}$	The C-weighted Peak sound pressure level during a designated time interval or a noise event.
Low Frequency	Noise containing major components in the low-frequency range (20Hz to 250Hz) of the frequency spectrum.
Maximum Noise Levels L_{max}	The maximum noise level over a sample period is the maximum level, measured on fast response, during the sample period.
Minimum Noise Levels L_{min}	The minimum noise level over a sample period is the minimum level, measured on fast response, during the sample period.
Noise Sensitive Receiver (NSR)	A noise sensitive receiver is any person or building or outside space in which they reside or occupy that has the potential to be adversely impacted by noise from an outside source, or noise not generated by the noise sensitive receiver.
Octave Bands	Octave bands are frequency ranges in which the upper limit of each band is twice the lower limit. Octave bands are identified by their geometric mean frequency, or centre frequency.
One-Third Octave Bands	One-Third Octave Bands are frequency ranges where each octave is divided into one-third octaves with the upper frequency limit being 1.26 times the lower frequency. They are identified by the geometric mean frequency of each band, or centre frequency.
Project-Specific Noise Levels	They are target noise levels for a particular noise generating facility. They are based on the most stringent of the intrusive or amenity criteria derived from the NSW Industrial Noise Policy.
RBL	The Rating Background Level for each period is the median value of the ABL values for the period over all the days measured. There is a therefore an RBL value for each period – daytime, evening and night-time.
Shoulder Periods	Where early morning (5 am to 7 am) operations are proposed, it may be unduly stringent to expect such operations to be assessed against the night-time criteria (especially if existing background noise levels are steadily rising in these early morning hours). In these situations, appropriate noise level targets may be negotiated with the regulatory/consent authority on a case-by-case basis.
Slow Time Weighting	1 second integration time while the signal level is increasing and decreasing.
Sound Level Difference (D)	The sound insulation required between two spaces may be determined by the sound level difference needed between them. A single figure descriptor, the weighted sound level difference, D_w, is sometimes used (see BS EN ISO 717-1).
Sound Power	The sound power level (L_w) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level varies as a function of distance from a source. However, the sound power level is an intrinsic characteristic of a source (analogous to its volume or mass), which is not affected by the environment within which the source is located.

Statistical Noise Levels	For levels of noise that vary widely with time, for example road traffic noise, it is necessary to employ an index which allows for this variation. The L_{10}, the level exceeded for ten per cent of the time period under consideration, has been adopted in this country for the assessment of road traffic noise. The L_{90}, the level exceeded for ninety per cent of the time, has been adopted to represent the background noise level. The L_1, the level exceeded for one per cent of the time, is representative of the maximum levels recorded during the sample period. A-weighted statistical noise levels are denoted L_{A10}, dBL_{A90} etc. The reference time period (T) is normally included, e.g. $dBL_{A10,\,5min}$ or $dBL_{A90,\,8hr}$.
L_{A1}	The L_{A1} level is the A-weighted noise level which is exceeded for 15 of the sample period. During the sample period, the noise level is below the L_{A1} level for 99% of the time.
L_{A10}	The L_{A10} level is the A-weighted noise level which is exceeded for 10% of the sample period. During the sample period, the noise level is below the L_{A10} level for 90% of the time. The L_{A10} is a common noise descriptor for environmental noise and road traffic noise.
L_{A50}	The L_{A50} level is the A-weighted noise level which is exceeded for 50% of the sample period.
L_{A90}	The LA90 level is the noise level which is exceeded for 90% of the sample period. During the sample period, the noise level is below the LA90 level for 10% of the time. This measure is a commonly referred to as the background noise level.
Temperature Inversion	An atmospheric condition in which temperature increases with height above the ground.
Tonality	Noise containing a prominent frequency and characterised by a definite pitch.
Typical Levels	Some noise levels of some common noise sources are given below:

Noise Level dB(A)	Example
130	Threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside disco
90	Heavy lorries at 5 m
80	Kerbside of busy street
70	Loud radio (in typical domestic room)
60	Office or restaurant
50	Domestic fan heater at 1m
40	Living room
30	Theatre
20	Remote countryside on still night

	10	Sound insulated test chamber
	0	Threshold of hearing
Vibration	Vibration Velocity (v), Acceleration (a) and Weighted Acceleration (a_w) Velocity is usually used to assess the effect of vibration on structures and as the first indicator of the potential effect of vibration on sensitive equipment and its use. It is also used in the calculation of structure-borne noise in buildings. Vibration amplitude can be expressed as an absolute value (e.g. in the case of velocity 1 mms-1) or as a ratio on a logarithmic scale in decibels: e.g. vibration velocity level, dB = 20 log (v/v_{ref}). where for velocity the preferred reference level, v_{ref}, = 10^{-9} $m.s^{-1}$ (i.e. 1 $mm.s^{-1}$ = 120dB) Note the reference for acceleration is a_{ref}, = 10^{-6} $m.s^{-2}$ Weighted acceleration (a_w) is most commonly used when assessing the effect of vibration on humans (velocity is also used as simple surrogate for weighted acceleration because 50.3 x v [$mm.s^{-1}$] = a_w [$m.s^{-2}$] for frequencies above 8 Hz and is an over-estimate of a_w at low frequencies). The weightings, defined by BS6841 for human response to whole body vibration, mimic the frequency response of humans to vibration. The weighting used varies according to the orientation of the person compared to the direction of vibration and the nature of the effect on the recipient (i.e. annoyance, comfort, activity disturbance or health). The weightings can be built into a measuring instrument such that weighted acceleration can be read directly from a meter or can be applied during post processing. Generally humans are more sensitive to changes in vibration amplitude than they are to changes in the duration of exposure to vibration. Vibration is a vector and therefore has direction. It is common practice to resolve the vibration into components in 3 orthogonal directions (co-ordinate axes). The orthogonal co-ordinate axes used will vary depending on the situation – e.g. basiocentric coordinate axes (z-axis = head to toe; x-axis = back to chest; and y-axis = arm-to-arm) or co-ordinate axes relative to the source (e.g. vertical, parallel to and perpendicular to a railway) or the receiving structure (e.g. vertical, parallel to and perpendicular to a building).	