Appendix H

Noise and Vibration Assessment

Edify Energy

Darlington Point Solar Farm

Construction & Operational Noise & Vibration Assessment

AC01

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Contents

1 Introduction

Arup Acoustics was engaged for provision of an acoustic assessment for the Environmental Impact Statement (EIS) for the proposed Solar Power Farm at Darlington Point in NSW.

In accordance with the requirement of the Secretary's Environmental Assessment Requirements (SEARs), acoustic requirements include the provision of an assessment of construction noise impacts in accordance with the Interim Construction Noise Guideline and an operational noise assessment in accordance with the NSW Industrial Noise Policy.

Additionally, the SEARs asks for provision of a draft noise measurement plan if construction noise is likely to exceed applicable criteria. An outline noise management has been provided in the EIS and it is expected that the detailed plan will be developed once the construction contractor has been appointed and the construction stages and work areas and detailed design are known.

The assessment for the EIS includes the acoustical impacts of both the construction and operational stages of the project. This report will address both construction and operational noise and vibration while providing recommendations for mitigation measures where necessary.

2 Methodology

The following methodology was used to undertake the noise and vibration assessment methodology:

- Establish existing ambient noise environment
- Derive project specific construction and operational noise and vibration assessment criteria
- Predict potential impacts on nearby noise sensitive receivers based on constructability information
- Predict operational noise impacts to nearby noise sensitive receivers based on input information available at this stage of development
- Provide mitigation options as required to demonstrate compliance with assessment criteria
- Provide comment on potential noise generated during the decommissioning phase.

3 Project details

The Darlington Point Solar Farm is located 10 km south of Darlington Point in western NSW. The proposed development is to contain up to 275 MW of solar photovoltaic electricity generation.

Nearby noise sensitive receivers have been identified within the vicinity of the project area and are summarised in Table 1. Further information on noise sensitive receiver types and applicable criteria for each is provided in Section 4.

Table 1: Nearby noise sensitive receivers and distances to the boundary

Receiver	Address / Location	Approximate distance from site boundary, m
1	14713 Sturt Highway	1750
2	122 Donald Ross Drive	790
3	336 Donald Ross Drive	100
4	382 Donald Ross Drive	100
5	456 Donald Ross Drive	700
6	510 Donald Ross Drive	1250
7	537 Donald Ross Drive	1500
8	Tubbo	1650

The site bounds, nearby noise sensitive receivers and monitoring locations are depicted in Figure 1.

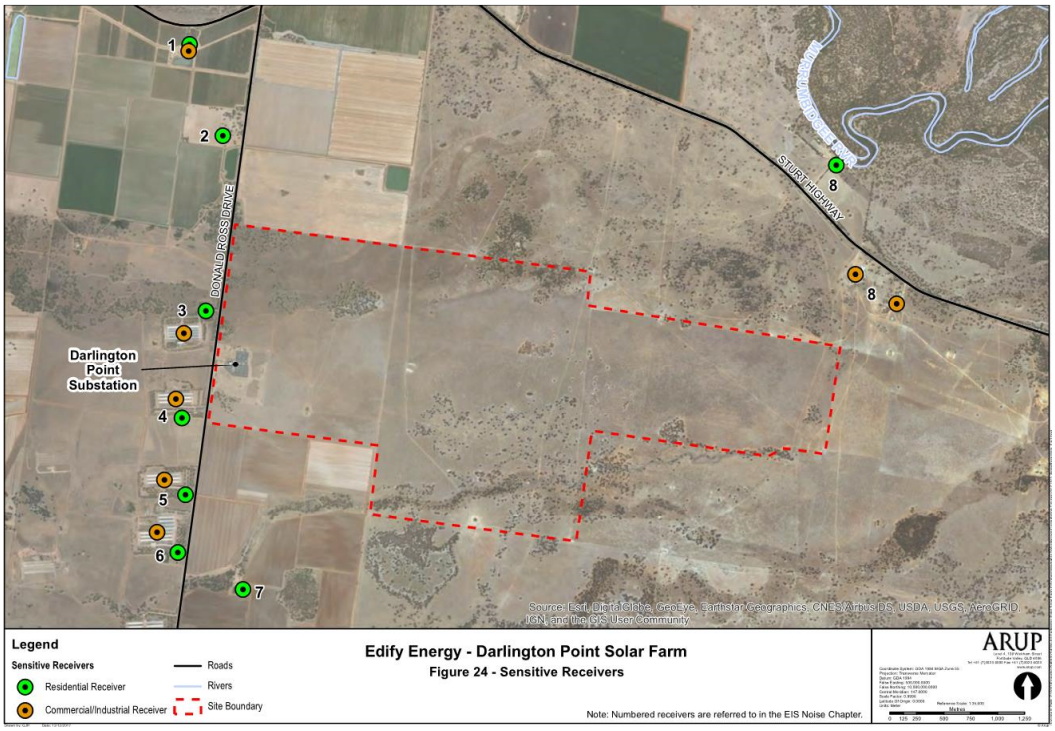


Figure 1 Site bounds with relevant receivers noted

3.1 Policies and guidelines

Construction noise and vibration impacts are assessed in accordance with the standards and guidelines summarised in Table 2.

Table 2: Policies and guidelines used for assessment.

Document Reference	Title
Interim Construction Noise Guideline	NSW Department of Environment Climate Change and Water (DECCW) Interim Construction Noise Guideline, July 2009
Industrial Noise Policy	NSW Environmental Protection Authority (EPA) Industrial Noise Policy, January 2000 [1]
Assessing Vibration: A Technical Guideline	NSW Environmental Protection Authority (EPA) Assessing Vibration: a Technical Guideline, February 2006
Road Noise Policy	NSW Department of Environment Climate Change and Water (DECCW) Road Noise Policy, March 2011

1 – The NSW INP 2000 has been used for this assessment as the newer Noise Policy for Industry 2017 is to apply to developments with SEARs agreed post October 2017.

3.2 Existing ambient noise environment

The methodology applied to the noise assessment is outlined in Section 2. Minimum standard background noise criteria have been used for the existing noise levels in a rural environment, in accordance with the NSW Industrial Noise Policy 2000 (INP) methodology. Additional on-site noise measurements were undertaken to confirm existing background noise levels were applicable to the standard background noise criteria for a rural environment.

Short term attended noise measurements were undertaken at various sensitive receptor and other representative background locations to determine the level of existing background noise in the area of the proposed development. Noise measurements were short 5-minute duration using a Burel and Kjaer 2236 sound level meter. Noise measurement data and survey information can be seen in Table 3.

Table 3: Noise survey measurement locations and results

Location (corresponding to numbering in Figure 1)	Description	Background noise level dB L_{A90} (5-minute)	
		Daytime	Night time
1	"Cavaso" 14713 Sturt Highway (commercial/industrial and residential receiver)	39 [1]	46 [1]
2	"Victor Filmer" 122 Donald Ross Drive (residential receiver)	29	28
3	"Farm 46" 336 Donald Ross Drive (Baida) (commercial/industrial and residential receiver)	29	29
4	"Farm 45" 382 Donald Ross Drive (Baida) (commercial/industrial and residential receiver)	30	29
7	"Terra Nova" 537 Donald Ross Drive (residential receiver)	30	29

Location (corresponding to numbering in Figure 1)	Description	Background noise level dB $L_{A90\ (5\text{-minute})}$	
		Daytime	Night time

1 – Background noise levels measured at this location consist of noise produced by localised mechanical equipment and plant. For this reason, noise measurements in this location have not been used for the basis of determining project noise criteria

A review of Table 3 shows that measured ambient background noise measurements are less than 29-30 $dBL_{A90\ (5\text{-minute})}$ during the day and 28-29 $dBL_{A90\ (5\text{-minute})}$ during the night. This supports the INP approach using minimum standard background noise criteria of 30 dB L_{A90} is applicable for the DPSF site.

3.3 Proposed development

The proposed development is a large scale solar farm development of 275MW (ac) generating capacity. Key infrastructure will include single access tracking solar photovoltaic panels to be installed in a distributed fashion across the site. In addition, a supporting transformer network will be used to distribute the captured power to grid. The concept design layout of key infrastructure is shown in Figure 2. The site will be run continuously with some minor support staff providing supervision and maintenance.

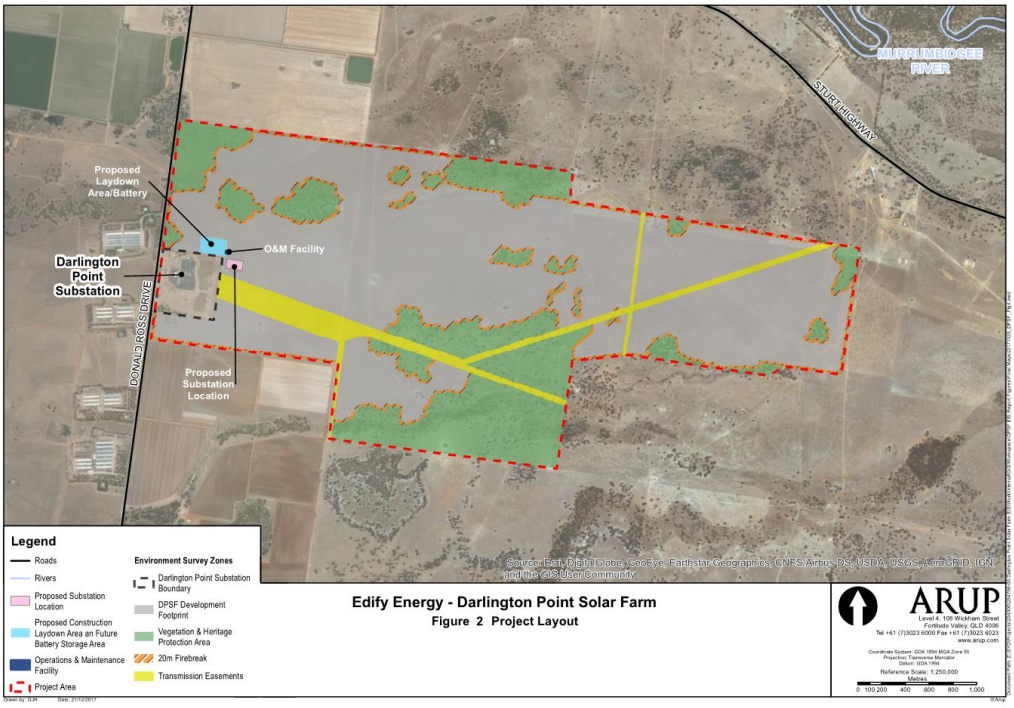


Figure 2 Concept design layout

3.4 Hours of operation

It is proposed that the Darlington Point Solar Farm will operate continuously, with solar tracker motor and photovoltaic panels providing little to no operation outside

of sunlight hours. Because of this, the hours of operation will vary seasonally but remain within daylight hours.

3.4.1 Construction hours

The construction period for the DPSF is expected to be 12 months. Construction is proposed to occur within the ICNG 'standard hours' period. This is as follows:

- Monday – Friday: 7:00 am to 6:00 pm
- Saturday: 7:00 am to 1:00 pm

In general, no construction activities will occur over night, on Sundays or public holidays, however exceptions to these hours may be required on limited occasions, for example:

- The delivery of materials as requested by the NSW Police Force or other authorities for safety reasons and/or to minimise disruption to local traffic;
- Augmentation works to the TransGrid substation, which may require a temporary power outage, such that the impact on power supplies to the local community is minimised; and
- Emergency work to avoid the loss of life, property and/or material harm to the environment.

The local council, surrounding landholders and other relevant authorities will be notified of any exceptions prior to the works being undertaken.

4 Criteria

4.1 Construction noise

The NSW *Interim Construction Noise Guideline* provides recommended noise levels for airborne construction noise at sensitive land uses. The guideline provides construction management noise levels above which all feasible and reasonable work practices should be applied to minimise the construction noise impact. The ICNG works on the principle of a 'screening' criterion – if predicted or measured construction noise exceeds the ICNG levels then the construction activity must implement all 'feasible and reasonable' work practices to reduce the impact of noise.

The ICNG provides two methods for assessing construction noise, varying typically on the basis of the project duration, being either a quantitative or a qualitative assessment. A quantitative assessment is recommended for major construction projects of significant duration, and involves the measurement of background noise levels for determination of management levels and prediction of construction noise levels. A qualitative assessment is recommended for small projects with a duration of less than three weeks and focuses on minimising noise disturbance through the implementation of feasible and reasonable work practices, and community notification. The Darlington Point Solar Farm is expected to warrant a quantitative assessment.

The ICNG sets out management levels for noise at noise sensitive receivers, and how they are to be applied. These management noise levels for residential receivers are reproduced below, in Table 4 and other sensitive receivers in Table 5 below.

Table 4: Construction noise management levels at residential receivers

Time of day	**Management level** [1] **$L_{Aeq\ (15\ min)}$**	**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 + 10dB	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured $L_{Aeq\ (15\ min)}$ 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 sensitive receivers of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.

Time of day	Management level [1] $L_{Aeq\ (15\ min)}$	How to apply
	Highly noise affected 75dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: • times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences • if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5dB	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 5dB(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.

1 - Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

Table 5: Construction noise management levels at other noise sensitive land uses

Land use	Where objective applies	Management level $L_{Aeq(15\ min)}$[1]
Commercial premises	External noise level	70 dB(A)
Industrial premises	External noise level	75 dB(A)

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

2 - Where some nearby receivers may operate with both commercial and residential land uses, the more stringent criteria will apply. For this project, residential criteria will prove more stringent.

For work within standard construction hours, if after implementing all 'feasible and reasonable' noise levels the site still exceeds the noise affected level, the ICNG does not require any further action – since there is no further scope for noise mitigation.

For out-of-hours work, the ICNG uses a noise level of 5 dB above the noise-affected level as a threshold where the proponent should negotiate with the community. While there is no 'highly-noise affected level' outlined in the ICNG

for out-of-hours work, this report adopts the terminology where the construction noise level is 5 dB above the noise affected level.

4.1.1 Project construction noise management levels

Construction noise criteria are typically set relative to the background noise levels of the project area, and therefore may differ across a construction site if variable background levels exist. Given the consistency of the measured background noise levels at the DPSF site and surrounds, a single Noise Management Level has been determined for receivers within the site vicinity. Additionally, as works are only proposed to be conducted during daytime hours, only a daytime criteria has been set.

Table 6: Project construction noise management levels

Time Period	**Daytime (7:00 to 18:00 weekdays / 8:00 to 13:00 Saturday)**	
Receiver	**Background Noise Level (RBL), L_{A90}**	**Noise Management level (NML), $L_{Aeq(15\text{-}minute)}$**
Residential	30[1]	40
Commercial		70
Industrial		75

Note: 1 – Section 3.1.2 of the NSW INP states that where measured background noise levels are below 30 dB(A), background noise levels should be set to 30 dB(A)

4.1.2 Construction traffic noise criteria

The NSW ICNG states that traffic increases on local roads as a result of construction traffic is to be assessed in accordance with the NSW Road Noise Policy (RNP).

The RNP outlines road traffic noise criteria impacting upon residential areas as a result of an increase in traffic flows. Where noise levels are predicted to exceed the criteria and pose a more than 2 dB(A) increase over an existing 'no-build' scenario, all feasible and reasonable mitigation measures should be applied.

4.2 Operational noise criteria (INP)

Operational noise emissions from the project has been assessed in accordance with the NSW *Industrial Noise Policy* (INP), which is primarily concerned with controlling intrusive noise impacts in the short-term for residences, and maintaining long-term noise level amenity for residences and other land uses.

4.2.1 Intrusive noise criteria

The intrusiveness criteria is applicable to residential premises only. The intrusiveness criterion is summarised as follows:

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

As the intrusiveness criteria is established from the prevailing background noise levels at the residential receiver locations, the rating background noise level is required to be quantified in order to establish the project's noise goals.

As per Section 3.1.2 of the NSW INP:

> *"Where the rating background level is found to be less than 30 dB(A), then it is set to 30 dB(A)."*

Consequently, where background noise levels are less than 30 dB(A), intrusiveness criteria will be set to 35 dB(A).

4.2.2 Amenity noise criteria

The INP amenity criteria are for the purpose of maintaining noise amenity, for which the INP recommends 'acceptable' and 'recommended maximum' cumulative noise levels for all industrial noise at different receiver types, including residential, commercial, industrial receivers and other sensitive receivers (refer Table 7).

Table 7: INP Amenity Criteria - Recommended L_{Aeq} noise levels from industrial noise sources (NSW INP Table 2.1)

Type of receiver	Indicative Noise Amenity Area	Time of day[1]	Recommended $L_{Aeq(Period)}$ noise level	
			Acceptable	Recommended maximum
Residence	Rural	Day	50	55
		Evening	45	50
		Night	40	45
Commercial premises	All	When in use	65	70
Industrial premises	All	When in use	70	75

1 – Daytime, 7.00am to 6.00pm; Evening 6.00pm to 10.00pm; Night-time 10.00pm to 7.00am
On Sundays and Public Holidays, Daytime 8.00am - 6.00pm; Evening 6.00pm - 10.00pm; Night-time 10.00pm - 8.00 am.

In accordance with INP principles, adjustments to acceptable and recommended noise levels are required where existing industrial noise dominates the ambient noise environment. As per site observations, the existing ambient noise environment is typical of a rural setting and is not dominated by industrial noise. Therefore the amenity goals remain as per Table 7.

Reference should be made to the INP (2000) for further details of the full assessment procedures and application, including modifying factor adjustments, background measurement procedures, adverse meteorological effects as well as assessment of sleep disturbance.

4.2.3 Project specific noise criteria

Based on the background and ambient noise monitoring, Table 8 summarises the derived project noise criteria based on the INP methodology.

Table 8: Project specific operational noise criteria, residential receivers

Noise level / Criteria	Criteria at time period, dB(A)		
	Day	**Evening**	**Night**
Background noise level, dBL_{A90}	29	28	28
Background noise level (corrected), dBL_{A90}[1]	30	30	30
Amenity criteria	50	45	40
Intrusive criteria	35	35	35
Final Criteria	**35**	**35**	**35**

1 – Section 3.1.2 of the NSW INP states that where measured background noise levels are below 30 dB(A), background noise levels should be set to 30 dB(A)

2 – Daytime, 7.00am to 6.00pm; Evening 6.00pm to 10.00pm; Night-time 10.00pm to 7.00am

On Sundays and Public Holidays, Daytime 8.00am - 6.00pm; Evening 6.00pm - 10.00pm; Night-time 10.00pm - 8.00 am.

4.2.4 Poultry farms

It is understood that in addition to the residential receivers along Donald Ross Drive, there are currently operating poultry farms with livestock kept on site.

There is no evidence that suggests that livestock or poultry is any more sensitive to noise to that of a residential receiver. As a result, properties with livestock have been assessed with the same criteria and procedure to that of residential receivers.

No additional assessment criteria has been imposed as a result of nearby poultry farms.

4.3 Vibration criteria

Vibration criteria relate to both operation, construction and decommissioning of the development and are generally assessed against two considerations:

- Structural damage; and
- Human exposure

The following sections summarise assessment criteria relevant to each.

4.3.1 Structural damage

Potential structural or cosmetic damage to buildings as a result of vibration is typically assessed in accordance with British Standard BS 7385. British Standard 7385-1, defines different levels of structural damage as:

- *Cosmetic - The formation of hairline cracks on drywall surfaces, or the growth of existing cracks in plaster or drywall surfaces; in addition the formation of hairline cracks in mortar joints of brick/concrete block construction.*

- *Minor - The formation of large cracks or loosening of plaster or drywall surfaces, or cracks through bricks/concrete blocks.*
- *Major - Damage to structural elements of the building, cracks in supporting columns, loosening of joints, splaying of masonry cracks, etc.*

BS7385-2 is based on peak particle velocity and specifies damage criteria for frequencies within the range 4–250 Hz, and a maximum displacement value below 4 Hz is recommended. Table 9 below sets out the BS7385 criteria for cosmetic, minor and major damage.

Table 9: BS 7385-2 structural damage criteria

Group	Type of structure	Damage level	Peak component particle velocity, mm/s[1]		
			4 Hz to 15 Hz	15 Hz to 40 Hz	40 Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	Cosmetic	50		
		Minor[2]	100		
		Major[2]	200		
2	Un-reinforced or light framed structures Residential or light commercial type buildings	Cosmetic	15 to 20	20 to 50	50
		Minor[2]	30 to 40	40 to 100	100
		Major[2]	60 to 80	80 to 200	200
1 - Peak Component Particle Velocity is the maximum Peak particle velocity in any one direction (x, y, z) as measured by a tri-axial vibration transducer. 2 - Minor and major damage criteria established based on British Standard 7385 Part 2 (1993) Section 7.4.2 All levels relate to transient vibrations in low-rise buildings. Continuous vibration can give rise to dynamic magnifications that may require levels to be reduced by up to 50%.					

4.3.2 Human exposure

Potential vibration disturbance to human occupants of buildings is made in accordance with the NSW DEC '*Assessing Vibration; a technical guideline*'. The criteria outlined in the guideline is based on the British Standard BS 6472-1. Sources of vibration are defined as either 'Continuous', 'Impulsive' or 'Intermittent', as described in Table 10 below.

Table 10: Types of vibration - Definition

Type of vibration	Definition	Examples
Continuous vibration	Continues uninterrupted for a defined period (usually throughout the day-time and/or night-time)	Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).
Impulsive vibration	A rapid build-up to a peak followed by a damped decay that may or may not involve several cycles of vibration (depending on frequency and damping). It can also consist of a sudden application of several cycles at approximately the same amplitude, providing that the	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading.

Type of vibration	Definition	Examples
	duration is short, typically less than 2 seconds	
Intermittent vibration	Can be defined as interrupted periods of continuous or repeated periods of impulsive vibration that varies significantly in magnitude	Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer, this would be assessed against impulsive vibration criteria.

Table 11 below is a reproduction of the 'Preferred' and 'Maximum' values for continuous and impulsive vibration from Table 2.2 of the Guideline.

Table 11: Preferred and maximum vibration acceleration levels for human comfort, m/s^2

Location	Assessment period1	Preferred values		Maximum values	
		z-axis	x- and y-axes	z-axis	x- and y-axes
Continuous vibration (weighted RMS acceleration, m/s2, 1-80Hz)					
Residences	Daytime	0.010	0.0071	0.020	0.014
	Night-time	0.007	0.005	0.014	0.010
Impulsive vibration (weighted RMS acceleration, m/s2, 1-80Hz)					
Residences	Daytime	0.30	0.21	0.60	0.42
	Night-time	0.10	0.071	0.20	0.14
1 - Daytime is 7:00am to 10:00pm and night-time is 10:00pm to 7:00am					

Table 12 reproduces the 'Preferred' and 'Maximum' values for intermittent vibration from Table 2.4 of the Guideline.

Table 12: Acceptable vibration dose values (VDV) for intermittent vibration ($m/s^{1.75}$)

Location	Daytime1		Night-time1	
	Preferred value	Maximum value	Preferred value	Maximum value
Residences	0.20	0.40	0.13	0.26
1- Daytime is 7:00am to 10:00pm and night-time is 10:00pm to 7:00am				

5 Construction Noise & Vibration Assessment

5.1 Construction activities

At this stage of the project proposed construction activities have not been finalised. As a result this section is subject to change as the proposal develops.

Likely construction activities, nominal equipment and sound power levels have been provided in Table 13.

Table 13: Nominal construction equipment and sound power levels per activity

Unit/Plant item	SWL per unit (A-weighted)	No. units	Operating time	SWL per activity (A-weighted)
Light vegetation clearing				**112**
Chainsaw	114	2	20%	
Dump truck	108	1	50%	
Excavation				**114**
Excavator (approx. 30 tonne)	110	1	100%	
Dump Truck	108	1	60%	
Water cart	107	1	100%	
Piling foundations				**114**
Bored Piling Rig	110	2	100%	
Dump Truck	108	1	80%	
Concrete pours				**113**
Concrete pump	108	1	90%	
Concrete truck	109	1	90%	
Truck (>20 tonne)	107	2	60%	
Installation of services				**117**
Pneumatic hammer	113	3	70%	
Vehicle (light commercial)	106	2	60%	
Hand tools (electric)	102	5	80%	
Generator	104	1	100%	
Onsite paths and road works				**117**
Vibratory Roller (approx. 10 tonne)	114	1	70%	
Scraper	110	1	40%	
Grader	113	1	100%	
Compactor	106	1	100%	

1 – Data inputs are based upon sound power levels for equipment and plant that have been provided to Arup from the client and/or manufacturer or industry standard performance data for nominal items. Where data for given items is not available Arup will base acoustic performance on similar equipment or our library of data.

5.2 Construction noise assessment

Construction noise levels at nearby receiver locations have been determined for the various construction activities outlined in Section 5.1. Predictions were calculated using SoundPLAN 7.4 acoustic modelling software and the CONCAWE environmental prediction algorithm.

Given the large area of the project site and the range of distances that may occur between construction activities and nearby receivers, predictions in Table 14 show construction noise levels at the nearest receivers for works located at the project site boundary where the distance to the nearest receivers is shortest. The distances used for these predictions can be seen in Table 1.

Table 14: Predicted construction noise levels from site boundary

Receiver (refer Figure 1)	Location	Predicted noise level at project site boundary, dB L_{Aeq}					
		Light vegetation clearing	Excavation	Piling	Concrete pours	Installation of services	Onsite paths and road works
1	14713 Sturt Highway	39	41	41	40	44	44
2	122 Donald Ross Drive	46	48	48	47	51	51
3	336 Donald Ross Drive	64	66	66	65	69	69
4	382 Donald Ross Drive	64	66	66	65	69	69
5	456 Donald Ross Drive	47	49	49	48	52	52
6	510 Donald Ross Drive	42	44	44	43	47	47
7	537 Donald Ross Drive	40	43	42	41	46	45
8	Tubbo Homestead	39	42	42	40	45	44

A review of Table 14 shows that construction is predicted to exceed noise management levels when conducted near to the project boundary. Given the size of the project site, it is likely that the majority of construction works will be undertaken at a greater distance from residential receivers resulting in lower noise levels.

Recommendations for mitigation measures are provided in Section 5.4.

Construction of the BESS facility

The BESS facility is proposed to be constructed over a 3 to 6 month period (expected Q3 to Q4 (August to December) 2020) once the DPSF has commenced operation. Only selected construction equipment as shown in Table 13 would be used during construction of the BESS facility (e.g. concrete pouring equipment, crane, grader, roller, miscellaneous light construction vehicles, and delivery vehicles with low-loader flat-bed).

Equipment used for the construction of the BESS facility would not be used at the same intensities and duration as that required for construction of the solar farm. Hence, it is expected that noise levels generated from equipment use would not reach the same levels at sensitive receivers as are expected for the construction of the solar farm as shown in Table 14. Standard noise mitigation measures would be applied to manage any noise concerns during construction of the BESS facility as per Section 5.4.

5.2.1 Construction traffic noise assessment

Throughout construction, nearby roads are likely to feature increased traffic flows.

A traffic noise assessment has been conducted to determine the acoustic impact of noise attributed to additional traffic volumes present on local roads as part of the construction activity.

Access to the development site will be via Donald Ross Drive.

RMS supplied traffic volume data for both the Sturt Highway and Kidman Way have been used to estimate existing volumes on Donald Ross Drive as outlined in the Traffic Impact Assessment. These traffic volumes have been used to undertake the traffic noise assessment.

As per the information provided about proposed construction movements, heavy vehicles traffic may produce up to 5 movements in a worst case 1 hour period. In addition to heavy vehicles, up to 215 light vehicle movements used in materials and personnel transport may be present in this worst case 1 hour period.

Based on the above traffic information, Table 15 presents an assessment based on predicted traffic noise levels with and without construction traffic.

Table 15: Construction traffic flows and predicted noise levels on Donald Ross Drive

Scenario	**Light vehicles, per hour (two-way)**	**Heavy vehicles, per hour (two-way)**	**Noise level at residences on Donald Ross Drive, dB L_{Aeq} (1 hour)**
Existing traffic (average hourly period)	72	27	60.2
Construction Traffic (worst case hourly period)	215	5	59.9
Combined traffic during DPSF constsruction	287	32	63

A review of Table 15 highlights that construction traffic will present a more than 2 dB increase in noise levels for road traffic noise on Donald Ross Drive. As a result it recommended that all feasible and reasonable mitigation measures are provided.

A list of mitigation measures to deal with construction traffic can be seen in Section 5.5.

BESS facility construction traffic

Construction of the BESS facility is proposed to run from Q3 to Q4 (August to December) 2020, once the solar farm is in operation. It is expected that an approximate 156 vehicle deliveries for the battery powerpacks, inverters, cables and concrete would be expected over the BESS facility construction period. A further 10 to 20 personnel (peak of 20 vehicles) would attend site during the BESS construction period.

From this, the expected number of vehicles attending the site during the BESS construction period would be approximately 176 vehicles spaced out over the period, which is significantly less than the traffic volumes expected for the solar farm construction period. In addition, the construction traffic noise generated by the BESS facility is considered to be of a shorter duration and lesser intensity than the expected solar farm construction traffic noise.

The consequent construction traffic noise levels for the BESS facility are not expected to exceed those levels identified for the solar farm construction (refer Table 15). On this basis, it is anticipated that the construction of the BESS facility would not result in significant additional traffic noise than compared to the solar farm construction (e.g. no worsening of impact).

5.3 Construction vibration assessment

Minimum working distances for typical mechanical and plant items have been published in documentation such as The Transport for NSW (TfNSW) Construction Noise Strategy[1]. Table 16 outlines recommended minimum working distances for vibration intensive plant.

This limits determine minimum distances between source and receiver to achieve the following requirements:

- "Cosmetic damage" as described in BS 7385
- Human comfort limits as described in the EPA's *Assessing Vibration: A Technical Guideline*

Table 16: Excerpt from TfNSW Construction Noise Strategy - Recommended minimum working distances for vibration intensive plant

Plant Item	Rating/Description	Safe Working Distance	
		Cosmetic Damage (BS 7385)	Human Response (OH&E Vibration Guideline)
Vibratory Roller	< 50 kN (Typically 1-2 tonnes)	5 m	15 m to 20 m
	< 100 kN (Typically 2-4 tonnes)	6 m	20 m

[1] Transport for New South Wales- *Construction Noise Strategy* (April, 2012)

Plant Item	Rating/Description	Safe Working Distance	
		Cosmetic Damage (BS 7385)	Human Response (OH&E Vibration Guideline)
	< 200 kN (Typically 4-6 tonnes)	12 m	40 m
	< 300 kN (Typically 7-13 tonnes)	15 m	100 m
	> 300 kN (Typically 13-18 tonnes)	20 m	100 m
	> 300 kN (> 18 tonnes)	25 m	100 m
Small Hydraulic Hammer	(300 kg - 5 to 12t excavator)	2 m	7 m
Medium Hydraulic Hammer	(900 kg – 12 to 18t excavator)	7 m	23 m
Large Hydraulic Hammer	(1600 kg – 18 to 34t excavator)	22 m	73 m
Vibratory Pile Driver	Sheet piles	2 m to 20 m	20 m
Pile Boring	≤ 800 mm	2 m (nominal)	N/A
Jackhammer	Hand held	1 m (nominal)	Avoid contact with structure

A review of Table 16 shows that use of vibration intensive plant within the project area is unlikely to affect nearby residential receivers given the locations and distances outlined in Section 3.

5.4 Construction noise and vibration mitigation

Noise mitigation measures for each major construction activity are discussed in the following sections. These mitigation measures are considered to represent ‘feasible and reasonable’ mitigation measures suitable for implementation during construction of the project.

A summary of general construction stage acoustic mitigation measures can be seen in Section 5.5.

5.4.1 General

In general, practices to reduce construction noise impacts will be required, and may include;

- Adherence to the standard approved working hours for construction projects where possible as outlined in Section 3.4.1
- The location of stationary plant (air-compressors, generators, etc.) as far away as possible from sensitive receivers
- Using natural screening by topography wherever possible to reduce noise impacts
- Using site sheds and other temporary structures or screens to limit noise exposure where possible

- Installing operational noise barriers as early as possible to provide ongoing screening from construction activities, where possible
- The appropriate choice of low-noise construction equipment and/or methods
- Modifications to construction equipment or the construction methodology or programme. This may entail programming activities to occur concurrently where a noisy activity will mask a less noisy activity, or, at different times where more than one noisy activity will significantly increase the noise. The programming should also consider the location of the activities due to occur concurrently.
- Restricting or redirecting vehicle movements to reduce flows during peak times.
- Community engagement and notification.

While the contractor will be able to achieve moderate reductions in noise and vibration, some impact is expected. A Construction Noise and Vibration Management Plan would be adopted for construction stages incorporating a programme of noise monitoring at sensitive receivers, a community information programme and a complaints hotline.

5.4.2 Construction noise and vibration management plan

For all construction works, the appointed contractor will be required to prepare a detailed Construction Noise and Vibration Management Plan (CNVMP). This plan should include but not be limited to the following:

- Roles and responsibilities
- Noise sensitive receiver locations
- Predicted impacts
- Mitigation strategy
- Monitoring methodology
- Community engagement strategy.

Specific engineering methods for controlling construction noise and vibration impacts relevant to this study are discussed in the following sections.

5.4.3 Universal work practices

The following noise mitigation work practices are recommended to be adopted at all times on site:

- Regularly train workers and contractors (such as at toolbox talks) to use equipment in ways to minimise noise.
- Site managers to periodically check the site and nearby residences for noise problems so that solutions can be quickly applied.
- Avoid the use of radios or stereos outdoors.
- Avoid the overuse of public address systems.
- Avoid shouting, and minimise talking loudly and slamming vehicle doors.

- Turn off all plant and equipment when not in use.

5.4.4 Maximum equipment noise levels

The Transport for NSW Construction Noise Strategy provides a framework for applying standard and additional mitigation measures for transport infrastructure construction projects. Table 17 summarises the maximum allowable noise levels for construction equipment as defined in the TfNSW Construction Noise Strategy, which could form an appropriate basis for screening machinery adopted for use on site by the construction contractor.

Table 17: TfNSW maximum allowable noise levels for construction equipment

Equipment	Maximum allowable noise level dB – $L_{Amax\ 1,2,3}$	
	Sound power level	Sound pressure level at 7 m
Excavator Hammer	122	97
Excavator (approx. 3 tonne)	90	65
Excavator (approx. 6 tonne)	95	70
Excavator (approx. 10 tonne)	100	75
Excavator (approx. 20 tonne)	105	80
Excavator (approx. 30 tonne)	110	85
Excavator (approx. 40 tonne)	115	90
Skidsteer Loaders (approx. 1/2 tonne)	107	82
Skidsteer Loaders (approx. 1 tonne)	110	85
Dozer (equiv. CAT D8)	118	93
Dozer (equiv. CAT D9)	120	95
Dozer (equiv. CAT D10)	121	96
Backhoe/FE Loader	111	86
Dump Truck (approx. 15 tonne)	108	83
Concrete Truck	112	87
Concrete Pump	109	84
Concrete Vibrator	105	80
Bored Piling Rig	110	85
Scraper	110	85
Grader	110	85
Vibratory Roller (approx. 10 tonne)	114	89
Vibratory Pile Driver	121	96
Impact Piling Rig	134	109
Compressor (approx. 600 CFM)	100	75
Compressor (approx. 1500 CFM)	105	80
Concrete Saw	118	93
Jackhammer	113	88
Generator	104	79
Lighting Tower	80	55
Flood Lights	90	65

Equipment	Maximum allowable noise level dB – $L_{Amax\ 1,2,3}$	
	Sound power level	Sound pressure level at 7 m
Cherry Picker	102	77
Mobile Crane	110	85

Notes:

1 - The Sound Power Level (SWL) represents the total noise output of the plant of equipment. The SWL is normally used in computer noise models to predict the Sound Pressure Levels (SPLs) at nearby receivers. When undertaking site compliance measurements, it is normally the SPL that is measured at a specified distance (typically 7m) from the plant or equipment.

2 - The SWLs presented in the above table have been compiled from a selection of field measurements conducted by Heggies Pty Ltd between 2004 and 2006 of plant and equipment operating on construction projects throughout NSW and are therefore considered to be representative of plant and equipment SWLs which are readily achieved by current plant and equipment normally used in the construction industry.

3 - Plant and equipment with SWLs higher than those presented in the table would be deemed to be emitting an excessive level of noise and should not be permitted to operate on construction sites.

5.4.5 Piling

To reduce the effect on residents of piling noise, nearby residents should be consulted regarding the intended activities associated with the piling process.

Should percussive piling be considered, activities to reduce the impact of this activity are:

- Using a resilient pad (dolly) between pile and hammer head
- Enclosing the hammer head in a temporary acoustic shroud.

Alternatively, rotary bored or vibro-piling may be used where consistent with the type of pile used and restrictions on soil disturbance.

Piling, in particular, should not be undertaken outside of the standard working hours.

5.4.6 Noise level reductions from mitigation

Indicative noise reduction for different noise mitigation measures relevant to construction activities for the project have been obtained from the guidance of AS2436 and BS5228.1, as summarised below in Table 18.

Table 18: Indicative noise reduction provided by noise mitigation measures

Construction equipment	Noise mitigation measure	Indicative noise reduction	Source
Compressor Cement mixers Hand-held tools	Screening	5 dBA	Table C3 AS2436:2010

Construction equipment	Noise mitigation measure	Indicative noise reduction	Source
Excavators/loaders Trucks Mobile cranes Asphalt paver Bulldozers Road graders Rollers/compactors	Residential-grade silencer	10 dBA	Table C2 AS2436:2010 Table B1 BS5228.1:2009
Excavator with hammer attachment	Residential-grade silencer Screening of hammer attachment	15 dBA	Table C2 AS2436:2010
Piling impact	Resilient pad (dolly) between pile and hammerhead	10 dBA	Table C2 AS2436:2010 Table B1 BS5228.1:2009

5.5 Summary of Mitigation Measures

A summary of construction stage mitigation measures proposed in this report are presented in Table 19 and Table 20. While not all mitigation measures need to apply, the below table presents a large range of mitigation measures that should all be considered where required. The mitigation measures will need to be confirmed by the contractor once appointed and more detail is known.

Table 19: Summary of construction work mitigation measures

Mitigation Measure	Responsibility
Appoint a construction staff member responsible for construction noise and vibration management on site. Ensure construction staff are trained in ways to minimise noise during work, eg. Minimise dropping items, avoiding the use of stereos outdoors, avoiding shouting, slamming doors.	Construction contractor & Responsible Member for construction noise
Turn off construction equipment when not in use. Maintain equipment and use quiet equipment where possible.	Construction contractor, Responsible Member & construction staff

Mitigation Measure	Responsibility
Ensure construction only occurs between 7am to 6pm on weekdays and 7am to 1pm on Saturdays. In general, no construction activities will occur over night, on Sundays or public holidays, however exceptions to these hours may be required on limited occasions, for example: • The delivery of materials as requested by the NSW Police Force or other authorities for safety reasons and/or to minimise disruption to local traffic; • Augmentation works to the TransGrid substation, which may require a temporary power outage, such that the impact on power supplies to the local community is minimised; and • Emergency work to avoid the loss of life, property and/or material harm to the environment. The local council, surrounding landholders and other relevant authorities will be notified of any exceptions prior to works being undertaken.	Construction contractor & Responsible Member
Undertake construction noise monitoring to alert the Contractor of potential exceedances of Noise Management Levels.	Construction contractor & Responsible Member
Maintain open communication channels with nearby receivers, including commercial tenants and residents. Maintain a complaints log including timing, issues, immediate and on-going actions.	Construction contractor & Responsible Member
Maintain minimum working distances for vibration intensive plant. Where this is not possible, vibration monitoring with real-time alerts should be considered.	Construction contractor & Responsible Member

Table 20: Summary of construction related traffic noise mitigation measures

Mitigation Measure	Responsibility
Schedule vehicle routing and movements in order to minimise the impact of road traffic noise within a given period. i.e. allow for arrival of workers and equipment deliveries to occur over a longer period to reduce the noise emission during peak periods.	Construction contractor, Responsible Member & construction staff
Reduce the impact of the use of compression brakes when accessing the site, management of speed to allow for minimal use of compression breaking when accessing the site.	Construction contractor, Responsible Member & construction staff
Ensure vehicles are adequately silenced and specified for site use. Selection of transport units should be undertaken with the thought to reduce noise emissions.	Construction contractor & Responsible Member
Install temporary noise barriers to reduce the noise impact at the nearest receivers on Donald Ross Drive. Use of localisation with positioning to allow for the best noise reduction outcomes.	Construction contractor & Responsible Member
Ongoing consultation with closest sensitive receivers on Donald Ross Drive. Agree acoustic treatment or management measures if construction noise exceeds criteria at these locations.	Construction contractor & Responsible Member

Mitigation Measure	Responsibility
Considerations for the duration and timing of traffic should be made with community consultation to act in the best interests of the affected receivers. Given the temporary nature of construction, the duration and intensity of works should be determined to best suit the affected receivers	Construction contractor & Responsible Member

6 Operational noise assessment

Operational noise from the Darlington Point Solar Farm is to be assessed in accordance with the policies and procedures outlined in the NSW Industrial Noise Policy.

Daily operations and maintenance activities by site staff would be undertaken during standard working hours of:

- Monday to Friday: 7:00 am to 6:00 pm
- Saturday: 8:00 am to 1:00 pm

Outside of emergencies or major asset inspection or maintenance programs, night works and work on Sundays and public holidays would be minimised.

6.1 Operational noise sources

The solar farm is proposed to operate 0.8 – 1 million solar panels. The panels are to be oriented on an east – west rotation, tracking the position of the sun throughout the day. The rotation of the solar panels is to be driven by a motor configured to operate an array of panels.

In addition to the solar panel array motors, the DPSF site will require the addition of transformers to supplement the capacity of the solar panels. It is proposed to supply additional transformer facilities throughout the extent of the property with a main transformer unit installed near the existing infrastructure towards the western boundary.

Personnel transport may involve operation of up to 5 light vehicles per hour. This number of vehicle movements is not anticipated to significantly increase the overall operational noise impact from the site and will not be discussed further.

Operational plant and equipment types, quantities and sound power levels are provided in Table 21. Sound Power Levels and unit quantities have been based on information provided by Edify Energy.

Table 21: Proposed operational plant quantities and sound power levels

Plant Item	**Sound Power Level (A-Weighted) per unit, dB L_{Aeq}**	**Number of units on site**
Solar panel array motor	78	11250
Medium voltage power station unit[1]	92	55
Main transformer	100	1

Plant Item	Sound Power Level (A-Weighted) per unit, dB L_{Aeq}	Number of units on site

[1] MVPS5500 inverters are proposed for the project. At the direction of Edify Energy, sound power data for SC2750-EV inverters are used for the basis of this assessment as being comparable.

6.2 Modifying factors and corrections

6.2.1 Tonality

In the absence of the spectral data for operating equipment it has been assumed that:

- Solar tracker motors are likely to be tonal and tonal corrections will be included in the assessment for this item
- Medium voltage transformer units are unlikely to be tonal and do not have tonal corrections included in the assessment for this item.

Tonality assessments have been made in accordance with Section 4.1 from the NSW Industrial Noise Policy. A 5 dB(A) tonality penalty has been applied to the predicted levels of solar tracker motors.

6.2.2 Time correction

Given the nature of solar tracking, noise generated from the solar panels is expected to be extremely intermittent given the small amount of movement required to track the sun over the period of a day.

Operational noise assessments assume solar tracker motors will operate no more than 0.2 minutes out of every 15. A time correction for this impact has been incorporated into predictions to allow assessment against INP criteria.

6.3 Operational noise assessment

Operational noise levels at nearby residential receivers has been predicted. Once determined, predicted noise levels have been compared to the relevant project criteria.

Operational noise emission predictions take into account the following:

- Sound power data determined in Table 21
- Proposed number of plant items determined in Table 21
- Distance attenuation and meteorological effects using the CONCAWE method
- Correction factors presented in Section 6.2

6.3.1 Meteorological effects

Consideration of meteorological effects has been used for operational noise assessments in accordance with the Industrial Noise Policy. The results of this

assessment have been included in the noise prediction calculations used to ascertain compliance with the criteria given in section 4.2.

A worst case scenario was adopted that, assumed a G-class inversion (using the CONCAWE determination of meteorological category[2]) and a wind speed of 3 m/s at 10 m above the ground.

Using the CONCAWE metrological curves for various octave bands[3] it was possible to determine that the increase in noise level resulting from these worst case meteorological conditions. This medication of noise levels was then taken into account within the prediction method.

6.3.2 Predicted operational noise levels

Table 22 outlines the predicted operational noise emissions in comparison to the criteria.

Table 22 Operational noise predictions and comparison with criteria

Receiver (refer Figure 1)	Location	Predicted Noise Level, dB L_{Aeq}	Criteria – All INP periods, dB L_{Aeq}
1	14713 Sturt Highway	15	35
2	122 Donald Ross Drive	21	
3	336 Donald Ross Drive	32	
4	382 Donald Ross Drive	29	
5	456 Donald Ross Drive	24	
6	510 Donald Ross Drive	20	
7	537 Donald Ross Drive	20	
8	Tubbo Homestead	17	

As shown in Table 22, operational noise is predicted to comply with the operational noise criteria at all locations. Noise emissions from the site are primarily driven by the collective sound pressure levels of the medium voltage transformer units with the solar tracker motors providing some minor contribution.

While a tonal penalty has not been applied to the transformer units as per the details outlined in Section 6.2.1, if this 5 dB(A) penalty were also applied to the medium voltage transformer units, compliance with the operational noise criteria is predicted to be achieved at all receiver locations.

It is important to note that the predictions in Table 22 represent noise levels on the basis of preliminary equipment selections. It is recommended that mitigation

[2] Table 5.6, p188: Engineering Noise Control – Theory and Practice, second edition, *Bies and Hansen*, E&FN Spon, 1996
[3] Figure 5.20, p189: Engineering Noise Control – Theory and Practice, second edition, *Bies and Hansen*, E&FN Spon, 1996

measures be reviewed once final equipment selections are made in order to achieve noise criteria targets for nearby residences.

BESS facility operation

The BESS facility is expected to be operational by December 2020. The noise specification sound power levels for the BESS facility are summarised below:

- Powerpack Inverter: <70 dBA at 1 meter
- Powerpack Unit: <82.5 dBA at 1 meter

Approximately 970 battery cubicles will be placed on individual concrete footings sized up to 2,000m^2 in total area across the 2 .

As per Table 21, the solar farm operational plant have higher sound power levels and quantities than the BESS facility (except for the solar arrays, which appear to have a lower sound power level than the batteries, but higher quantities). This suggests that the noise to be generated by the batteries will be at a lower intensity (lower sound power levels and quantities) than compared to other solar farm operational plant. Therefore, it is considered that the operation of the BESS facility is unlikely to significantly contribute to an exceedance of the operational noise criteria for sensitive receivers identified in Table 22.

During detailed design, the exact location of the batteries will be configured in such a way as to minimise any potential noise level exceedances to the sensitive receivers noted in Table 22, with the potential to mitigate any exceedances by increasing the distance between the BESS facility and the nearest sensitive receiver.

7 Decommissioning

The expected life of the DPSF is 30 years. The BESS facility's life is specified for 15 years, so it is likely that the battery cubicles would be removed and replaced at year-15. Given the likely advancements of battery technology into the future, it is assumed that a more efficient and quieter technology would be installed at the site in year-15. The facility would operate for another 15 years up to the DPSF's expected life of 30 years. Following this, the farm would be decommissioned or there may be options to extend the life of the plant.

It is expected that the indicative construction activities listed in Table 13 would be reasonably representative of noise and vibration impacts associated with decommissioning. For the replacement of the battery cubicles at year-15, approximately 90 to 100 deliveries over a 2 to 3 month window would occur. No changes to the concrete slab, cables and transformers would be expected. Similar noise impacts would be considered for the battery replacement activities but would occur over a shorter duration.

This would need to be reviewed once specific activities are known. An updated analysis of existing ambient noise environment would also potentially be required to ascertain whether the background noise level had changed and updated assessment criteria be required.

8 Conclusion

Arup has conducted an assessment into construction and operational noise impacts produced by the proposed solar farm development in accordance with relevant noise and vibration policies and guidelines.

Background noise criteria were determined using validation measurements and the procedures written within the NSW INP. It was noted that background noise levels are considerably low resulting in fairly low (stringent) noise criteria. Predictions, recommendations and mitigation measures have been produced with this in mind.

Construction noise impacts have been modelled and are predicted to affect some properties at particular stages of construction. As a result, recommendations for mitigation have been provided in order to minimise any disturbance caused during construction stages.

Construction traffic was investigated to determine the increase in noise levels due to traffic noise during peak deliveries, unloading and personnel transport periods. It was found that construction traffic noise levels are predicted to exceed the project criteria at the nearest affected residences. Additionally, construction traffic noise levels are predicted to pose more than a 2 dB(A) increase in noise levels over a ‘no-build’ scenario. As a result, it is recommended that all feasible and reasonable mitigation measures apply in order to reduce noise emissions.

A preliminary summary of mitigation measures for construction activities noise and vibration and construction traffic noise has been provided. A detailed Construction Noise and Vibration Management Plan will be required to be provided by the Contractor once more specific information is known regarding construction methodologies and staging.

Requirements for noise amenity at nearby residential receivers as a result of operations was predicted to comply with industrial noise emission criteria at all nearby noise sensitive receivers. As operational equipment has not yet been finalised, several mitigation strategies have been outlined for potential approaches to dealing with noise emission where operational noise levels may be predicted to exceed the noise criteria.

Appendix A

Glossary of Terms

A1 Glossary of Terms

Ambient Noise Level

The ambient noise level is the overall noise level measured at a location from multiple noise sources. When assessing noise from a particular development, the ambient noise level is defined as the remaining noise level in the absence of the specific noise source being investigated. For example, if a fan located on a city building is being investigated, the ambient noise level is the noise level from all other sources without the fan running. This would include sources such as traffic, birds, people talking and other nearby fans on other buildings.

Background Noise Level

The background noise level is the noise level that is generally present at a location at all or most times. Although the background noise may change over the course of a day, over shorter time periods (e.g. 15 minutes) the background noise is almost-constant. Examples of background noise sources include steady traffic (e.g. motorways or arterial roads), constant mechanical or electrical plant and some natural noise sources such as wind, foliage, water and insects.

Assessment Background Level (ABL)

A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night time period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background L_{A90} noise levels – i.e. the measured background noise is above the ABL 90% of the time.

Rating Background Level (RBL / min$L_{A90,1hour}$)

A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or night time period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey. This parameter is denoted RBL in NSW, and min$L_{A90,1hour}$ in QLD.

Decibel

The decibel scale is a logarithmic scale which is used to measure sound and vibration levels. Human hearing is not linear and involves hearing over a large range of sound pressure levels, which would be unwieldy if presented on a linear scale. Therefore a logarithmic scale, the decibel (dB) scale, is used to describe sound levels.

An increase of approximately 10 dB corresponds to a subjective doubling of the loudness of a noise. The minimum increase or decrease in noise level that can be noticed is typically 2 to 3 dB.

dB(A)

dB(A) denotes a single-number sound pressure level that includes a frequency weighting ("A-weighting") to reflect the subjective loudness of the sound level.

The frequency of a sound affects its perceived loudness. Human hearing is less sensitive at low and very high frequencies, and so the A-weighting is used to account for this effect. An A-weighted decibel level is written as dB(A).

Some typical dB(A) levels are shown below.

Sound Pressure Level dB(A)	Example
130	Human threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside nightclub
90	Heavy trucks at 5 m
80	Kerbside of busy street
70	Loud stereo in living room
60	Office or restaurant with people present
50	Domestic fan heater at 1m
40	Living room (without TV, stereo, etc)
30	Background noise in a theatre
20	Remote rural area on still night
10	Acoustic laboratory test chamber
0	Threshold of hearing

L_{90}

The L_{90} statistical level is often used as the "average minimum" or "background" level of a sound level that varies with time.

Mathematically, L_{90} is the sound level exceeded for 90% of the measurement duration. As an example, 45 dB $L_{A90,15min}$ is a sound level of 45 dB(A) or higher for 90% of the 15 minute measurement period.

L_{eq}

The 'equivalent continuous sound level', L_{eq}, is used to describe the level of a time-varying sound or vibration measurement.

L_{eq} is often used as the "average" level for a measurement where the level is fluctuating over time. Mathematically, it is the energy-average level over a period

of time (i.e. the constant sound level that contains the same sound energy as the measured level). When the dB(A) weighting is applied, the level is denoted dB $L_{Aeq.}$ Often the measurement duration is quoted, thus $L_{Aeq,15\ min}$ represents the dB(A) weighted energy-average level of a 15 minute measurement.

L_{max}

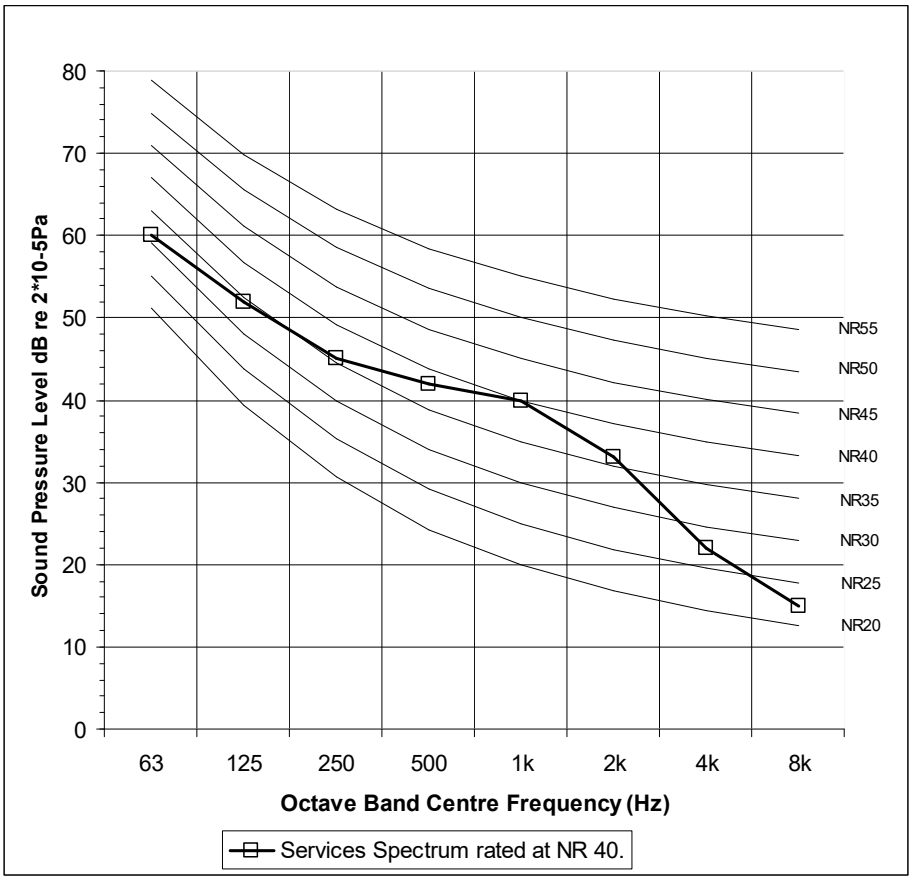
The L_{max} statistical level can be used to describe the "absolute maximum" level of a sound or vibration level that varies with time.

Mathematically, L_{max} is the highest value recorded during the measurement period. As an example, 94 dB L_{Amax} is a highest value of 94 dB(A) during the measurement period.

Since L_{max} is often caused by an instantaneous event, L_{max} levels often vary significantly between measurements.

Frequency

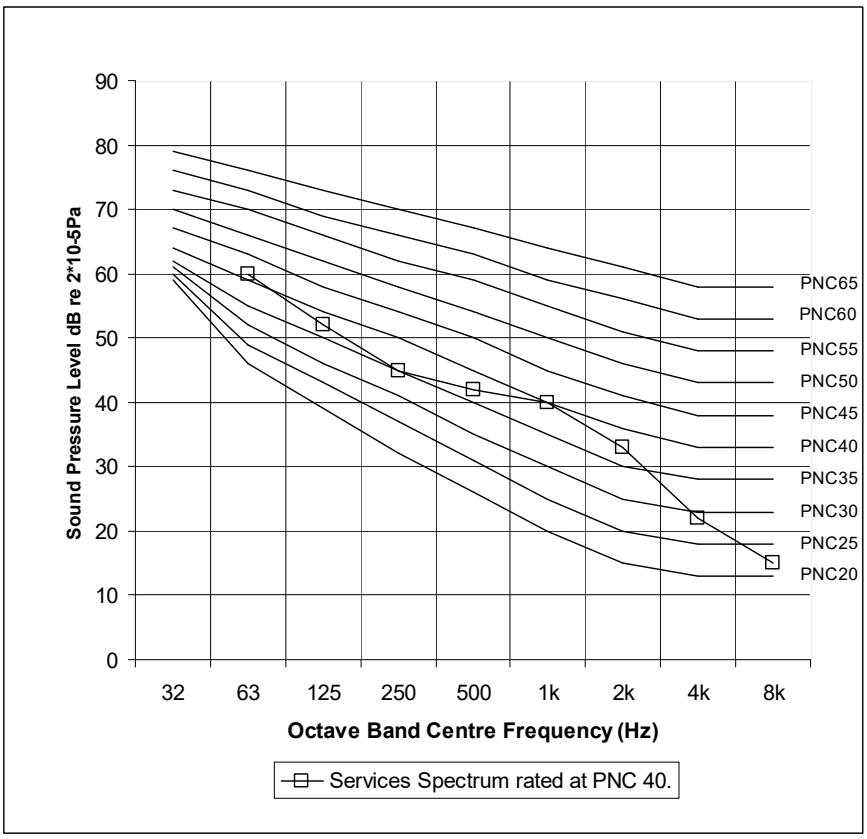
Frequency is the number of cycles per second of a sound or vibration wave. In musical terms, frequency is described as "pitch". Sounds towards the lower end of the human hearing frequency range are perceived as "bass" or "low-pitched" and sounds with a higher frequency are perceived as "treble" or "high pitched".



Peak Particle Velocity (PPV)

Peak Particle Velocity (PPV) is the highest velocity of a particle (such as part of a building structure) as it vibrates. Most sound level meters measure *root mean squared* (RMS) values; it is common to approximate the PPV based on an RMS measurement.

PPV is commonly used as a vibration criteria, and is often interpreted as a PPV based on the L_{max} or $L_{max,spec}$ index.Preferred Noise Criterion (PNC) Curves



A set of curves, similar in principle to NR curves, but considered to correlate better to subjective acceptability in very low noise areas such as music auditoria.

Sound Power and Sound Pressure

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 (L_p) varies as a function of distance from a source. However, the sound power level is an intrinsic characteristic of a source (analogous to its mass), which is not affected by the environment within which the source is located.

Vibration

Waves in a solid material are called “vibration”, as opposed to similar waves in air, which are called “sound” or “noise”. If vibration levels are high enough, they

can be felt; usually vibration levels must be much higher to cause structural damage.

A vibrating structure (eg a wall) can cause airborne noise to be radiated, even if the vibration itself is too low to be felt. Structureborne vibration limits are sometimes set to control the noise level in a space.

Vibration levels can be described using measurements of displacement, velocity and acceleration. Velocity and acceleration are commonly used for structureborne noise and human comfort. Vibration is described using either metric units (such as mm, mm/s and mm/s^2) or else using a decibel scale.