15 August 2018

630.11166-Lot5A_MechPlant-v1.0.doc

Goodman Property Services (Aust) Pty Ltd
Level17
60 Castlereagh Street
Sydney NSW 2000

Attention: Guy Smith

Dear Guy

Oakdale South Estate
Lot 5A DHL
Clarification of Noise Model Inputs - Mechanical Plant

SLR Consulting Australia Pty Ltd (SLR) prepared the DA Noise Impact Assessment (NIA) for the DHL development at Lot 5A of the Oakdale South Estate (the OSE). The NIA is detailed in SLR Report *630.11166-R09-v1.0*, dated 8 May 2018.

Goodman Property Services (Aust) Pty Ltd (Goodman) has provided SLR with updated plans for the development which detail the locations of the primary items of mechanical plant associated with the temperature control system. In order to confirm that the modelled noise emissions detailed in the NIA are consistent with the updated plans, SLR has reviewed the provided documents, as listed in **Table 1**.

Table 1 Development Documents Reviewed by SLR

Document Title	Document ID	Document Date	Document Author
DHL – Roof Plan	OAK DHL DA 205(E)	31 July 2018	SBA Architects
DHL – Elevations & Section	OAK DHL DA 301(G)	31 July 2018	SBA Architects

Review of the above plans indicates a total of 13 mechanical plant units located on the roof of the warehouse. No details of specific types or models have been provided (assumed to have not been determined at this stage of the development).

Details of the indicative mechanical plant modelled as part of the NIA are as follows:

- 16 units located on the warehouse roof
- 8 units located on the southeast office roof
- 8 units located on the northwest office roof

All units have been modelled with a Sound Power Level (SWL) of 70 dBA per unit, and have been conservatively assumed to operate continuously, 24 hours per day.

The updated plans indicate fewer mechanical plant units than have been modelled in the NIA. Assuming these units have a similar SWL to that modelled in the NIA, noise emissions from mechanical plant would be consistent with or lower than the modelled noise emissions detailed in the NIA.

Noise emissions from mechanical plant should be confirmed during detailed design when specific types and models of plant have been determined. Should the SWL's of the selected units be higher than those modelled it is expected that the noise emissions of the individual units could be sufficiently mitigated through standard acoustic measures such as judicious selection of mechanical plant and localised shielding around fixed plant.

As such, noise impacts associated with the updated development plans are considered to be consistent with those of the approved development.

I trust that this letter covers your requirements.

Yours sincerely

JOSHUA RIDGWAY
Senior Consultant

Checked/
Authorised by: NV

OAKDALE SOUTH ESTATE

Lot 5A DHL
DA Noise Impact Assessment

Prepared for:

Goodman Property Services (Aust) Pty Ltd
Level 17
60 Castlereagh Street
Sydney NSW 2000

SLR Ref: 630.11166-R09
Version No: -v1.0
May 2018

PREPARED BY

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Goodman Property Services (Aust) Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
630.11166-R09-v1.0	8 May 2018	Joshua Ridgway	Antony Williams	Antony Williams

EXECUTIVE SUMMARY

Operational Noise

An operational noise impact assessment has been conducted for Lot 5A DHL of the Oakdale South Estate (OSE). Operational Noise Limits consistent with those in the Development Consent SSD 6917 for the OSE Masterplan have been adopted, as modified by SSD 6917 MOD 1 (April 2017), MOD 3 (October 2017), MOD 4 (December 2017), and MOD 5 (November 2017).

An analysis of the prevailing weather conditions for the OSE indicated that adverse weather is a feature of the area only during the night-time period.

The operational noise modelling for Lot 5A found no exceedances of the Noise Limits at any sensitive receivers under both neutral (day, evening and night periods) and adverse (night period) weather conditions.

Cumulative operational noise levels of Lot 5A and the OSE Masterplan design are predicted to be below the Noise Limits at all identified residential receivers under both neutral and adverse weather conditions during the applicable periods.

The $L_{A1(1minute)}$ noise emissions are predicted to be compliant with the nominated noise criteria at all identified receivers under both neutral and adverse weather conditions during the applicable periods.

As such, with consideration of the above, operational noise emissions from Lot 5A DHL are considered to be acceptable.

The limiting sound power levels for rooftop fixed plant units was found to be SWL of 70 dBA per unit and should be confirmed during detailed design when the corresponding equipment is selected.

Off-site traffic movements associated with Lot 5A are predicted to have a negligible impact on road traffic noise levels in the vicinity of the main access routes of Lenore Drive and Old Wallgrove Road, given the existing high volume of traffic on these arterial roads.

Construction Noise and Vibration

A construction noise and vibration impact assessment has been conducted for Lot 5A DHL of the Oakdale South Estate. Construction noise management levels (NMLs) consistent with those in the Development Consent SSD 6917 for the OSE Masterplan have been adopted.

Works are anticipated to be completed during standard construction hours only. Construction noise levels are predicted to be compliant with the noise goals at the surrounding residential receivers, with the exception of the proposed Jacfin and Capitol Hill residential areas.

Worst-case construction noise emissions of up to 50 dBA are predicted in the Jacfin area, and up to 56 dBA in the Capitol Hill area. It should be noted that this is the realistic worst-case noise impacts at the boundary of these areas closest to the works, and that noise impacts would decrease further back within the residential areas, and when the construction works are further back in Lot 5A DHL.

EXECUTIVE SUMMARY

It is noted that construction in Lot 5A DHL is likely to occur before construction of the residential buildings within the Jacfin and Capitol Hill areas. The construction NMLs apply only to dwellings occupied during construction of the OSE.

Construction noise mitigation measures should be implemented as recommended in this report, where feasible and reasonable.

Predicted cumulative construction noise impacts of Lot 5A DHL and the whole OSE estate are consistent with those predicted in the SSD Masterplan Noise Impact Assessment.

The separation distance between Lot 5A and the nearest existing vibration sensitive receivers is considered to be sufficient to mitigate potential impacts at residential and existing commercial receivers. Where buildings within the Jacfin or Capitol Hill areas, or other commercial buildings in the OSE, have been constructed prior to construction of Lot 5A, vibration impacts should be managed where works are required within the safe working distances of these buildings.

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1 Introduction

1.1 Background

Goodman Property Services (Aust) Pty Ltd (Goodman) is currently developing the Oakdale South Estate (OSE) site on Milner Avenue, Kemps Creek. Lot 5A DHL (the project) is proposed to be developed and integrated into the OSE.

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Goodman to prepare a Noise Impact Assessment (NIA) for Lot 5A DHL assessing the potential noise impacts associated with the project. This report presents the results of the assessment and forms part of the Development Application (DA) for the project.

1.2 Relevant Guidelines

Noise from the operation of the project has been assessed in accordance with the *NSW Industrial Noise Policy* (INP), NSW EPA, 2000. It is noted that the EPA released the *Noise Policy for Industry* (NPI) in October 2017, which replaces the INP. However, the project is required to be assessed under the INP.as the Development Consent for the OSE was issued prior to the NPI being released.

Construction noise has been assessed in accordance with the *Interim Construction Noise Guideline* (ICNG), DECC, 2009.

Vibration from operation and construction has been assessed in accordance with *Assessing Vibration: A Technical Guideline*, DEC, 2006.

1.3 Terminology

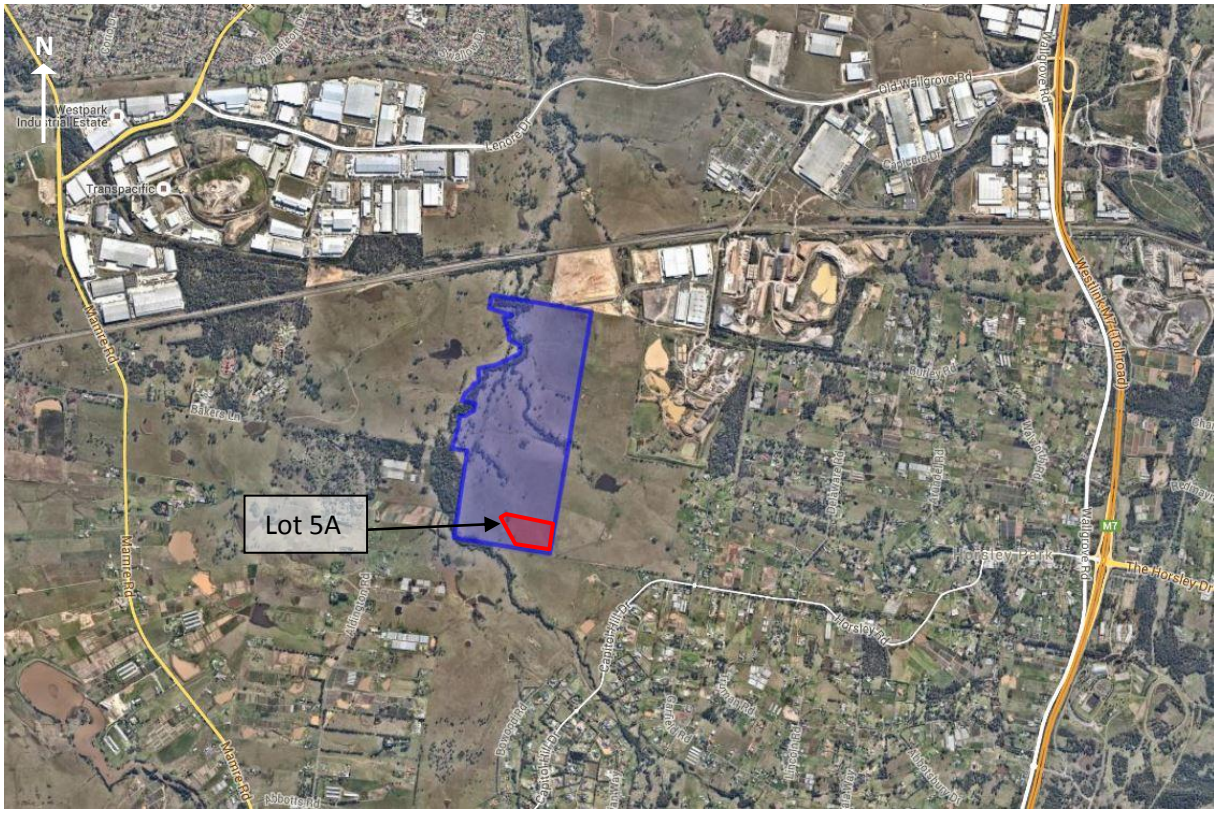
The assessment has used specific acoustic terminology. An explanation of common terms is included as **Appendix A**.

2 Project Description

2.1 Oakdale South Estate

The location of the Oakdale South Estate (OSE) development site is shown in **Figure 1**.

Figure 1 Oakdale South Estate Site Location



Note 1: OSE site indicated in blue, Lot 5A indicated in red.

The Lot 5A DGL development is within the OSE SSD 6917 Masterplan. The approved Masterplan for the OSE is shown in **Figure 2**.

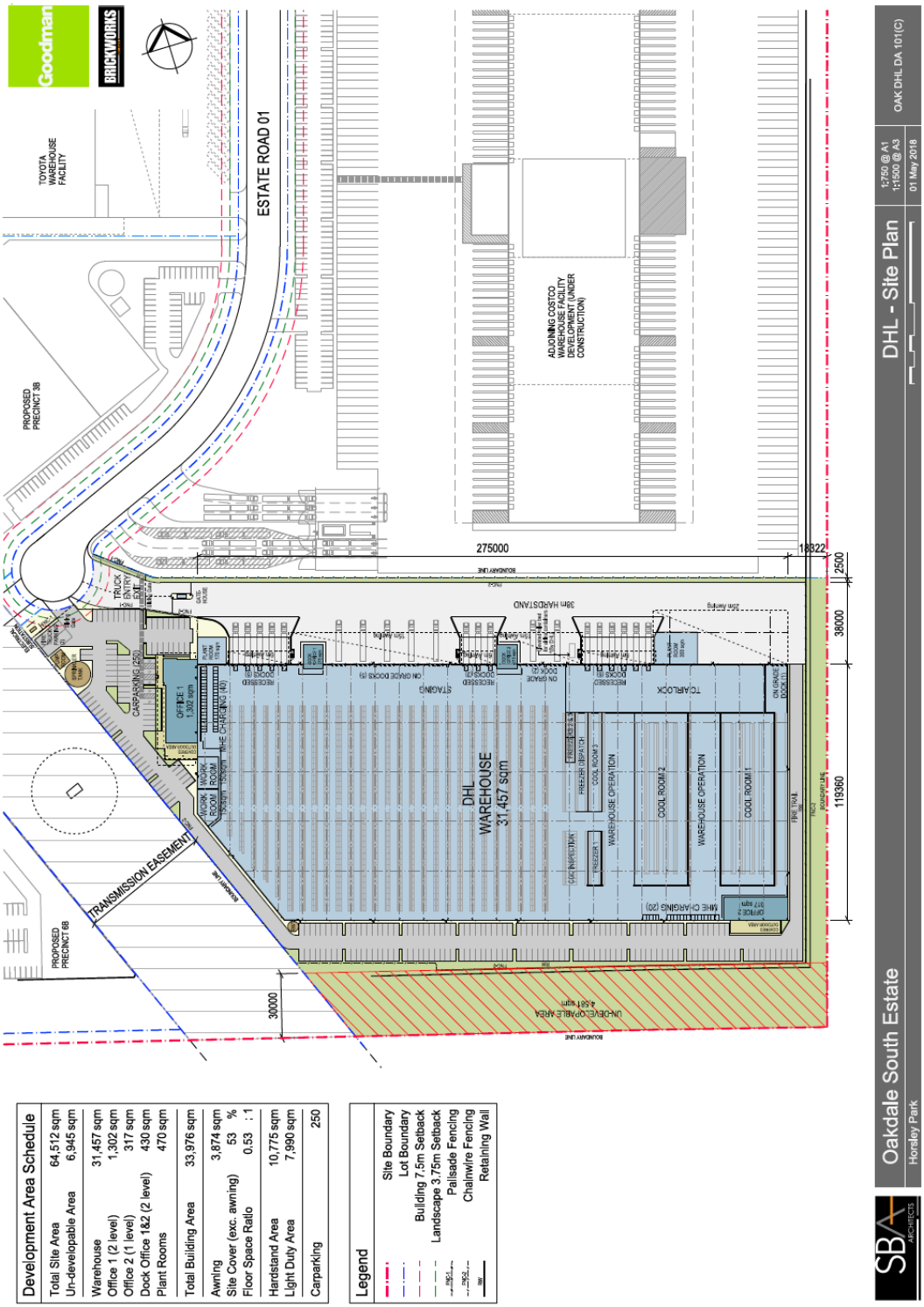
Figure 2 Approved Oakdale South Estate Masterplan

Note 1: Lot 5A DHL indicated in red.

2.2 Lot 5A DHL

The current DA covers the construction and operation of Lot 5A DHL as indicated in drawing OAK DHL DA 101(A), dated 9 March 2018, as shown in **Figure 3**.

Figure 3 Lot 5A DHL Design Plans



Development Area Schedule	
Total Site Area	64,512 sqm
Un-developable Area	6,945 sqm
Warehouse	31,457 sqm
Office 1 (2 level)	1,302 sqm
Office 2 (1 level)	317 sqm
Dock Office 1&2 (2 level)	430 sqm
Plant Rooms	470 sqm
Total Building Area	33,976 sqm
Awning	3,874 sqm
Site Cover (exc. awning)	53 %
Floor Space Ratio	0.53 : 1
Hardstand Area	10,775 sqm
Light Duty Area	7,990 sqm
Carparking	250

Legend
Site Boundary
Lot Boundary
Building 7.5m Setback
Landscape 3.75m Setback
Palisade Fencing
Chainwire Fencing
Retaining Wall

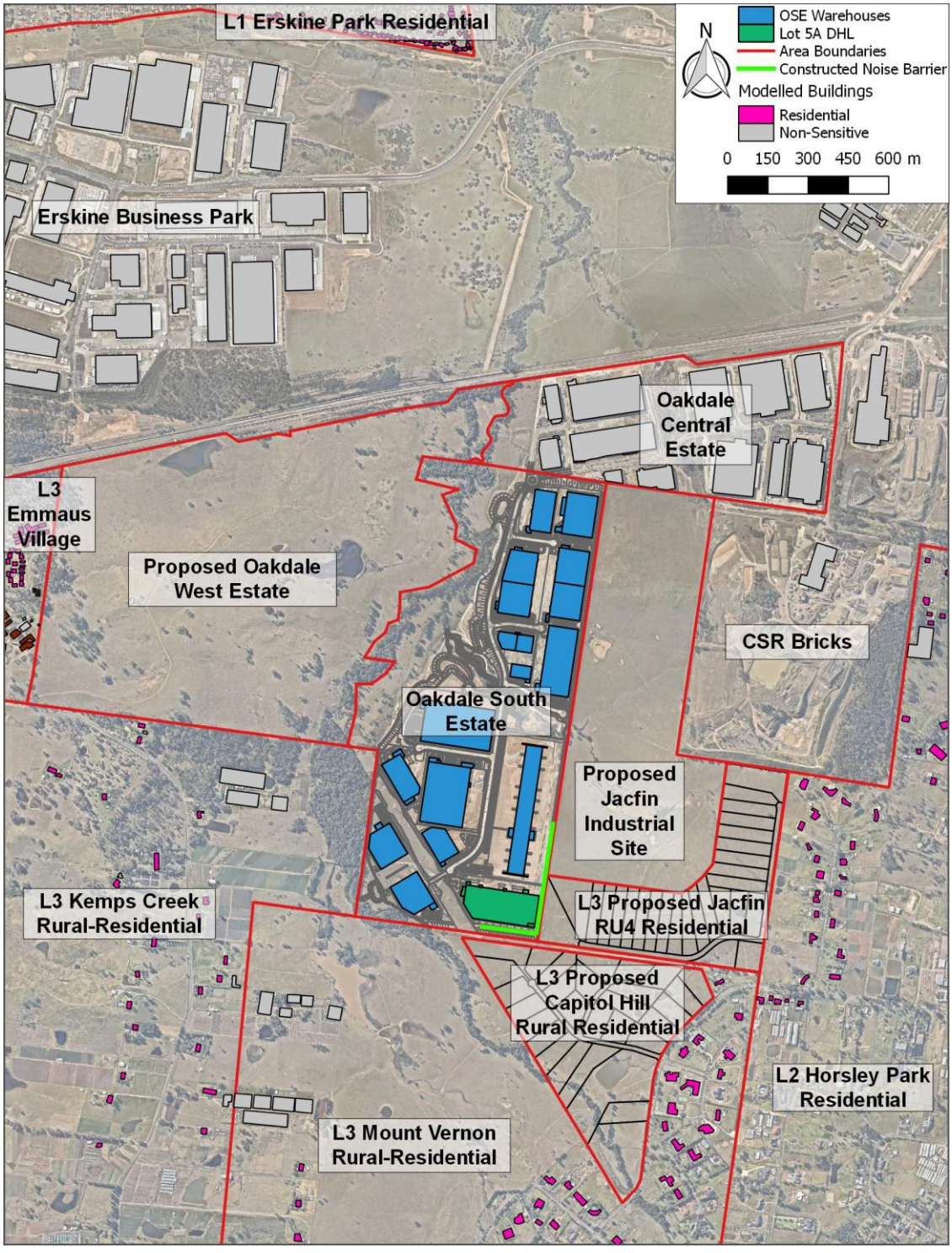
Note 1: Drawing provided by Goodman, dated 9/03/2018.

3 Noise Limits and Receiver Locations

3.1 Receiver Locations

The locations of noise sensitive receivers in the vicinity of the OSE are shown in **Figure 4**.

Figure 4 Residential Receiver Areas and Modelled Buildings



3.2 Operational Noise Limits

The operational noise limits applicable to the OSE are defined in Condition B18 of the site's Development Consent SSD 6917. The operational noise limits are reproduced in **Table 1**.

Table 1 Oakdale South Estate Operational Noise Limits – Residential

Location	Day	Evening	Night	Night
	$L_{Aeq(15minute)}$	$L_{Aeq(15minute)}$	$L_{Aeq(15minute)}$	$L_{A1(1minute)}$
L1 North of Warragamba Pipeline	37	37	37	47
L2 Horsley Park	39	39	39	49
L3 Kemps Creek, Mt Vernon, Jacfin and Capitol Hill	40	40	40	48

Note 1: As per the *NSW Industrial Noise Policy* (INP), the above criteria are applicable at the most-affected point on or within the residential property boundary or, if this is more than 30 m from the residence, at the most-affected point within 30 m of the residence.

3.3 Construction Noise Goals

The Development Consent SSD 6917 for the OSE stipulates several conditions relating to noise from construction of the OSE. The conditions applicable to this report and the proposed development are reproduced below.

E18. Construction activities associated with the Development shall be undertaken during the following hours:
a) 7:00 am to 6:00 pm Mondays to Fridays, inclusive; and
b) 8:00 am to 1:00 pm Saturdays; and
c) At no time on Sundays or public holidays.

E27. The development shall be constructed with the aim of achieving the construction noise management levels detailed in the Interim Construction Noise Guideline *(ICNG, Department of Environment and Climate Change, 2009). All feasible and reasonable noise mitigation measures shall be implemented and any activities that could exceed the construction noise management levels shall be identified and managed in accordance with the management and mitigation measures in the RTS.*

The Noise Management Levels (NMLs) for the OSE (as per the ICNG) were detailed in the SSD Masterplan Noise Impact Assessment (SLR *Report 630.11166-R1R3*, dated 28 October 2015) and are reproduced in **Table 2**.

Table 2 Oakdale South Estate Construction Noise Management Levels

Receiver	Time of Day	$L_{Aeq(15minute)}$ Construction Noise Management Levels (dB)	
		Standard Construction Hours	Highly Noise Affected
Residential	Daytime	42	75
	Evening	n/a	75
	Night-time	n/a	75

3.4 Prevailing Weather Conditions

Adverse weather conditions such as wind and temperature inversions have the potential to increase noise levels from industrial or road noise sources at nearby receivers.

In order to determine the prevailing weather conditions for the OSE, 12 months of weather data (January 2016 to December 2016) was obtained from the Bureau of Meteorology automatic weather station at Horsley Park, which is approximately 5 km to the southeast of the project site. This data was analysed to determine the frequency of noise enhancing wind and temperature inversion conditions which may affect noise levels at the site.

3.4.1 Wind

Wind has the potential to increase noise at a receiver when wind is light and stable, and blows from the direction of the source of noise to the receiver. At higher wind speeds, the noise produced by the wind can obscure noise generated from industrial and transport sources.

Wind effects need to be considered where wind is a feature of the project area. The INP states that where wind blows from the source to the receiver at speeds up to 3 m/s for more than 30% of the daytime, evening or night-time in any season, then wind is considered to be a feature of the area and noise level predictions must be made under these conditions.

The measured weather data was analysed to determine the frequency of occurrence of wind speeds up to 3 m/s in each period. The results of the wind analysis for the daytime, evening and night-time periods are presented in **Table 3**, **Table 4** and **Table 5**, respectively. In each table, the wind direction and percentage occurrence are those dominant during each season.

Table 3 Seasonal Frequency of Occurrence of Wind Speed Intervals in 2016 – Daytime

Season	Dominant Wind Direction	Frequency of Occurrence			
		Calm	0.5 to 2 m/s	2 to 3 m/s	0.5 to 3 m/s
Annual	N	10.2%	14.7%	5.7%	20.4%
Summer	NNE	11.2%	14.3%	7.3%	21.6%
Autumn	N	10.9%	15.9%	5.9%	21.8%
Winter	NW	12.8%	18.8%	5.6%	24.4%

Table 4 Seasonal Frequency of Occurrence of Wind Speed Intervals in 2016 – Evening

Season	Dominant Wind Direction	Frequency of Occurrence			
		Calm	0.5 to 2 m/s	2 to 3 m/s	0.5 to 3 m/s
Annual	ESE	17.8%	9.1%	6.1%	15.2%
Summer	E	9.5%	10.4%	10.3%	20.8%
Autumn	S	25.4%	12.1%	6.3%	18.4%
Winter	WSW	24.1%	15.3%	8.2%	23.5%

Table 5 Seasonal Frequency of Occurrence of Wind Speed Intervals in 2016 – Night-time

Season	Dominant Wind Direction	Frequency of Occurrence			
		Calm	0.5 to 2 m/s	2 to 3 m/s	0.5 to 3 m/s
Annual	SW	37.8%	17.9%	8.7%	26.6%
Summer	SSW	42.0%	18.7%	8.8%	27.5%
Autumn	SW, WSW	44.0%	21.0%, 20.7%	10.6%,9.7%	31.6%, 30.3%
Winter	WSW	32.1%	17.6%	9.9%	27.5%

The above analysis of prevailing wind conditions indicates that during the daytime and evening periods, winds of up to 3 m/s did not exceed the 30% threshold during any season. However, the 30% threshold was exceeded during the night-time period in autumn, in both the SW and WSW directions.

Based on the prevailing wind analysis conducted for the 2016 weather data, assessment of adverse weather during the daytime and evening periods is not required under the INP.

3.4.2 Temperature Inversions

Temperature inversions have the ability to increase noise levels by focusing sound waves towards sensitive receivers. Temperature inversions occur predominantly at night-time when the atmosphere is stable and temperatures are cooler. For a temperature inversion to be a significant characteristic of the area, the INP defines that it needs to occur for approximately 30% of the total night-time during winter. This equates to approximately two nights per week.

The Pasquill-Gifford assignment scheme identifies seven Stability Classes – A to G – to categorise the degree of atmospheric stability, as shown in **Table 6**.

Table 6 Description of Atmospheric Stability Classes

Atmospheric Stability Class	Category Description
A	Extremely unstable
B	Moderately unstable
C	Slightly unstable
D	Neutral
E	Slightly stable

The measured weather data has been analysed to determine the frequency of each stability class and is presented in **Table 7**. Noise enhancing temperature inversions are categorised as atmospheric stability Class F or Class G.

Table 7 Night-time Stability Class Distribution – 2016

Stability Class	Frequency of Occurrence				
	Annual	Summer	Autumn	Winter	Spring
A	0.0%	0.0%	0.0%	0.0%	0.0%
B	0.0%	0.0%	0.0%	0.0%	0.0%
C	0.0%	0.0%	0.0%	0.0%	0.0%
D	39.5%	37.4%	34.7%	45.2%	41.5%
E	12.0%	11.7%	10.5%	12.4%	13.6%
F	12.9%	11.2%	13.7%	14.0%	12.9%
G	35.5%	39.7%	41.1%	28.5%	32.0%
F+G	48.4%	50.9%	54.8%	42.4%	44.9%

The above analysis indicates that temperature inversions of Class F or Class G occur more than 30% of the night-time period during all four seasons. Therefore, temperature inversions should be included in the assessment of noise impacts during the night-time period under the INP.

4 Operational Noise Impact Assessment

4.1 Operational Noise Modelling

Noise modelling of the Lot 5A DHL development site was undertaken by modifying the SoundPLAN V7.1 noise models prepared for the Masterplan operational noise impact assessment for the OSE.

The three-dimensional models were updated to reflect the current design of Lot 5A DHL, based on the provided design plans.

The noise model includes the noise barrier located along the southeastern boundary of the OSE, as constructed (refer to **Figure 4**).

4.1.1 Daytime and Evening Periods

In order to assess the operational noise impacts from Lot 5A DHL, worst-case peak light and heavy vehicle movements for Lot 5A have been modelled across the development. Light vehicles have been modelled on the estate roads and in the car parking areas. Heavy vehicles have been modelled on the estate roads and manoeuvring in the hardstand areas. Modelled vehicle volumes are provided in **Table 8**.

Table 8 Daytime / Evening Peak Vehicle Volumes for Lot 5A DHL

Lot	Vehicles per Hour (Peak)	Heavy Vehicle Percentage
5A DHL	57	15%

Note 1: Vehicle volumes provided by the traffic consultants for the project (Ason Group).

This is further broken down to peak 15 minute volumes of:

- 12 light vehicles
- 2 heavy vehicles

External forklift movements within Lot 5A have been modelled in the at-grade dock areas of the hardstand. It has been assumed that forklifts would operate continuously during any one 15-minute period. Two forklifts have been modelled operating externally in the hardstand areas.

Sound power levels and speed assumptions for the modelled vehicle movements are outlined in **Table 9**.

Table 9 Sound Power Levels for Onsite Vehicle Movements

Noise Source	Sound Power Level (SWL)	Average Speed
Heavy Vehicles	103 dBA[1]	25 km/h
Light Vehicles	96 dBA	40 km/h
Gas-powered Forklifts[2]	93 dBA	n/a

Note 1: Based on SLR's noise measurement database, this sound power level is typical of trucks travelling at low speeds, such as within industrial estates.

Note 2: If electric forklifts are proposed for the development, noise emissions from forklifts would be considerably lower than gas-powered forklifts.

The majority of fixed plant associated with Lot 5A is proposed to be located within the warehouse or within the dedicated plant rooms located on the northern side of the warehouse. The plant rooms are proposed to be constructed such that noise emissions through the structure would be negligible. The acoustic properties of the construction of the plant room should be investigated during the detailed design phase when final details of plant and construction are known.

External fixed plant is proposed to consist of rooftop HVAC units on the warehouse (approximately 16 units), and on the office rooftops (approximately eight units on each office). Rooftop fixed plant units have been modelled with a SWL of 70 dBA per unit. These SWLs have been calculated as the limit where fixed plant does not increase the predicted $L_{Aeq(15minute)}$ noise emissions at the nearest sensitive receivers. The Lot 5A DHL noise emissions are dominated by vehicle movements at this point.

It should be noted that during detailed design, noise emitted by the fixed mechanical plant items will need to be confirmed and, if required, mitigated to achieve the required noise emission levels. This can be achieved through standard acoustic measures such as incorporating acoustic louvres, judicious selection of mechanical plant and localised shielding around fixed plant.

4.1.2 Night-time Period

It has been advised by the traffic consultants for the project (Ason Group) that the night-time peak vehicle movements would be 30% of the daytime / evening peak vehicle movements. Night-time movements have been modelled in order to assess the noise impacts under adverse weather conditions during this period (refer to **Section 3.4**).

It has been conservatively assumed that all fixed plant would operate at 100% capacity during the night-time period.

In order to assess the possibility of sleep disturbance, in addition to the above noise sources, heavy vehicle brake releases and reverse alarms (non-tonal) have been modelled in the hardstand areas of the development with a sound power level (SWL) of 115 dBA.

4.2 Predicted Operational Noise Impacts

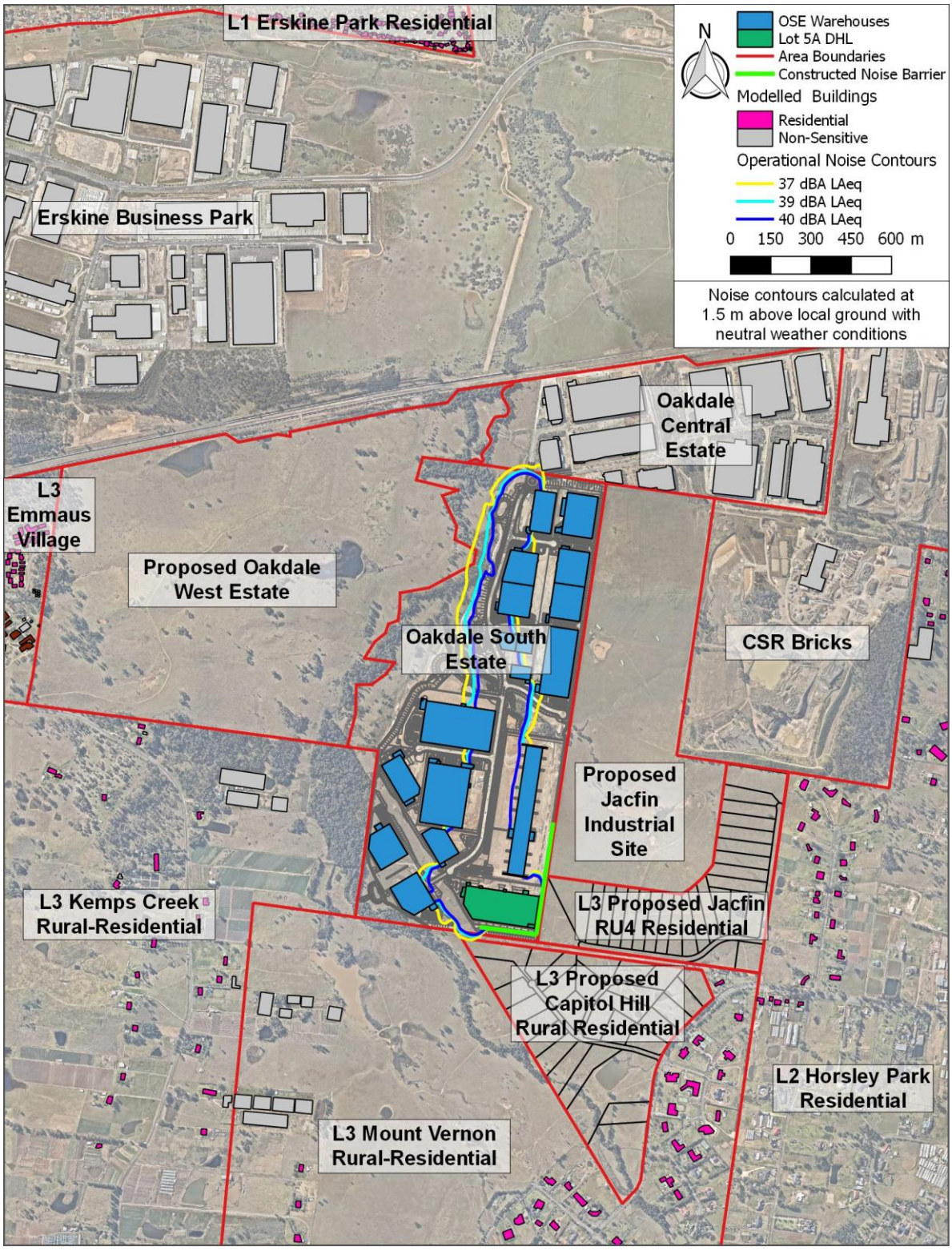
The predicted operational noise levels for Lot 5A DHL are summarised in **Table 10**. Noise contour maps of the operational results during the daytime and evening periods under neutral weather conditions are shown in **Figure 5**, and during the night-time period under neutral weather conditions and adverse weather conditions in **Figure 6** and **Figure 7** respectively.

Table 10 Predicted Operational Noise Levels – Lot 5A DHL

Sensitive Receiver Area	Noise Limits (dBA)				Predicted Noise Levels (dBA) – Most-Affected Receiver				
	$L_{Aeq(15minute)}$			$L_{A1(1minute)}$	$L_{Aeq(15minute)}$			$L_{A1(1minute)}$	
	Day	Eve	Night	Night	Day/Eve	Night		Night	
					Neutral Weather	Neutral Weather	Adverse Weather[1]	Neutral Weather	Adverse Weather[1]
L1 Erskine Park Residential	37	37	37	47	<30	<30	<30	30	36
L2 Horsley Park Residential	39	39	39	49	<30	<30	<30	31	38
L3 Proposed Jacfin Residential	40	40	40	48	34	33	35	46	48
L3 Proposed Capitol Hill Residential	40	40	40	48	32	31	33	44	46
L3 Mount Vernon Residential	40	40	40	48	<30	<30	<30	31	38
L3 Kemps Creek Residential	40	40	40	48	<30	<30	<30	30	40
L3 Emmaus Village Residential	40	40	40	48	<30	<30	<30	30	36

Note 1: Applicable parameters for adverse weather are discussed in **Section 3.4** and are outlined in the INP, ie 3 m/s source to receiver wind or F class temperature inversion with 2 m/s source to receiver drainage flow during the night-time period.

Figure 5 Predicted Operational Noise Contours – Lot 5A DHL Daytime / Evening Periods – Neutral Weather Conditions

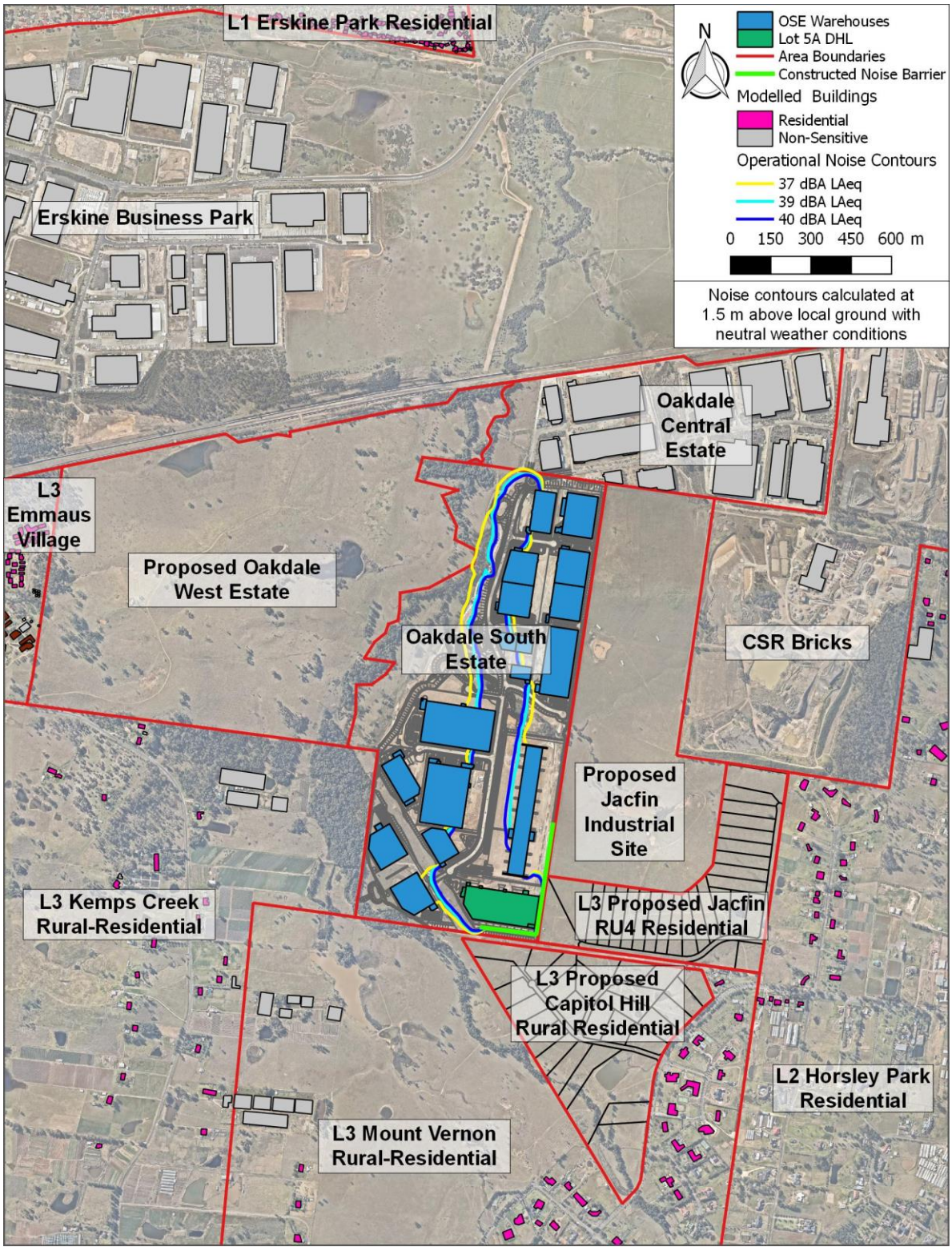


Note 1: 37 dBA LAeq noise contour (yellow) corresponds to the noise limit for residences in L1.

Note 2: 39 dBA LAeq noise contour (light blue) corresponds to the noise limit for residences in L2.

Note 3: 40 dBA LAeq noise contour (dark blue) corresponds to the noise limit for residences in L3.

Figure 6 Predicted Operational Noise Contours – Lot 5A DHL Night-time Period – Neutral Weather Conditions

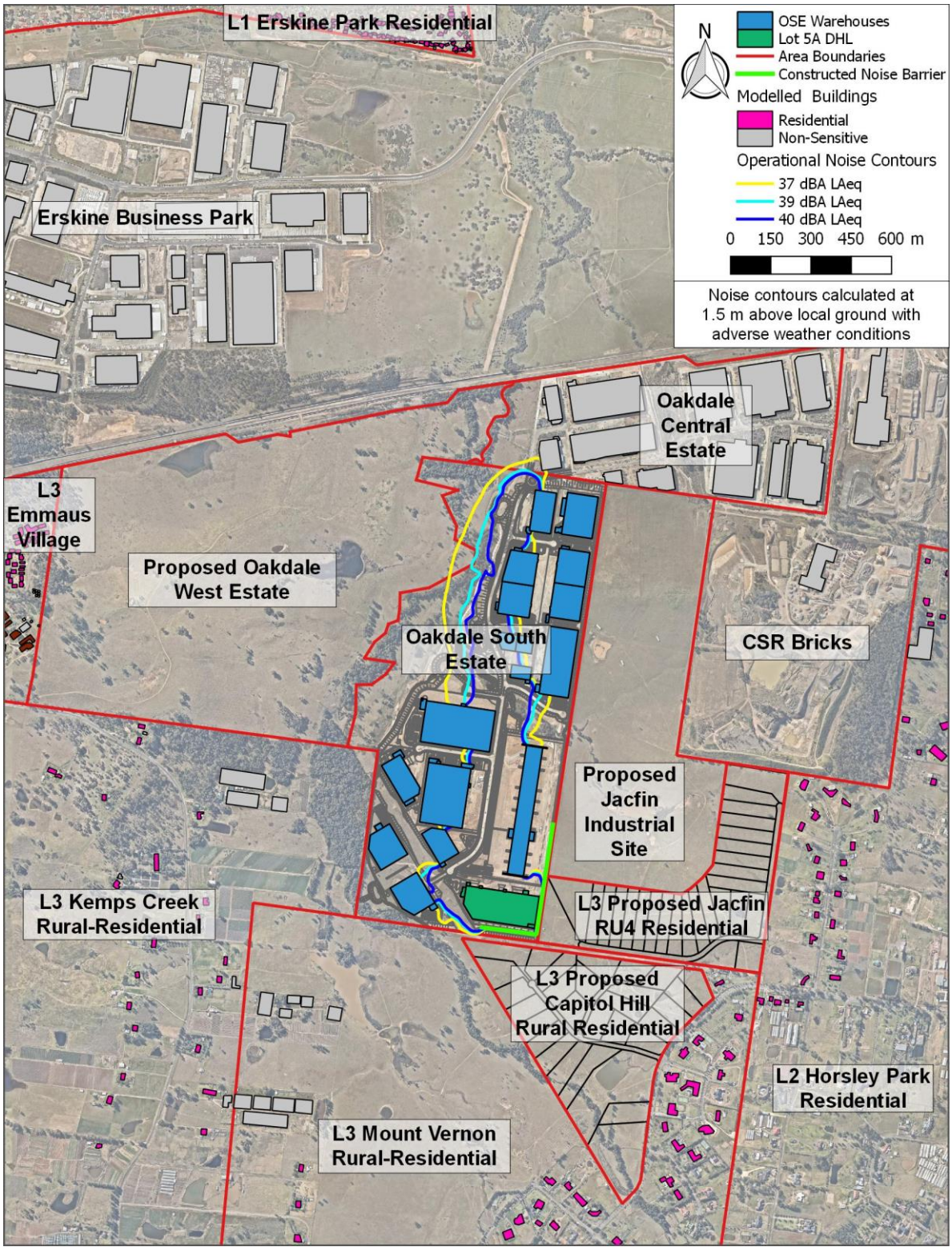


Note 1: 37 dBA LAeq noise contour (yellow) corresponds to the noise limit for residences in L1.

Note 2: 39 dBA LAeq noise contour (light blue) corresponds to the noise limit for residences in L2.

Note 3: 40 dBA LAeq noise contour (dark blue) corresponds to the noise limit for residences in L3.

Figure 7 Predicted Operational Noise Contours – Lot 5A DHL Night-time Period – Adverse Weather Conditions



Note 1: 37 dBA LAeq noise contour (yellow) corresponds to the noise limit for residences in L1.

Note 2: 39 dBA LAeq noise contour (light blue) corresponds to the noise limit for residences in L2.

Note 3: 40 dBA LAeq noise contour (dark blue) corresponds to the noise limit for residences in L3.

The above results indicate that operational noise levels from Lot 5A DHL are predicted to be below the nominated noise criteria at all identified residential receivers under both neutral and adverse weather conditions during the applicable periods.

The $L_{A1(1minute)}$ noise emissions are also predicted to be below the nominated noise criteria at all identified receivers under both neutral and adverse weather conditions during the applicable periods.

4.3 Cumulative Noise Impacts

In order to assess the cumulative operational noise impacts from Lot 5A DHL with the OSE as a whole, worst-case peak light and heavy vehicle movements have been modelled across the development, as per the most recent noise assessment for the masterplan design. Modelled vehicle volumes for the other lots of the OSE are provided in **Table 11**.

These have been modelled in addition to the noise sources outlined for Lot 5A in **Section 4.1**.

Table 11 Vehicle Volumes for Oakdale South Estate

Lot	Vehicles per Hour (Peak)	Heavy Vehicle Percentage
1A	36	15%
1B	40	15%
1C	46	15%
1D	49	15%
2A	19	15%
2B	25	15%
3A	68	15%
3B	62	15%
3C	18	15%
3D	25	15%
4A	144	17%
6A	28	15%
6B	26	15%

Note 1: Vehicle volumes have been provided by the traffic consultants for the project (Ason Group).

It has been advised by the traffic consultants for the project (Ason Group) that the peak night-time vehicle movements would be 30% of the daytime / evening peak vehicle movements. Night-time movements have been modelled in order to assess the noise impacts under adverse weather conditions during this period (refer to **Section 3.4**).

It has been conservatively assumed that all fixed plant would operate at 100% capacity during the night-time period.

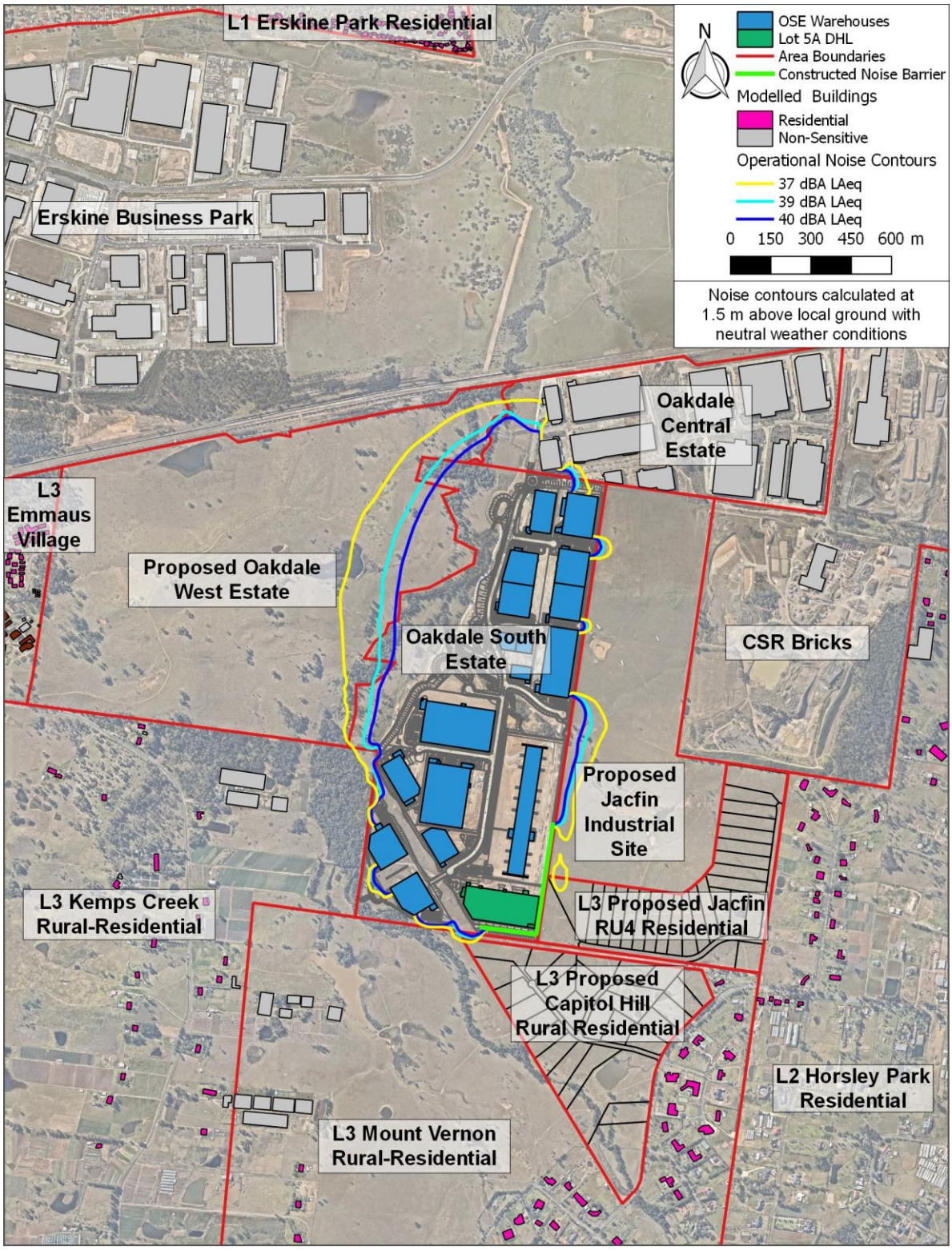
Cumulative noise impacts of Lot 5A DHL and the OSE Masterplan design have been modelled and the predicted operational noise levels are summarised in **Table 12**. Noise contour maps of the cumulative operational results during the daytime and evening periods under neutral weather conditions are shown in **Figure 8**, and during the night-time period under neutral weather conditions and adverse weather conditions in **Figure 9** and **Figure 10** respectively.

Table 12 Predicted Operational Noise Levels – Lot 5A DHL and OSE Cumulative Impacts

Sensitive Receiver Area	Noise Limits (dBA)				Predicted Noise Levels (dBA) – Most-Affected Receiver				
	$L_{Aeq(15minute)}$			$L_{A1(1minute)}$	$L_{Aeq(15minute)}$			$L_{A1(1minute)}$	
	Day	Eve	Night	Night	Day/Eve	Night		Night	
					Neutral Weather	Neutral Weather	Adverse Weather[1]	Neutral Weather	Adverse Weather[1]
L1 Erskine Park Residential	37	37	37	47	<30	<30	31	30	36
L2 Horsley Park Residential	39	39	39	49	<30	<30	32	31	38
L3 Proposed Jacfin Residential	40	40	40	48	38	36	40	46	48
L3 Proposed Capitol Hill Residential	40	40	40	48	36	34	38	44	46
L3 Mount Vernon Residential	40	40	40	48	<30	<30	32	31	38
L3 Kemps Creek Residential	40	40	40	48	30	<30	34	30	40
L3 Emmaus Village Residential	40	40	40	48	<30	<30	31	30	36

Note 1: Applicable parameters for adverse weather are discussed in **Section 3.4** and are outlined in the INP, ie 3 m/s source to receiver wind or F class temperature inversion with 2 m/s source to receiver drainage flow during the night-time period.

Figure 8 Predicted Operational Noise Contours – Lot 5A DHL and OSE Cumulative Impacts Daytime / Evening Periods – Neutral Weather Conditions

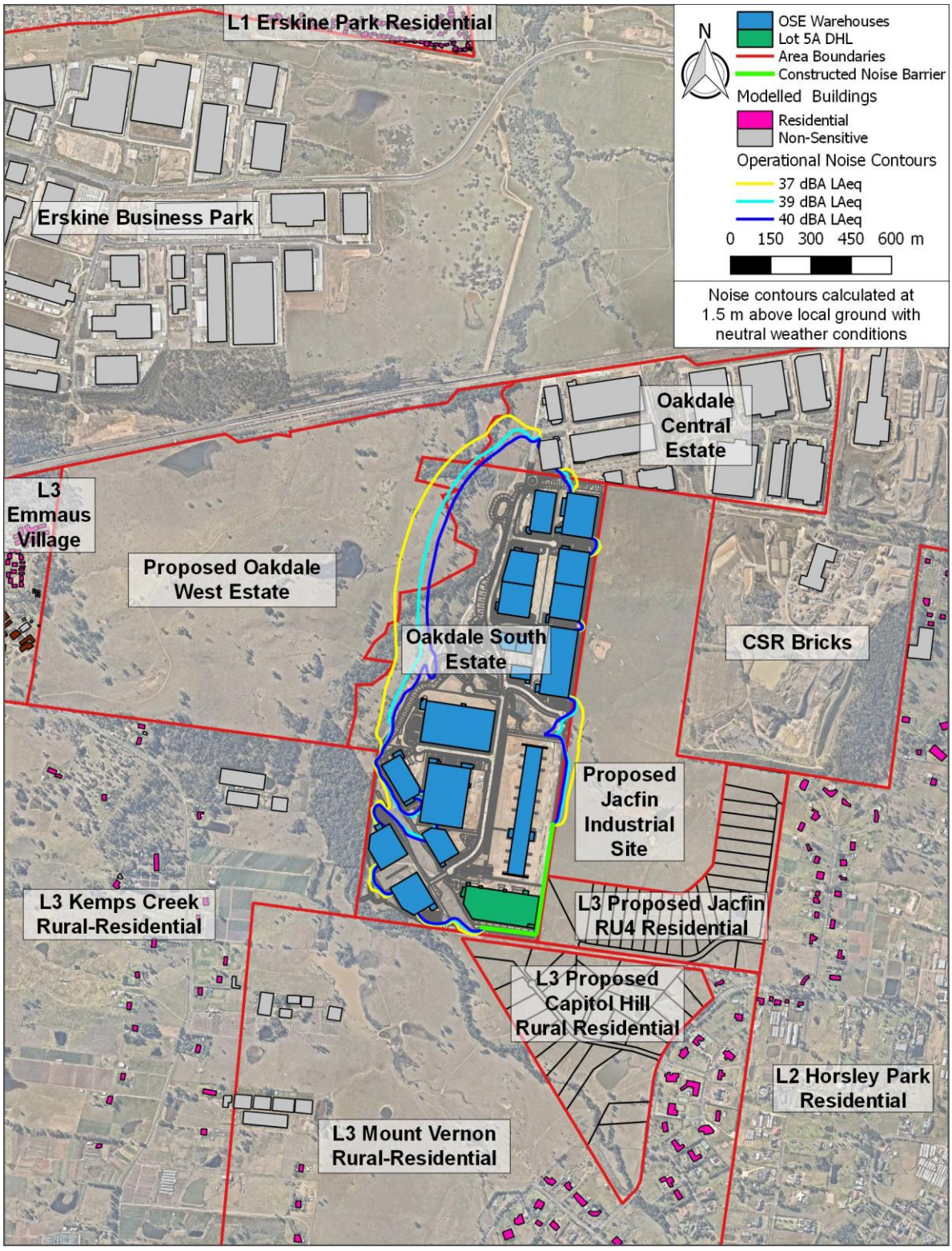


Note 1: 37 dBA LAeq noise contour (yellow) corresponds to the noise limit for residences in L1.

Note 2: 39 dBA LAeq noise contour (light blue) corresponds to the noise limit for residences in L2.

Note 3: 40 dBA LAeq noise contour (dark blue) corresponds to the noise limit for residences in L3.

Figure 9 Predicted Operational Noise Contours – Lot 5A DHL and OSE Cumulative Impacts Night-time Period – Neutral Weather Conditions

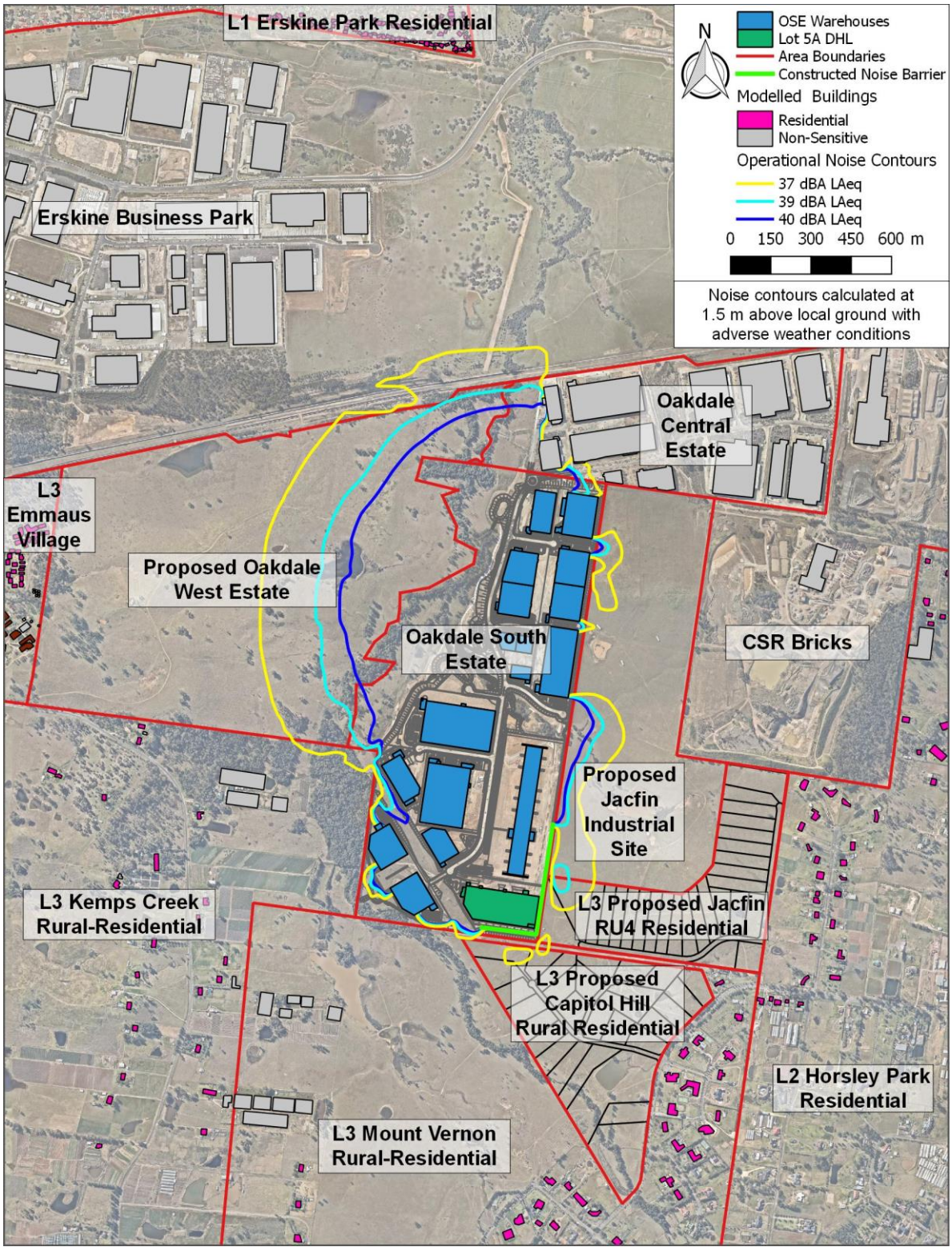


Note 1: 37 dBA LAeq noise contour (yellow) corresponds to the noise limit for residences in L1.

Note 2: 39 dBA LAeq noise contour (light blue) corresponds to the noise limit for residences in L2.

Note 3: 40 dBA LAeq noise contour (dark blue) corresponds to the noise limit for residences in L3.

Figure 10 Predicted Operational Noise Contours – Lot 5A DHL and OSE Cumulative Impacts Night-time Period – Adverse Weather Conditions



Note 1: 37 dBA LAeq noise contour (yellow) corresponds to the noise limit for residences in L1.

Note 2: 39 dBA LAeq noise contour (light blue) corresponds to the noise limit for residences in L2.

Note 3: 40 dBA LAeq noise contour (dark blue) corresponds to the noise limit for residences in L3.

The above results indicate that cumulative operational noise levels of Lot 5A DHL and the OSE Masterplan design are predicted to be below the residential noise limits at all identified residential receivers under both neutral and adverse weather conditions during the applicable periods.

The $L_{A1(1minute)}$ noise emissions are also predicted to be below the nominated noise criteria at all identified receivers under both neutral and adverse weather conditions during the applicable periods.

As such, with consideration of the above, operational noise emissions from Lot 5A DHL are considered to be acceptable.

4.4 Off-site Operational Traffic Movements

While light and heavy vehicle movements within the OSE are classified as part of the operational site noise, once they move off the OSE site and onto public roads they are assessed under the *NSW Road Noise Policy* (RNP).

The RNP requires noise mitigation to be considered where new land use developments increase road traffic noise by more than 2 dB. An increase of greater than 2 dB requires an increase in traffic volumes of approximately 60% or higher.

The main access route to the development site is via Milner Avenue, Old Wallgrove Road and Lenore Drive. No residential receivers are located adjacent to Milner Avenue.

Potential noise increases on the arterial roads of Old Wallgrove Road and Lenore Drive are anticipated to be negligible given the high existing volumes of traffic on these routes in comparison to traffic associated with Lot 5A of the OSE. Therefore, a significant increase in traffic noise is not anticipated on these routes and no mitigation is required to be considered.

Forecast traffic volumes for Lot 5A of the OSE are consistent with those in the approved Masterplan design.

5 Construction Noise and Vibration Impact Assessment

5.1 Construction Noise Modelling

Noise modelling of the Lot 5A DHL development site was undertaken by modifying the SoundPLAN V7.1 noise models prepared for the Masterplan construction noise impact assessment for the OSE.

The three-dimensional models were updated to reflect the current design of Lot 5A DHL, based on the provided design plans.

The noise model includes the noise barrier located along the southeastern boundary of the OSE, as constructed (refer to **Figure 4**).

Sound power levels (SWLs) for the typical construction equipment items and construction activities that have been used in the noise modelling are listed in **Table 13**. It is noted that works associated with bulk earthworks, construction of the boundary retaining wall, earth mounds and noise barrier have previously been completed as part of the Masterplan Stage 1 development.

Table 13 Sound Power Levels for Construction Equipment

Construction Activity	Equipment	Operating minutes in 15-min period	No of items in same location	Sound Power Level SWL (dB)	
				Item	Activity
Paving Works including Concrete Pours	Concrete Pump	7.5	1	106	113
	Concrete Truck / Agitator	7.5	1	106	
	Concrete Vibrator	15	1	102	
	Paving Machine	15	1	104	
	Plate Compactor	5	1	108	
	Vibratory Roller (10-12 tonne)[1]	15	1	109	
Construction of Warehouse and Office Structures	Elevated Working Platform	15	2	97	107
	Flatbed Truck	15	1	100	
	Hand Tools (electric)	15	4	96	
	Mobile Crane (100 tonne)	15	1	101	
	Welding Equipment	15	1	97	
Landscaping and Finishing Works	Hydromulching Equipment	15	1	97	102
	Skidsteer Loader (approx. ½ tonne)	15	1	97	
	Ute	15	1	98	

Note 1: In accordance with the ICNG, for activities identified as particularly annoying (such as jackhammering, rock breaking and power saw operations), a 5 dB 'penalty' is added to the source sound power level when predicting noise using the quantitative method.

Consistent with the requirements of the ICNG, and to inform the scheduling of construction activity and management of noise during the detailed design phase, the construction noise impacts are based on a worst-case assessment. The ICNG recommends that the realistic worst-case or conservative noise levels from the source should be predicted for assessment locations representing the most noise-exposed residences or other sensitive land uses. For each receiver area the noise levels are predicted at the most noise-exposed location, which would usually be the closest receiver.

For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst-case assessment.

Furthermore, other receivers within each receiver area would generally experience lower noise levels compared to the most noise-exposed location as construction work is undertaken at greater separation distance from receivers. To provide an indication of the likely reduction in construction noise levels, the following can be assumed:

- A doubling of the distance between the source and receiver would provide an approximate 6 dB reduction in noise level. For example the sound pressure levels from most items of plant would decrease by around 6 dB as the distance increases from 10 m to 20 m.

- Buildings and other solid structures located between the construction noise source and sensitive receivers would act as barriers and would typically reduce noise levels by up to 15 dB. For example, in a residential area adjoining a construction site the first row of houses would provide an effective shield to the second and subsequent rows with resulting noise levels up to 10 dB lower than would otherwise be experienced in the absence of the first row.

5.2 Predicted Construction Noise Impacts

Construction noise impacts from Lot 5A DHL at the surrounding sensitive receivers have been quantitatively assessed for the activities described in **Table 13**. The predicted typical $L_{Aeq(15minute)}$ noise levels at the surrounding noise sensitive receivers are provided in **Table 14** for each of the construction activities and are representative of the 'noisiest' construction periods with the simultaneous operation of noise intensive construction plant in close proximity. These predictions relate to the plant operating at the closest proposed construction location to the receiver.

Construction noise levels have been predicted during the daytime period only, as per the Development Consent for the OSE, which limits construction to standard construction hours, ie:

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

Table 14 Predicted Construction Noise Levels – Lot 5A DHL

Sensitive Receiver Area	Construction $L_{Aeq(15minute)}$ Noise Goal (dBA) (Standard Hours)	Noise Level – $L_{Aeq(15minute)}$ (dBA)	
		Worst-case Predicted	Noise Goal Exceedance
Paving Works including Concrete Pours			
L1 Erskine Park Residential	42	<30	-
L2 Horsley Park Residential	42	32	-
L3 Proposed Jacfin Residential	42	50	8
L3 Proposed Capitol Hill Residential	42	56	14
L3 Mount Vernon Residential	42	36	-
L3 Kemps Creek Residential	42	35	-
L3 Emmaus Village Residential	42	<30	-
Construction of Warehouse and Office Structures			
L1 Erskine Park Residential	42	<30	-
L2 Horsley Park Residential	42	<30	-
L3 Proposed Jacfin Residential	42	44	2
L3 Proposed Capitol Hill Residential	42	50	8
L3 Mount Vernon Residential	42	30	-
L3 Kemps Creek Residential	42	<30	-
L3 Emmaus Village Residential	42	<30	-

Sensitive Receiver Area	Construction $L_{Aeq(15minute)}$ Noise Goal (dBA) (Standard Hours)	Noise Level – $L_{Aeq(15minute)}$ (dBA)	
		Worst-case Predicted	Noise Goal Exceedance
Landscaping and Finishing Works			
L1 Erskine Park Residential	42	<30	-
L2 Horsley Park Residential	42	<30	-
L3 Proposed Jacfin Residential	42	39	-
L3 Proposed Capitol Hill Residential	42	45	3
L3 Mount Vernon Residential	42	<30	-
L3 Kemps Creek Residential	42	<30	-
L3 Emmaus Village Residential	42	<30	-

The results presented in **Table 14** indicate the noise levels are predicted to generally be compliant with the noise goals at the surrounding residential receivers, with the exception of the proposed Jacfin and Capitol Hill residential areas. Worst-case construction noise emissions of up to 50 dBA are predicted in the Jacfin area, and up to 56 dBA in the Capitol Hill area.

It should be noted that this is the realistic worst-case noise impacts at the boundary of these areas closest to the works, and that noise impacts would decrease further back within the residential areas, and when the construction works are further back in Lot 5A.

It is noted that construction in this precinct may occur before construction of the residential buildings within the Jacfin and Capitol Hill areas. The construction NMLs apply only to dwellings occupied during construction of the OSE.

Where occupied dwellings are present during construction, works adjacent to the proposed Jacfin and Capitol Hill residential areas should be scheduled so that multiple noise intensive construction activities are minimised, where practicable.

Predicted cumulative construction noise impacts of Lot 5A DHL and the whole OSE estate are consistent with those predicted in the SSD Masterplan Noise Impact Assessment (SLR Report *630.11166-R1*).

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

Where exceedances of the NMLs are predicted, it is recommended that the following construction noise mitigation measures should be considered, where feasible and reasonable. Typical construction noise mitigation measures include the following:

- Avoiding the coincidence of noisy plant working simultaneously close together would result in reduced noise emissions.
- Equipment which is used intermittently is to be shut down when not in use.
- Where possible, equipment with directional noise emissions should be oriented away from sensitive receivers.

- Regular compliance checks on the noise emissions of all plant and machinery used for the project would indicate whether noise emissions from plant items were higher than predicted. This also identifies defective silencing equipment on the items of plant.
- Non-tonal reversing alarms should be used on all items of plants and heavy vehicles used for construction.

5.3 Construction Vibration Impacts

The effects of vibration in buildings can be divided into three main categories – those in which the occupants or users of the building are inconvenienced or possibly disturbed, those where the building contents may be affected and those in which the integrity of the building or the structure itself may be prejudiced.

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

The recommended safe working distances for construction plant in **Table 15** are referenced from the TfNSW *Construction Noise Strategy*.

Consistent with British Standard BS 7385 Part 2-1993 and the *Assessing Vibration: A Technical Guideline*, the recommendations are for the practical management of potential vibration to minimise the likelihood of cosmetic damage to buildings and disturbance or annoyance in humans. The human comfort safe working distances are conservative, developed with reference to the more stringent objectives for continuous vibration for typical residential building constructions.

The safe working distances referenced from BS 7385 have been used to determine safe working distances for the German Standard DIN 4150 criteria for dwellings specified in the Development Consent for the Masterplan. It is noted that the criteria for commercial buildings is higher than that for dwellings, therefore, the safe working distances for commercial buildings would be smaller than those outlined below. However, the below distances can still be used as a screening criteria before considering detailed assessment of vibration levels at commercial buildings.

Table 15 Recommended Safe Working Distances for Vibration Intensive Plant

Plant Item	Rating / Description	Safe Working Distance		
		Cosmetic Damage		Human Response[3]
		BS 7385[1] – Residential and light commercial	DIN 4150[2] – Group 2 - dwellings and similar	
Vibratory Roller	< 50 kN (Typically 1-2 tonnes)	5 m	7 m	15 m to 20 m
	< 100 kN (Typically 2-4 tonnes)	6 m	8 m	20 m
	< 200 kN (Typically 4-6 tonnes)	12 m	16 m	40 m
	< 300 kN (Typically 7-13 tonnes)	15 m	20 m	100 m
	> 300 kN (Typically 13-18 tonnes)	20 m	26 m	100 m
	> 300 kN (Typically > 18 tonnes)	25 m	33 m	100 m
Small Hydraulic Hammer	300 kg – 5 to 12t excavator	2 m	3 m	7 m
Medium Hydraulic Hammer	900 kg – 12 to 18t excavator	7 m	10 m	23 m
Large Hydraulic Hammer	1600 kg – 18 to 34t excavator	22 m	29 m	73 m
Vibratory Pile Driver	Sheet piles	2 m to 20 m	3 m	20 m to 100 m
Pile Boring	≤ 800 mm	2 m (nominal)	3 m	N/A
Jackhammer	Hand held	1 m (nominal)	2 m	Avoid contact with structure

Note 1: Referenced from British Standard BS 7385 Part 2-1993.

Note 2: Referenced from German Standard DIN 4150-3.

Note 3: Referenced from *Assessing Vibration: A Technical Guideline*.

Vibration intensive items of plant proposed for use during the construction of the development would include plate compactors and vibratory rollers. These items of equipment are proposed to be used during paving works including concrete pours.

The nearest existing vibration sensitive receivers to the development construction works are located over 650 m from the nearest point of Lot 5A. The separation distance between the works location and the nearest existing vibration sensitive receivers is considered sufficient to mitigate potential vibration generated from the site and specific vibration mitigation measures are not required.

Where buildings are constructed within the Jacfin and Capitol Hill areas, or other commercial buildings within the OSE, prior to construction of Lot 5A, vibration impacts should be considered further in the construction noise and vibration management plan. This may include the requirement for vibration monitoring at the start of the works to ensure vibration levels remain at an appropriate level where works are required within the safe working distances of these buildings.

6 Conclusion

The recommendations made in this report are based on 24 hour operation of warehouse and distribution facilities in the site. As such, this is considered a worst-case assessment of potential impacts. Typical impacts are likely to be lower than the worst-case predicted impacts.

6.1 Operational Noise Impacts

An operational noise impact assessment has been conducted for Lot 5A DHL of the Oakdale South Estate. Operational Noise Limits consistent with those in the Development Consent SSD 6917 for the OSE Masterplan have been adopted.

An analysis of the prevailing weather conditions for the OSE indicated that adverse weather is a feature of the area only during the night-time period.

The operational noise modelling for Lot 5A found no exceedances of the Noise Limits at any sensitive receivers under both neutral (day, evening and night periods) and adverse (night period) weather conditions.

Cumulative operational noise levels of Lot 5A and the OSE Masterplan design are predicted to be compliant with the Noise Limits at all identified residential receivers under both neutral and adverse weather conditions during the applicable periods.

The $L_{A1(1minute)}$ noise emissions are predicted to comply with the nominated noise criteria at all identified receivers under both neutral and adverse weather conditions during the applicable periods.

As such, with consideration of the above, operational noise emissions from Lot 5A DHL are considered to be acceptable.

The limiting sound power levels for rooftop fixed plant units was found to be SWL of 70 dBA per unit and should be confirmed during detailed design when the corresponding equipment is selected.

Off-site traffic movements associated with Lot 5A are predicted to have a negligible impact on road traffic noise levels in the vicinity of the main access routes of Lenore Drive and Old Wallgrove Road, given the existing high volume of traffic on these arterial roads. Traffic volumes for Lot 5A are consistent with the approved Masterplan.

6.2 Construction Noise and Vibration Impacts

A construction noise and vibration impact assessment has been conducted for Lot 5A DHL of the Oakdale South Estate. Construction noise management levels (NMLs) consistent with those in the Development Consent SSD 6917 for the OSE Masterplan have been adopted.

During standard construction hours, noise levels are generally predicted to be compliant with the noise goals at the surrounding residential receivers, with the exception of the proposed Jacfin and Capitol Hill residential areas.

Worst-case construction noise emissions of up to 50 dBA are predicted in the Jacfin area, and up to 56 dBA in the Capitol Hill area. It should be noted that this is the realistic worst-case noise impacts at the boundary of these areas closest to the works, and that noise impacts would decrease further back within the residential areas, and when the construction works are further back in Lot 5A.

It is noted that construction in these precincts may occur before construction of the residential buildings within the Jacfin and Capitol Hill areas. The construction NMLs apply only to dwellings occupied during construction of the OSE.

Predicted cumulative construction noise impacts of Lot 5A DHL and the whole OSE estate are consistent with those predicted in the SSD Masterplan Noise Impact Assessment.

Construction noise mitigation measures should be implemented as recommended in this report, where feasible and reasonable.

The separation distance between Lot 5A and the nearest existing vibration sensitive receivers is considered to be sufficient to mitigate potential impacts at residential and existing commercial receivers. Where buildings with the Jacfin or Capitol Hill areas, or other commercial buildings in the OSE, have been constructed prior to construction of Lot 5A, vibration impacts should be managed where works are required within the safe working distances of these buildings.

Acoustic Terminology

1 Sound Level or Noise Level

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

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

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

2 'A' Weighted Sound Pressure Level

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

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

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

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

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

3 Sound Power Level

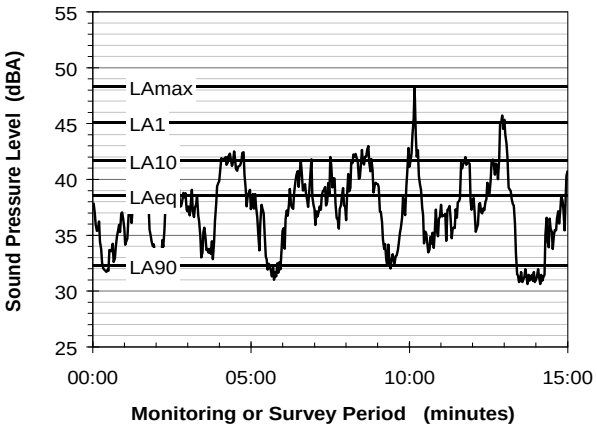
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 10^{-12} W.

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

4 Statistical Noise Levels

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

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



Of particular relevance, are:

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

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

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

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

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

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

5 Tonality

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

6 Impulsiveness

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

7 Frequency Analysis

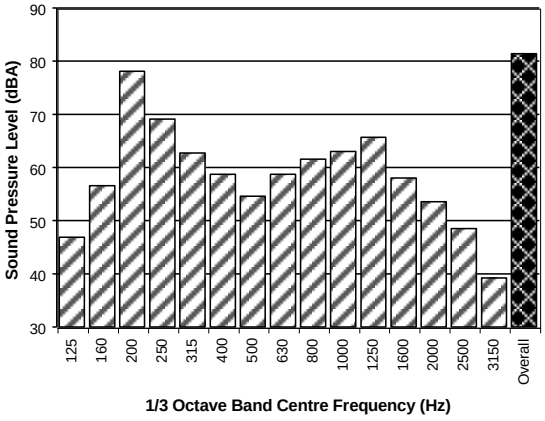
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

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

Frequency analysis can be in:

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

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



8 Vibration

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

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

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

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

9 Human Perception of Vibration

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

10 Over-Pressure

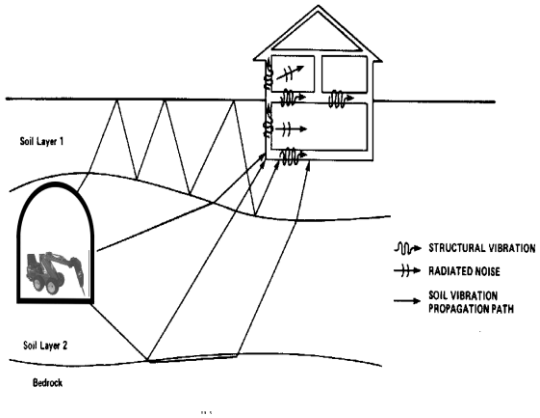
The term 'over-pressure' is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

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

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

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

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



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

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