Australia Pacific LNG Project

Volume 5: Attachments

Attachment 34: Noise and Vibration Impact Study – LNG Facility

Disclaimer

This report has been prepared on behalf of and for the exclusive use of Australia Pacific LNG Pty Limited, and is subject to and issued in accordance with the agreement between Australia Pacific LNG Pty Limited and WorleyParsons Services Pty Ltd. WorleyParsons Services Pty Ltd accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party.

Noise and vibration impact study
Downstream LNG plant
Australia Pacific LNG
Curtis Island, Gladstone

Document No. S878.1, Revision 1

Prepared for:

WorleyParsons Infrastructure & Environment

PO Box 15081

City East Brisbane Qld 4002

27 January 2010

DOCUMENT CONTROL PAGE

SAVERY & ASSOCIATES PTY LTD
4 Paltarra Street
PO Box 265
The Gap, QLD. 4061
Telephone: (07) 3300 6288
Facsimile: (07) 3300 6244

Revision History

Revision No	Issue Date	Description	Checked By	Issued By
0	11 Dec 09	Draft	JS	MC
1	15 Dec 09	Draft	JS	MT
1	27 Jan 10	Final	JS	MC

Distribution Record

Copy No(s)	Rev No	Destination
1	0	WorleyParsons Energy & Environment
2	0	Savery & Associates – File

Contents

1.0 Introduction

Savery & Associates Pty Ltd was commissioned by WorleyParsons to assess environmental noise and vibration emissions associated with the construction and operation of the proposed Australia Pacific LNG liquefied natural gas (LNG) plant on Curtis Island, near Gladstone.

The analysis of noise impacts was based upon data supplied by Australia Pacific LNG (the Project) and field investigations of baseline acoustic and vibration conditions that were conducted by Savery & Associates.

The report addresses the requirements for the noise and vibration assessment outlined within the Terms of Reference for the Project's Environmental Impact Statement (EIS).

The report summarises the investigations that have been conducted to:

- Quantify baseline ambient noise levels and describe the acoustic environmental values in the Project area.
- Assess the noise and vibration impact of construction and operational phases of the proposed LNG plant, based upon applicable Queensland regulations and guidelines.
- Assess the cumulative noise impacts of the proposed LNG plant considering noise emissions from other existing and proposed industrial facilities in the study locality.

2.0 Proposed development

2.1 Site context

The proposed site for the LNG plant is near Laird Point, Curtis Island as illustrated within Figure 1. The site is located within the Curtis Island industry precinct of the Gladstone State Development Area.

The site location is well removed from residential dwellings. The proximity of the site to the nearest residential areas is summarised in Table 1 and illustrated on Figure 1.

Table 1: Nearest residential areas

Receiver area	Description	Distance to LNG site centre
Passage Islands	Two isolated dwellings on Tide Island and Witt Island.	6.2km and 7.2km
Fisherman's Road	One isolated dwelling at 2 Fisherman's Road.	>7.8km
Targinie area	Approximately 20 rural residential dwellings.	8.7km to 10km
Gladstone city	Large residential population centre.	>10.9km
South End	Residential community of approximately 100 dwellings.	>11.4km

2.2 LNG plant overview

Initially it is proposed to construct and operate two LNG trains, with construction of the final two trains commencing after the first two trains become operational. The proposed layout of the LNG plant for the full proposal of four LNG compression trains development is illustrated on Figure 2 and Figure 3.

Construction will involve a material off-loading facility (MOF) to enable the transfer of personnel, building materials and heavy equipment to the Project site for construction and operation. A wharf with jetty structures will also need to be constructed to enable the loading of LNG transport vessels.

The construction of the marine infrastructure will involve dredging at the MOF, jetties, and berth pockets.

An EIS for the capital dredging required for the shipping channel that is adjacent to the LNG plant is being developed by Gladstone Ports Corporation (GPC) as part of the Western Basin Dredging and Disposal Project.

3.0 Airborne noise impact assessment

3.1 Baseline noise survey

3.1.1 Site selection for baseline noise monitoring

Baseline monitoring sites were selected to represent known sensitive receptor locations that may be critical with regard to noise emission constraints for a future LNG plant.

Figure 1 presents the LNG plant site at Laird Point on Curtis Island against significant sensitive receptor locations and noise monitoring locations.

The receptor area at isolated residences on Tide Island and Witt Island is referred to in this report as the 'passage area'. Baseline levels relevant to these residences were sampled just north of Tide Island on Hamilton Point (Site 1), and just south of Witt Island on Picnic Island (Site 2). Baseline levels relevant to the Gladstone City residential area (Site 5) have been sourced from the Heggies Pty Ltd noise monitoring results reported in the Santos GLNG EIS for No.1 Auckland Street, Gladstone. Baseline levels relevant to the South End residential community in the south-east corner of Curtis Island (Site 6) have been sourced from the ERM Australia Pty Ltd noise monitoring results from Turtle Street, South End, reported in the and from the Queensland Curtis EIS.

The baseline noise levels to determine emission limits are likely to be most significant at isolated residences in the Targinie area. While the isolated dwellings in the passage area and Fisherman's Road have similar separation distances from the proposed LNG site, the influence of existing industrial noise is much lower in the Targinie area.

Baseline noise levels in the Targinie area were sampled at an orchard on the south side of Forest Road (Site 4). While aerial photography may show dwellings at this location the dwellings were removed prior to monitoring that began in April 2008. This site was free of irrigation infrastructure (e.g. pumps, sprays etc). Baseline noise levels on Fisherman's Road were sampled from an existing dwelling at 2 Fisherman's Road (Site 3).

The details of the baseline monitoring locations are summarised in Table 2.

Table 2 Summary of noise monitoring sites

Site number.	Description	Details
Site 1	Hamilton Point, Curtis Island	Appendix B
Site 2	Picnic Island (north end), Gladstone Harbour	Appendix C
Site 3	2 Fisherman's Road, Yarwun	Appendix D
Site 4	Forest Road, Targinie (uninhabited orchard)	Appendix E
Site 5	No.1 Auckland Street, Gladstone	Santos GLNG EIS Appendix U1
Site 6	Turtle Street, South End	BG Qld Curtis EIS Appendix 5.14

3.1.2 Noise monitoring procedures

Noise monitoring was conducted with reference to the following standards and procedures:-

- Australian Standard AS1055.1-1997 Acoustics – Description and measurement of environmental noise, Part 1: General procedures.
- Queensland's Environmental Protection Agency (EPA) Noise Measurement Manual (3rd Edition, 1 March 2000).

The minimum monitoring duration of seven days at each location was selected to determine the 'rating background noise levels' (RBLs) in accordance with the methodology set out within the Department of Environment and Resource Management (DERM) Ecoaccess Guideline Planning for noise control (the Guideline).

3.1.3 Noise monitoring instrumentation

Baseline noise monitoring was conducted utilising CESVA SC310 Type 1 one-third octave logging sound level meters and CESVA TK1000 outdoor microphone assembly at 1.5m microphone height. At each logging site the microphone was separated as far as practicable from local vegetation. Instrumentation was field-calibrated prior to and following measurements, with all post-calibration results within 0.2dBA1 of the pre-calibration level of 94.0dBA.

Logger sampling was conducted at one-second intervals in frequency bands from 20Hz to 10kHz. The data was post-processed to obtain statistical parameters such as LA10 and LA90 at 15 minute intervals2.

3.1.4 Meteorological monitoring instrumentation

For Sites 1 and 2, hourly data from the Bureau of Meteorology Gladstone Radar Weather Station was obtained for the duration of monitoring.

For Sites 3 and 4, simultaneous monitoring of windspeed, direction, temperature, pressure and humidity conditions was conducted at one of the two baseline noise monitoring

[1] See glossary for explanation of acoustic terminology.
[2] See glossary for explanation of acoustic terminology.

locations in accordance with the requirements of AS1055 Acoustics – Description and measurement of environmental noise, Part 1: General procedures. This instrumentation sampled the meteorological parameters at two-second intervals, and produced summary information for 15-minute intervals corresponding to the noise monitoring intervals. Sensors were located at a 4m reference height. The meteorological monitoring sites are indicated on Figure 1.

3.1.5 Analysis of baseline records

Seasonal insect noise

The Noise Measurement Manual indicates that the influence of insect noise on baseline noise levels should be carefully considered, to ensure that sampling during warmer months, that may include significant insect noise contribution to LA90 levels3, is not inadvertently used to represent baseline conditions at other times of the year when insect noise may be less significant.

One-third octave spectral baseline logging was conducted within the frequency range of 20 hertz (Hz) to 10 kilo-hertz (kHz) to enable the identification of seasonal or episodic insect and frog noise. The presence (or absence) of such noise was determined from inspection of the spectrogram for the noise-monitoring period. The spectrogram is a graphical plot of sound pressure level, represented by colour, versus frequency (y-axis) and time (x-axis). Typically, insect activity may be identified as a constant contribution in one or more one-third-octave bands above 2kHz.

If significant evening4 or night-time insect noise is detected this noise is filtered by post-processing the measurement data prior to calculation of the aggregate background noise levels for day, evening and night-time periods. Both the filtered and unfiltered aggregate background noise levels are reported. The filtered data provides an estimate of background noise conditions in cooler months of the year when the contribution of insect noise is often minimal (Caley & Savery 20075).

Significant insect noise was identified in the records from Sites 3 and 4. Details of the influence of insect noise at these locations can be inspected in the detailed data presented in Appendix D and Appendix E.

Meteorological conditions

Noise data that were affected by excessive wind speed or precipitation has been excluded from the aggregate noise level statistics. The proportion of data for each day, evening and night interval, for which meteorological conditions were compliant, are also documented in the tabular data within each of Appendices B, C, D and E.

Intervals with any precipitation, or average wind-speeds above five metres per second (m/s), were cross-referenced to the noise monitoring data, identified in the combined noise and weather data plots and excluded from statistical summary data (shown in Appendices B, C, D and E).

For Sites 1 and 2, for which noise data is referenced to the Bureau of Meteorology weather data, it is likely that the weather data recorded at approximately 75m above sea level significantly overstates the wind-speed at the microphone location, which is 1.5m above

[3] See glossary for explanation of acoustic terminology

[4] Daytime: 7am to 6pm, Evening: 6pm to 10pm, Night: 10pm to 7am

[5] Caley, M. & Savery, J. 2007 *The Case for Spectral Baseline Noise Monitoring for Environmental Noise Assessment* 14th International Congress on Sound and Vibration, Cairns 2007

ground level. Therefore it is likely that only a fraction of the data that have been excluded from the statistical analysis on the basis of the bureau wind-speed data (indicated by grey shading of the level history plots in Appendix B and Appendix C) are actually non-compliant.

3.1.6 Rating background noise levels

The RBLs determined in accordance with the Ecoaccess Guideline are presented in Table 3.

At sites 1 and 2 the RBLs are consistently higher during the evening and at night. This is attributed to industrial noise on the basis of the combined wind-speed, direction and sound level histories, as presented in Appendix B and Appendix C. Sites 1 and 2 are generally upwind of existing industrial noise sources during the day and downwind of industrial sources at night.

It is concluded from inspection of meteorological and spectragram data that wave noises were not a significant or persistent feature of the ambient noise at either Site 1 or Site 2.

Table 3: Rating background levels

Measurement location	Rating background level (minLA90 – dBA)		
	Day (7am–6pm)	Evening (6pm–10pm)	Night (10pm–7am)
Site 1 – Hamilton Point	41	44	45
Site 2 – Picnic Island	39	41	45
Site 3 – 2 Fisherman's Road	40	39	40
Site 4 – Forest Road	30	32	31
Site 5 – 1 Auckland Street, Gladstone[6]	42	42	37
Site 6 – Turtle Street, South End	32	35	27

3.1.7 Minimum equivalent hourly noise levels

A summary of the minimum LAeq,1hour data for the day, evening and night periods for each monitoring location is presented in Table 4.

At Sites 1 and 2 the same trend (as observed for RBLs) of higher levels during the evening and night periods is evident due to wind-dependent effects on industrial noise propagation.

Table 4: Minimum equivalent levels

Measurement location	Minimum equivalent level (minLAeq,1hour – dBA)		
	Day (7am–6pm)	Evening (6pm–10pm)	Night (10pm–7am)
Site 1 – Hamilton Point	44	49	48
Site 2 – Picnic Island	44	46	48
Site 3 – 2 Fisherman's Road	45	46	44
Site 4 – Forest Road	37	48	38
Site 5 – 1 Auckland Street, Gladstone [1]	47	47	40

[6] Sourced from Santos GLNG EIS

Measurement location	Minimum equivalent level (minLAeq,1hour – dBA)		
	Day (7am–6pm)	Evening (6pm–10pm)	Night (10pm–7am)
Site 6 – Turtle Street, South End	46	40	38

3.2 Noise criteria

3.2.1 Environmental values to be protected

The Queensland Environmental Protection (Noise) Policy 2008 (EPP Noise) broadly identifies the environmental values to be enhanced or protected within the state of Queensland as:

- The qualities of the acoustic environment that are conducive to protecting the health and biodiversity of ecosystems.
- The qualities of the acoustic environment that are conducive to human health and well-being, including by ensuring a suitable acoustic environment for individuals to do any of the following:
- (i) sleep
- (ii) study or learn
- (iii) be involved in recreation, including relaxation and conversation
- The qualities of the acoustic environment that are conducive to protecting the amenity of the community.

In the context of this study, the acoustic environment in the context of biodiversity and includes the marine acoustic environment as it relates to endangered and protected species.

3.2.2 Construction noise goals

Standard day-time construction hours

Local government may gazette local laws to manage environmental nuisance, including construction noise, under the Queensland Environmental Protection Act 1994 (EP Act).

However, if specific local laws are not enacted to manage construction noise (as is the case throughout the study area), the Division 3 default noise standard – section 440R Building work – of the EP Act applies, as per the following extract:

"440R Building work

(1) A person must not carry out building work in a way that makes an audible noise

(a) on a business day or Saturday, before 6:30am or after 6:30pm; or

(b) on any other day, at any time."

There are currently no noise limits or guidelines7 applicable to construction noise within the nominal regulated construction hours of 6.30am to 6.30pm business days and Saturdays, as defined in the EP Act. However, the Act does provide a mechanism for controlling unreasonable construction noise in the event that a noise complaint is investigated and validated by an authorised officer.

[7] The former Department of Environment and Heritage E1 Guideline for construction noise was formally withdrawn and has not been replaced.

Other times of the day or night

Currently, there is no Queensland guideline that addresses construction noise outside standard hours and at night.

The EPP Noise defines 'Acoustic quality objectives' for the environment that are conducive to human health and well-being, including the ability for individuals to sleep, study, relax or converse. The key acoustic quality objectives relevant to residential locations are reproduced below in Table 5 (explanations of terminology may be found in the Appendix G glossary). These objectives may be used for assessing the reasonableness of temporary evening or night-time construction noise.

Table 5: EPP Noise Acoustic quality objectives for residential dwellings

Schedule 1 Acoustic quality objectives

section 8

Column 1	Column 2	Column 3			Column 4
Sensitive receptor	**Time of day**	**Acoustic quality objectives (measured at the receptor) *dB(A)***			**Environmental value**
		$L_{Aeq,adj,1hr}$	$L_{A10,adj,1hr}$	$L_{A1,adj,1hr}$	
dwelling (for outdoors)	daytime and evening	50	55	65	health and wellbeing
dwelling (for indoors)	daytime and evening	35	40	45	health and wellbeing
	night-time	30	35	40	health and wellbeing, in relation to the ability to sleep

The measurement parameters for the acoustic quality objectives (LAeq,adj,1hr LA10,adj,1hr LA1,adj,1hr) include an adjustment (designated by the 'adj' subscript) for tonal and/or impulsive characteristics of the noise under investigation that may increase the subjective loudness of a noise. The required adjustment for tonal and/or impulsive characteristics is the sum of correction factors K1 and K2, as summarised in Table 6 and in accordance with AS1055 Acoustics –Description and measurement of environmental noise Part 1: General procedures.

Table 6: Adjustments for audible characteristics 'adj' = K1 + K2

Audible characteristic	Criterion	Correction
Tonality	Subjectively just detectable	K1 = 2-3dB
	Subjectively prominent (clearly audible)[8]	K1 = 5-6 dB
Impulsivity	Subjectively detectable[9]	K2 = 2dB

The EPP Noise defines the relevant night-time acoustic quality objectives within a dwelling for residential receptors. The indoor objectives of 30dBA LAeq,adj,1hr and 40dBA LA1,adj,1hr can be translated to outdoor objectives by accounting for a nominal 10dBA reduction through the building facade.

The resulting equivalent outdoor noise criteria relevant to assessment of temporary night-time construction noise are 40dBA LAeq,adj,1hr and 50dBA LA1,adj,1hr.

The DERM guideline includes advice on the probability of sleep awakening depending on the outdoor LAmax level (refer Table 9). The guideline suggests achieving no higher than 10% probability of sleep awakening, which indicates a LAmax of 47 to 67 dBA depending on whether the window is wide open, partially closed or fully closed. It is therefore recommended that 50dBA LA1,adj,1hour acoustic quality objective be replaced with the sleep disturbance criterion.

Noise measurement experience around construction sites generally indicates that construction noise attracts a tonal and/or impulse noise characteristic adjustment of 5dBA.

The recommended unadjusted outdoor construction noise criteria for out-of-hours construction activities are therefore 35dBA LAeq,1hr and sleep disturbance criteria (Table 9, 10% awakening possibility).

3.2.3 Operational noise Criteria

DERM advises that noise emission limits for new major industrial noise sources should be determined utilising the Queensland Ecoaccess Guideline: Planning for noise control (the Guideline) to protect acoustic environmental values.

The Guideline is intended to manage three aspects of the acoustic environment that may be affected by new industrial development, commercial premises and mining operations:

- The control and prevention of 'background noise creep' (the gradual cumulative increase in minimum noise levels generated by continuously operating machinery).
- The containment of variable noise levels and short-term noise events to an 'acceptable level' above the background noise levels (for example, noise associated with a short-term but periodic noise, such as a process pressure relief valve).
- The setting of noise limits for transient noise events to avoid 'sleep disturbance' (for example, temporary flaring or a process alarm).

[8] The objective test of tonality is as per AS1055.1 Clause 6.6.3

[9] The objective test of impulsive characteristics is as per AS1055.1 Clause 6.6.4

Design planning noise levels

The guideline recommends a Planning noise level (PNL) for a new facility be expressed as an unadjusted equivalent continuous A-weighted sound pressure level (LAeq 1 hour), with built-in penalties for assumed tonal and/or impulsive characteristics of a future noise source (or sources). However, as the adjustments for tonal and impulse noise characteristics cannot be anticipated in advance for all source/receiver situations, it is more appropriate that the PNLs are expressed as adjusted levels (LAeq 1 hour, adj)10. The detailed derivation of the PNLs for this project is provided in Appendix A.

The resultant PNLs at representative residential receiver areas around the LNG plant site are summarised in Table 7. The received noise level (predicted or measured) should be adjusted for tonal and/or impulsive characteristics when using these PNLs to assess the predicted noise at a residence from a specific noise source, as detailed in Table 8.

In all surrounding areas the night period is the most critical with regard to compliance, as the background noise levels are at their lowest and noise criteria is most stringent.

Table 7: PNLs at residential receivers (outdoors)

Receiver areas	Design planning noise level (LAeq,1hour,adj – dBA)		
	Day (7am-6pm)	Evening (6pm-10pm)	Night (10pm-7am)
Targinie area	38	38	36
Passage area	49	39	38
Gladstone city	45	35	30
Fisherman's Road	55	47	39
South End	40	28	30

[10] On other projects, the presumption of a tonal correction in deriving the PNLs has caused confusion in the specification of licensed levels. It is more appropriate and accurate that the determination of adjustments for tonal and impulse corrections is performed when emissions from a specific source at a given distance are assessed.

Table 8: Guideline corrections to design PNLs for audible characteristics

Audible characteristic	Criterion	Correction
Tonality	Subjectively just detectable	K1 = 2 - 3dB
	Subjectively prominent (clearly audible)[11]	K1 = 5 - 6 dB
Impulsivity	Subjectively detectable[12]	K2 = 2 dB

Consideration of sleep disturbance

The relationship between the level of a noise event external to a dwelling and sleep awakenings is dependent upon many factors, including the sound pressure level, sound frequency, how rapidly the noise increases (i.e. impulsive sound versus a gradual increase), the familiarity of the noise to the individual, the frequency of events and individual sensitivity. The Guideline advises an approximate relationship between the maximum external noise event level (LAmsx), the degree of dwelling sound insulation and the resulting likelihood of sleep awakening as shown in Table 9.

Table 9: Guideline probability of sleep awakening

Typical facade noise feduction	Facade Description	External maximum instantaneous noise level (LAmax, dBA) corresponding to awakening probability (%)			
		0%	5%	10%	20%
5	Windows wide open	37	42	47	52
10	Windows partially closed	42	47	52	57
20	Single glazed, closed	52	57	62	67
25	Double glazed, closed	57	62	67	72

Low-frequency noise criteria

Low-frequency noise at frequencies of less than 20Hz, below the audible frequency range, is termed 'infra-sound'. At high intensities, sound within this frequency range can cause resonances of body cavities (for example, chest resonance at 10Hz) that have been linked to symptoms of un-wellness in some studies (Carrol et al 200413).

Regulatory assessment criteria have not yet been developed in this area. However, manufacturers of gas turbines have been aware of the potential problem for some time and guidelines have been established to avoid air-borne low-frequency vibration effects. ANSI B133.8-197714 suggested a guideline of 75dBC to 80dBC15 for turbine exhaust noise to

[11] The objective test of tonality is as per AS1055.1 Clause 6.6.3

[12] The objective test of impulsive characteristics is as per AS1055.1 Clause 6.6.4

[13] Carroll et al, 2004 'The health effects of environmental noise – other than hearing loss', Department of Health and Aging, Australia.

[14] ANSI B133.8-1977 (reaffirmed 1989) Gas Turbine Installation Sound Emissions, American National Standards, The American Society of Mechanical Engineers

avoid sound-induced low-frequency vibration in buildings. Hessler 2004[16] has recommended a much lower criterion for turbine noise of 60dBC measured outdoors, for 'very quiet suburban or rural residential areas', with the additional condition that the difference between the A-weighted and C-weighted emissions should not be greater than 20dB.

3.3 Noise modelling methodology

An environmental noise model of the LNG plant and surroundings was constructed using ISO 9613-2 (1996), Acoustics - Attenuation of sound during propagation outdoors, Part 2: General method of calculation, as implemented in SoundPLAN software. The method predicts A-weighted sound pressure levels under meteorological conditions favourable to sound propagation from noise sources towards receptor locations (mild temperature inversion with slight downwind). The overall model accuracy is estimated as ± 3dBA.

The graphical noise contours generated by the model represent the envelope of results for noise propagation in all directions (that is, a summary of typical worst-case noise propagation in all directions).

The detailed calculation of sound propagation from the source to the receiver locations is calculated with specific algorithms for the following physical effects:

- geometrical divergence
- atmospheric absorption (in accordance with ISO 9613 Part 1)
- ground effect (hard ground reflects sound, soft ground absorbs sound)
- reflection from surfaces (typical 1dBA reflection loss for buildings)
- screening by obstacles (horizontal and vertical diffraction)
- dense vegetation (none included)

Noise contours were modelled 2m above local ground level.

The ground around LNG plant is assumed to be hard-packed and acoustically reflective. Water areas are also modelled as acoustically reflective. Grassland and forested areas are modelled as acoustically soft. No other modification to propagation has been made the effect of forested areas.

Topography

The model terrain for the mainland and Curtis Island was based upon 5m elevation contours and modelled as 100% absorptive, which is consistent with the predominant forested grass-land between the site and residential receivers. The waterway between the LNG site and Curtis Island was modelled as 100% reflective.

Mechanical plant

The sound-attenuated source noise level data for the LNG plant was supplied by for this Project and is detailed within Table 42 of Appendix I.

This data models the inclusion of the following noise controls:

- Enclosures for gas turbines and electricity generators (GTGs) and silencing of gas turbine inlet air paths and exhausts.

---

[15] The 'C' frequency weighting adjustments are much reduced at low frequencies compared to 'A' weighting, giving greater 'prominence' to the low-frequency components in the overall measured dBC sound pressure level compared to the measured dBA sound pressure level.

[16] Hessler, G.F., 2004 Proposed criteria in residential communities for low-frequency noise emissions from industrial sources, Journal of Noise Control Engineering 52(4), 2004

- Enclosures for gas turbines that drive the compression trains and silencing of gas turbine inlet air paths and exhausts.
- 100mm thick acoustic insulation lagging on large centrifugal compressor inlet, discharge and recycle piping.
- Attenuation of gas turbine exhausts to 85dBA at 1m.
- Low noise air coolers with a sound power level limit of 95dBA (PWL) per fan.
- Acoustic blankets for refrigerant compressor casings.
- Noise hoods for refrigeration compressor gearboxes.

3.4 Assessment – construction noise

Construction of the LNG plant will entail bulk site earthworks, preparation of concrete foundations and plant fabrication works. An on-site concrete batching plant and a number of cranes and cement mixers will be utilised during the preparation of foundations. Piling operations will be required for the construction of LNG storage tanks, the MOF and the jetty structures. Localised dredging will also be required to enable construction of the jetties and the MOF and will be performed by Gladstone Ports Corporation as part of the Western Basin Dredging and Disposal Project.

With the exception of possible impact piling noise associated with LNG storage tanks and jetty structures, construction noise would not be significant at existing residential receptors during the day or night due to the large separation distance between the construction site and residential receptors. Anticipated vibratory sheet piling for the MOF is not a significant airborne noise source.

The actual pile sizes, rigs, methods and ground conditions that would need to be known to accurately determine piling noise emissions are not known at this stage of the project.

Worst-case piling noise has been assessed by modelling the level of noise that may be received at residential locations from a large Delmag D80-32 diesel driven impact hammer rig. A rig of this capacity may be used for driving steel pipe piles for the jetty, or for driving solid concrete piles for the LNG storage tanks.

At the point of pile refusal[17] this equipment may produce an unattenuated source sound power level of 144dBA (L_{Amax}), based upon a source sound pressure level for this plant of 116dBA (L_{Amax}) at seven metres[18]. A flat un-weighted spectrum of sound energy has been assumed for the purpose of noise propagation calculations.

The predicted levels of impact noise at residential receptors are summarised in Table 10. The night-time criterion is taken from the DERM Guideline sleep disturbance criteria for naturally ventilated dwellings. The daytime and evening criteria are taken from the EPP Noise $L_{A1,adj,1hour}$ acoustic quality objectives, allowing for an assumed +2dB impulse adjustment to the propagated piling noise. The $L_{A1,1hour}$ criteria has been evaluated[19] with predicted maximum levels.

The predicted levels of impact noise at the on-site construction camp is summarised in Table 11. The night-time criterion is taken from the DERM Guideline sleep disturbance criteria for an air-conditioned dwelling, consistent with the normally air-conditioned construction camp accommodation. Daytime criteria are not applicable for piling noise at

[17] Refusal is achieved when the pile is unable to be driven any further at maximum impact force

[18] Pileco Technical Data – February 2006

[19] This is slightly conservative, as $L_{A1,1hour}$ piling levels would be lower than the L_{Amax} level for an individual pile impact. It is not possible however to reliably predict L_{A1} levels over substantial propagation distances based on L_{Amax} source data.

the construction camp as the project does not anticipate shift-workers sleeping during the day.

Table 10: Worst-case piling noise at residential receivers (outdoors)

Receiver		Predicted Delmag D80-32 pile impact noise at refusal (LAmax – dBA)	
		Jetty piling	LNG tank piling
Targinie area		52	51
Tide Island		44	44
Gladstone City		38	38
Fishermans Rd		51	52
South End		37	38
Construction noise criteria (L_{Amax})	**Day** (7am-6pm)	63	63
	Evening (6pm-10pm)	63	63
	Night (10pm-7am)	47	47

Table 11: Worst-case piling noise at construction camp (outdoors)

Receiver		Predicted Delmag D80-32 pile impact noise at refusal (LAmax – dBA)	
		Jetty piling	LNG tank piling
Site construction camp		58	73
Construction noise criteria (L_{Amax})	**Day** (7am-6pm)	67	67
	Evening (6pm-10pm)	67	67
	Night (10pm-7am)	67	67

From these preliminary modelling results it is concluded that noise from piling either the jetty or LNG tank foundations could potentially produce sleep disturbance in the Targinie area and at Fisherman's Road if conducted at night. Piling for the LNG tank foundations could additionally potentially cause sleep disturbance within air-conditioned sleeping quarters at the project construction camp and adjoining project construction camp, if conducted at night.

The actual potential for piling noise impacts will depend on the specific piling method and ground conditions encountered. The specific details for noise management will therefore need to be established when particulars of actual piling methods, piling schedule and rig capacities are known.

3.5 Assessment - traffic and transportation

3.5.1 Vessel traffic

There are only two isolated dwellings on Tide Island and Witt Island aton the east side of the north-south shipping channel that may be potentially affected by increased vessel traffic associated with construction and operation phases of the project.

During the construction phase of the project there will be a significant increase in the frequency of materials and equipment barges and passenger vessels that travel past Tide Island and Witt Island to service the LNG construction site. Noise generated by these additional movements will be similar existing marine construction traffic associated with the development of marine facilities for Fishermans Landing wharves.

During the operational phase of the project there will be some increase in the frequency of large freighters that travel past Tide Island and Witt Island due to the export of LNG. These carriers will be manoeuvred by four pilot tugs within Port Curtis, so noise generated by these additional LNG carrier pass-by events will not differ significantly from existing movements of coal and other bulk material freighters that currently utilised the channel.

3.5.2 Road traffic to mainland ferry and barge terminal

The construction phases of the LNG plants are projected to generate relatively more traffic than the typical operating phases. The traffic generated will consist of private vehicles and buses to allow staff and building personnel to travel to and from the ferry terminal, along with trucks for delivery of construction material and other operational deliveries. This traffic would approach Auckland Point from the north along Gladstone-Mt Larcom Road via Port Access Road and the south along the Dawson Highway via Port Access Road.

The additional traffic volumes are anticipated to be predominantly private vehicles, which have noise emissions very similar in character to existing traffic along Port Access Road, Gladstone-Mt Larcom Road and the Dawson Highway. The increased regularity of private vehicles on the public road to Auckland point is not anticipated to be a significant noise issue. The potential for annoyance to residences in the area is anticipated to come from the increase in heavier vehicles such as buses and trucks along the route to the dock.

A Noise Management Plan will be prepared to minimise the noise impact of the buses and delivery trucks on surrounding residences. The most significant factor of noise control of these movements is anticipated to be the control of the time of operations. The scheduling, volumes involved and the route to be taken would all require careful consideration during the detailed design of the project for inclusion in the Noise Management Plan.

3.6 Assessment - LNG plant operation

3.6.1 Noise sources

This assessment considers the full operational scenario of four-train operation.

The following noise controls are proposed to meet recommended project noise limits at sensitive receptor locations, as follows:

- Enclosures for gas turbines and electricity generators (GTGs) and silencing of gas turbine inlet air paths and exhausts.
- Enclosures for gas turbines that drive the compression trains and silencing of gas turbine inlet air paths and exhausts.

- 100mm thick acoustic insulation lagging on large centrifugal compressor inlet, discharge and recycle piping.
- Attenuation of gas turbine exhausts to 85dBA at 1m.
- Low noise air coolers with a sound power level limit of 95dBA (PWL) per fan.
- Acoustic blankets for refrigerant compressor casings.
- Noise hoods for refrigeration compressor gearboxes.

The significant steady noise sources within the proposed LNG plant and associated sound power data supplied by the Project are summarised in Table 42 of Appendix I. The project construction contractor has advised that plant noise will be free of significant tonal characteristics that would otherwise attract upward adjustments to the predicted noise levels, as per Table 6.

Low frequency noise

There have been instances of open cycle gas turbines (OCGTs) (i.e. without downstream steam generation) where acoustic pulsations from the exhaust side of the turbine have led to perception of low-frequency 'vibration' or 'infra-sound' at frequencies comparable to the cavity resonances of the human body (generally below 20Hz).

The proposed plant includes a number of OCGTs that will be fitted with silencers on both the inlet and exhaust air paths. Significant levels of low frequency noise are not expected at any of the existing residential receivers which are located relatively remote from the site. However, the data required to test this expectation is not yet available. Numerical analysis of low frequency noise potential requires detailed noise emission spectra at frequencies in the range of 10Hz to 200Hz. It is therefore recommended that the detailed design phase includes a requirement to conduct analysis of the low frequency noise utilising the criteria discussed in Section 3.2.3.

Transient noise sources

Occasionally some parts of the LNG liquefaction process must be interrupted for maintenance purposes, or in response to process 'upset'. On these occasions it is necessary to expel gas from parts of the process. The safest method of removal of this process gas is via a flare. The worst case (highest flow rate and noise) for flaring is when there is a total major "upset" which typically lasts 30 minutes or less. The frequency of this event is rare, may be less and is typically expected to occur no more than once per year. Other flaring scenarios will produce significantly less noise compared with the major upset condition.

Flares for this project will consist of ground flare areas consisting of a number of smaller flare burners. The "wet-flare" area will consist of 140 burners for each 2 trains, and 214 burners for each two trains for the "dry-flare" area. The maximum level of noise produced by each flare burner (wet or dry) for this project is presented in Appendix I.

Another transient noise source directly associated with maintenance or upset interruptions to the LNG process are audible process alarms for the safety of plant employees. The typical range of sound outputs available for this type of device is dependent on the distance between employees and hazardous areas and dependent upon the ambient noise conditions where employees work. Generally these devices produce an intermittent tone within the range of 500-2000Hz at levels in the range of 100-120 dBA (PWL). Selection of such devices must ensure that noise is not excessive at the nearest residential areas. This may be an issue in relation to the construction camp or an adjoining project, but is unlikely to be a significant issue at existing residential areas, when considering the very large separation distances.

3.6.2 Noise levels at receptors - normal operation

For the purpose of noise modelling assessment, it has been assumed that the LNG plant will operate at 100% capacity, 24 hours per day, seven days a week.

The predicted LAeq noise contours for the LNG plant are shown for the near-field of the LNG plant on Figure 29 in Appendix H. This figure indicates that operating sound pressure levels at the construction camp would eventually reach around 55dBA to 60dBA when the plant is fully operational. This level of noise is compatible with air-conditioned dwelling facilities, which would be expected given the camp's proximity to the plant.

Predicted noise contours for the fully developed (four-train) LNG plant with proposed noise mitigation are shown on Figure 30 and summarised in Table 12.

At all locations the predicted levels comply with the critical night-time PNLs.

During the initial operating phase (just two of the four process trains operating), noise levels at receivers can be expected to be approximately 3dB lower than the levels detailed in Table 12.

Table 12: Assessment of night-time LNG noise

Receiver	Predicted Level (LAeq,adj - dBA)	Planning Noise Level (LAeq,1hour,adj – dBA)
Targinie area	35	36
Passage area (Tide Island)	33	38
Gladstone City	25	30
Fishermans Rd	35	39
South End	25	30

Transient flare-off events

Ground flare noise has been assessed assuming temporary shut-down of two LNG process trains, resulting in flaring of the full gas stream to either the wet or dry ground-flares.

As the frequency of major flaring is expected to be very low, noise emissions have been compared with recommended sleep awakening criteria in residential areas. Consideration of flaring noise is not relevant at the project construction camp.

The predicted level of transient flare noise at the receptor locations have been highlighted separately and combined with the base LNG plant noise (refer to Table 13).

It is concluded that overall LNG plant noise levels, inclusive of transient flare noise events, will comply with the recommended design criterion.

Table 13: Assessment of night-time flare noise

Receiver	Flare Only (2 train equivalent) (LAmax - dBA)	Flare plus Plant (4 train plant) (LAmax - dBA)	Design Goal (LAmax – dBA)
Targinie area	40	41	47
Tide Island	38	39	47
Gladstone City	33	34	47
Fishermans Rd	45	45	47

Receiver	Flare Only (2 train equivalent) (LAmax - dBA)	Flare plus Plant (4 train plant) (LAmax - dBA)	Design Goal (LAmax – dBA)
South End	31	32	47

3.6.3 Cumulative impact including other industrial facilities

The cumulative impact of industrial noise from other proposed industrial facilities has been modelled and is presented within Appendix H Figure 31, based on noise contour modelling results presented in EIS reporting of the following facilities in the region:-

- Queensland Curtis LNG plant, Curtis Island (adjoining proposed site)
- Santos LNG plant, Curtis Island
- Gladstone LNG plant, Fisherman's Landing
- Wiggins Island coal terminal[20]

The noise impact of existing facilities within the region are not included in the cumulative noise mapping as the contributions of these projects are implicitly included in the assessment by virtue of the baseline noise monitoring and DERM Guideline methodology for determining PNLs.

The cumulative impact of industrial noise, including the Project, is presented in Figure 32 and summarised numerically in Table 14.

It is concluded that the noise contribution from the Project may be significant at residential receptors in the Targinie area and at South End. At these locations the predicted cumulative noise would comply with the Project's noise goals.

Table 14: Assessment of cumulative industrial noise levels (L_{Aeq} dBA)

Receiver	APLNG PNLs	APLNG contribution	Other plant contribution	Total contribution
Targinie area	36	35	30	36
Passage area (Tide Island)	38	33	55	55
Gladstone City	30	25	35	35
Fishermans Rd	39	35	41	42
South End	30	25	23	27

3.6.4 Noise effects on avifauna

The introduction of excessive engineered noise to the environment can have the following adverse effects upon fauna (terrestrial, marine and avifauna):

- Masking and thereby impairing the detection of noise emissions from predator or food species.
- Interference with communication.
- Disruption of breeding.
- Induced avoidance of unnatural noise sources.
- For extreme levels of noise, temporary or permanent hearing damage.

[20] Noise mapping for this project was presented as a continuously graduated colour key

Consideration has been given to the potential impact of industrial noise during migratory bird fly-overs and the effect of noise to birds feeding and roosting in nearby tidal areas.

The work of Larkin 1996[21] suggests that birds respond to noise on the basis of meaning, and quickly habituate to noise that is not associated with predators, or noise associated with adverse natural events of significance to bird-life (e.g. thunder storms). Many examples are provided of sea-birds that voluntarily co-exist with relatively loud noise environments, such as around airports and birds roosting on light-posts above busy motorways. In relation to the proposal, migratory birds can choose to completely avoid the site, or fly over the site at significant altitude.

On the basis of Larkin's review it is concluded that near-field industrial noise emissions that are maintained at levels appropriate to ground level human hearing conservation programmes (i.e. generally less than 85dBA at 1m) are unlikely to particularly deter or adversely affect birds during migratory fly-over events.

Birds in surrounding natural areas will be exposed to steady noise levels of less than 55 dBA. Such levels are comparable to transient ambient sources of noise, such as the noise generated by wind gusts in vegetation, bird chorus and insect noise (cicadas).

[21] Larkin, R.P. 1996 *Effects of military noise on wildlife: a literature review* Center for Wildlife Ecology, Illinois, USA

4.0 Vibration impact assessment

4.1 Vibration issues

Environmental values to be protected

The values to be protected with regard to vibration are the same as for noise (refer Section 3.2.1).

Ambient vibration levels

The geographic area relevant to construction vibration is limited to the Curtis Island land area, within which ambient vibration levels are not significant.

Construction vibration sources

Vibration impacts associated with any blasting for the initial earthworks could conceivably be significant at the Project's construction camp, or at an adjoining LNG plant construction project. It is very unlikely that blasting would be of any significance at South End.

Vibration associated with tank piling would not be significant at the construction camp, or at a construction camp of an adjoining LNG project. This is due to the camps being more than 800m distant from the nearest tank piling activity. Piling vibration impacts within the Project's construction footprint (other than consideration of temporary construction camps) could conceivably be significant in relation to any other structures, but are not within the scope of this analysis.

In relation to possible vibration impacts from marine piling on marine fauna, any vibration transmitted to the water column is comprehensively addressed by the underwater noise assessment of peak pressure (refer Section 5.0).

Operational phase vibration

The primary industrial processes within an LNG plant involve high-speed rotating machinery, from which vibration transfer to the ground is negligible. Accordingly, environmental values are not at risk and vibration criteria are not recommended for the operational phase of the project.

4.2 Blasting vibration criteria

The EP Act defines acceptable levels of ground vibration and air-blast over-pressure for buildings in section 440ZB, as follows:

- Airblast overpressure not to exceed 115dBZ for four out of five consecutive blasts with a maximum of 120dBZ Peak for any blast.
- Ground vibration not to exceed 25mm a second, peak particle velocity respectively, for vibrations of more than 35Hz and 10mm a second for vibrations no more than 35Hz.

4.3 Assessment - blasting impacts

There are no specific locations where it is known that blasting will be required during site earthworks.

However, if blasting is required, the blast should be designed to achieve vibration and air-blast levels that will comply with the statutory criteria in Section 4.2 and with regard to any specific vibration requirements or sensitivities of structures associated with any adjoining LNG plant (including habitable construction camps).

5.0 Marine noise impact assessment

5.1 Environmental values to be protected

There is a range of underwater noise that could potentially impact marine creatures that may be relevant to conservation and protection of the species.

Significant behavioural disturbance is the mildest form of marine noise impact. The impact is deemed significant if the behavioural response may impact the long-term survival chances of the individual or species.

An example of the behavioural response of an animal to marine noise may be to relocate away from the noise source. If this relocation caused displacement from a unique feeding ground during critical stages of a breeding cycle, the behavioural disturbance could cause impaired reproduction and may therefore be significant to survival chances. However if alternative foraging grounds were readily available and accessible, the behavioural response of relocation may not be significant.

Direct physiological impacts associated with higher levels of underwater noise are normally described in terms of the effect on the auditory system. The types of impacts are described similarly to the impacts of high levels of noise to humans.

Temporary threshold shift (TTS) describes the effect of sudden or cumulative noise exposure noise, causing temporary loss of hearing sensitivity. This can directly impact survival by diminishing response to danger, or by diminishing the acuity of acoustic methods of food detection.

Permanent threshold shift (PTS) describes the effect of more severe sudden or cumulative noise exposure, causing permanent loss of hearing sensitivity due to tissue damage within the auditory system.

The most severe possible acoustic impact on marine species is mortality, as may occur close to underwater explosive noise sources. Damage may occur in the form of vascular damage to critical organs, or damage to air-filled cavities such as swim-bladder damage, in the case of fish.

5.2 Significant species to be protected

There are many marine creatures that use sound to communicate, navigate, forage and detect danger. These include marine mammals such as dugong and dolphins, turtle and fish. The most significant marine species in the context of marine construction noise disturbance in the vicinity of the proposed pipeline crossing of The Narrows are outlined below.

5.2.1 Dugong

The Rodds Bay/Port Curtis area, including the area adjacent and south of the proposed pipeline crossing of The Narrows, is designated a dugong protection area by the Great Barrier Reef Marine Park Authority. This area is illustrated on Figure 4.

The primary management intent for dugong conservation is to facilitate the recovery of dugong populations, to the point where the species fulfil its ecological role within the Great Barrier Reef ecosystem. To do this there are two relevant management goals:

- Reduced mortality of dugongs from all human-related causes[22] to facilitate population recovery.
- Protection of the quality and extent of habitat for dugongs, including feeding, calving and mating areas and migratory pathways.

Consideration of the marine acoustic environment is relevant to this second goal.

5.2.2 Dolphin

The Australian *Environment Protection and Biodiversity Conservation Act 1999* protected matters database identifies ten (10) cetacean[23] species that may occur in the Port Curtis region including off-shore areas. Of these, it is understood that the Indo-Pacific humpback dolphin (*Sousa chinensis*), the Australian snubfin dolphin (*Orcaella heinsohni*) and the bottlenose dolphin (*Tursiops aduncus* and *Tursiops truncatus*) are known to occur in the general vicinity of the proposed pipeline crossing.

5.2.3 Marine turtles and fish

Marine turtles and a wide range of fish species occur within the general vicinity of The Narrows and Graham Creek.

5.3 Marine noise management guidelines

5.3.1 Dolphins

The auditory and behavioural effects of anthropogenic (engineered) marine noise to dolphin species has been extensively studied, reviewed and summarised by Southall et al. 2007[24]. The authors for this study represented specialists in behavioural, physiological and physical aspects of noise impacts to marine mammals. The recommendations of this study have been utilised as the basis of marine noise exposure criteria for this assessment.

The dolphin species reported occur in the general vicinity of The Narrows pipeline crossing site[25] by Southall et al are classified as 'medium-frequency cetaceans'. These dolphins produce and use high-frequency sounds (tens of kHz to 100+kHz) for eco-location of prey and for navigation. Lower frequency sounds (approximately 1kHz to tens of kHz) are produced for communication, resulting in an overall sound production frequency range of approximately 1kHz to greater than 100kHz. The estimated auditory frequency range of mid-frequency cetaceans reported by Southall et al. is 150Hz to 160kHz.

Noise exposure criteria

In developing marine noise criteria for temporary loss of hearing sensitivity (i.e. temporary threshold shift or TTS) and permanent auditory tissue damage (permanent threshold shift or PTS), distinction is made between:-

- Noise sources that are pulsed (e.g. marine air-gun noise, pile-strike).
- Continuous noise sources that are 'non-pulses' (e.g. vessel pass-by noise, continuous dredging noise).

[22] Excluding lawful traditional hunting

[23] aquatic mammals with no hind limbs and a blowhole for breathing, including whales dolphins and porpoises

[24] Southall B L; Bowles A E; Ellison W T; Finneran J J; Gentry R L; Green C R; Kastak D; Ketten D R; Miller J H; Nactigall P E; Richardson W J; Thoas J A; and Tyack P L. *Marine Mammal Noise Exposure Criteria* Aquatic Mammals, Volume 33(4) 2007.

[25] Indo-Pacific humpback dolphin (*Sousa chinensis),*Australian snubfin dolphin (*Orcaella heinsohni)* and Bottlenose Dolphin (*Tursiops truncates)*

Laboratory studies of the effect of both pulsed and non-pulsed sound on TTS in cetaceans (principally bottlenose dolphins and Beluga whales) were reviewed by Southall et al. to develop TTS criteria for mid-frequency cetaceans. The large body of TTS and PTS data from other mammals, including humans were utilised to develop conservative estimates of PTS criteria based upon the measured TTS data.

It is recommended that the un-weighted[26] wave-form peak sound pressure level (SPL) measurement parameter is used to assess potential for immediate temporary loss of hearing sensitivity (i.e. TTS), or at a higher exposure, the immediate onset of permanent tissue damage within the dolphin auditory system (i.e. PTS). This is the same measurement parameter used to assess the potential for immediate auditory damage in human hearing conservation programs.

Southall et al. recommend that the noise measurement metric utilised should not include sound energy that lies outside the functional hearing range of a species to assess potential for cumulative temporary loss of hearing sensitivity (i.e. TTS), or at a higher exposure, the cumulative onset of permanent tissue damage within the dolphin auditory system (i.e. PTS). Southall et al also recommend use of M-weighted measurements of cumulative noise exposure for marine mammals. The recommended M-weighting curve for sound exposure measurement pertaining to medium-frequency cetaceans is shown in Figure 5, reproduced from Southall et al.

Noise criteria for TTS and PTS

The recommended criteria for dolphin, for avoidance of TTS and PTS impacts are detailed in Table 15. The SPL or sound exposure level (SEL) criteria should be tested, and the more stringent criterion deemed to apply.

Table 15: Criteria for avoidance of TTS and PTS in mid-frequency cetaceans

Impact	Unit of measure	Single or multiple pulses	Non-pulses
TTS	SPL Re: 1μPa (un-weighted Peak)	224dB	224dB
	SEL Re: $1\mu Pa^2$-s (M_{mf}-weighted)	183dB	195dB
PTS	SPL Re: 1μPa (un-weighted Peak)	230dB (TTS + 6)	230dB (TTS + 6)
	SEL Re: $1\mu Pa^2$-s (M_{mf}-weighted)	198dB (TTS + 15)	215dB (TTS + 20)

Noise criteria for behavioural disturbance

Southall et al. conducted an extensive review of documented behavioural studies of cetaceans and pinnipeds (seals) and critically summarised the range and significance of behaviours associated with documented noise level exposures for specific quantified noise sources. This analysis summarised studies of both free-ranging and laboratory subjects.

In the context of marine mammal conservation, significant behavioural responses were defined as responses that may result in demonstrable effects on individual growth, survival, or reproduction. Examples given for the onset of significant behavioural response include:

- Individual and/or group avoidance of a sound source.

[26] 'un-weighted' is also termed 'flat-weighted' or 'linear-weighted'

- Aggressive behaviour
- Startled response (that may expose an individual to danger).
- Brief or minor separation of mother-and-calf.
- Extended cessation of vocal behaviour.
- Brief cessation of reproductive behaviour.

The behavioural response of marine mammals to engineered noise was concluded by Southall et al. to be highly context-specific, depending upon the significance of the noise to the subject and depending upon the prior experience of a subject to a given stimulus. There was not a consistent linear relationship between increasing stimulus (as measured by SPL or SEL metrics)

"Current available data, pooled by functional hearing group, do not support specific numerical criteria for the onset of disturbance. Rather, they indicate the context-specificity of behavioural reactions to noise exposure and point to some general conclusions about response severity in certain, specific conditions."

Marine noise sources associated with construction of the proposed pipeline crossing would include various work vessels and a range of possible dredges. Qualitatively, suction dredging noise has similarities to vessel noise, with the gradual on-set of noise generation, but much slower physical movement than vessels. It is therefore considered reasonable for the behavioural response of dolphin species to dredge noise to be considered similar to the documented response of dolphins to vessel noise.

In the summary of behavioural studies presented by Southall et al., vessel noise was not found to result in a significant behavioural response for free-ranging mid-frequency cetaceans (e.g. Beluga Whale, Bottlenose Dolphin, Indo Pacific Dolphin).

It can be expected that dolphin species in the general vicinity of Port Curtis are very familiar with vessel noise and dredging noise associated with existing traffic and previous and ongoing dredging works (e.g. Fisherman's Landing berth dredging).

5.3.2 Dugong

Auditory system

The auditory system of the dugong (*Dugong dugon)* (refer Figure 6) is beginning to receive detailed research attention to support the development of appropriate marine conservation measures that address lethal and sub-lethal risks posed by boat-strike, seismic surveys and use of explosives in marine defence artillery practice areas(Hodgson 2007)[27]. In relation to boat-strike, recent research has been directed at improving knowledge of the extent to which dugong are able to detect the approach of motor-vessels.

Iwashina 2008[28] conducted anatomical studies on deceased dugong subjects to estimate the dugong auditory range at between 24-34Hz and 24-27kHz, based upon comparative studies of cochlea geometry in dugong and humans. Iwashina also investigated the physical nature of the sound conduction structures of the outer ear, skull and middle-ear. Iwashina

---

[27] Hodgson, A. *A Dugong Research Strategy for the Torres Strait, Great Barrier Reef World Heritage Area and south-east Queensland 2006-2011* Great Barrier Reef Marine Park Authority, Townsville, Research Publication No.86, 2007

[28] Iwashina, Y. *A Preliminary Study of the Basic Ear Anatomy of the Dugongs* School of Earth and Environmental Science, James Cook University, Queensland 2008

concludes that it is unclear whether the sound transmission via the narrow external ear canal is redundant in comparison to sound conduction to the middle-ear via tissue and the skull. It is noted that the connection of the middle-ear structures to the dugong skull may preclude significant binaural hearing capability, as sound conduction via the skull tends to present the same external sound signal to both ears (in contrast to dolphin where the left and right sound transmission structures to the middle-ear are mechanically isolated to a greater degree).

Based on the experimental work of Hodgson[29] and Hodgson and Marsh 2007[30] in relation to dugong boat-strike potential and anatomical studies by Iwashina, it does not appear that dugong use binaural processing of differentially received sound to help localise the source of sound in water. Hodgson reported experimental observations of dugong behaviour in response to close vessel pass-bys at distances less than 50m. Dugong did not show a tendency to move away from the boat and appeared to be inclined to move towards the boat if this direction led to deeper water. Hodgson reports that some planned experimental close-range pass-by testing was not conducted due to the absence of evidence that the dugong would exhibit a successful rather than erroneous avoidance response.

Estimates of the optimal hearing sensitivity of dugong are based upon the evolutionary logic that the optimal hearing sensitivity would likely match the frequency range of dugong vocalisations. These vocalisations have been quantified by Anderson and Barclay 1995[31] and to be within the range of 3kHz to 18kHz for 'chirp-squeaks', and between 500Hz and 2.2kHz for 'barks'.

Noise management criteria

Noise criteria have not been developed specifically for dugong to manage potential TTS and PTS impacts. However, a conservative approach can be developed by comparing what is known about the dugong auditory system with better-studied cetaceans for which TTS and PTS guidelines are available.

The reported range of optimal hearing sensitivity of dugong is consistent with the low-frequency hearing sensitivity reported for 'mid-frequency cetaceans' and high-frequency sensitivity reported for 'low-frequency cetaceans' as illustrated on Figure 5. It can be concluded that measurements using the M_{mf} frequency weighting for mid-frequency cetaceans will not under-estimate the significance of noise to dugong.

The anatomical work of Iwashina suggests that the overall hearing sensitivity of dugong would likely be less than that of dolphins, which appear to have far more evolved sound conduction structures to the middle-ear.

On this basis, it is assumed that the TTS and PTS criteria for mid-frequency cetaceans as detailed in Table 15, would provide a conservative management basis for considering TTS and PTS impacts to dugong.

5.3.3 Fish

Noise impacts to fish have been studied in detail, principally in the context of marine pile-driving, marine explosions and marine air-gun arrays. At high intensities these noise

[29] Hodgson, A J *Dugong behaviour and responses to human influences* PhD Thesis, School of Earth and Environmental Science, James Cook University, Queensland 2004

[30] Hodgson, A J and Marsh H.. *Response of dugongs to boat traffic: The risk of disturbance and displacement* Journal of Experimental Marine Biology and Ecology 340 (2007) 50-61

[31] Anderson, P.K. and Barclay, M.R *Acoustic Signals of Solitary Dugongs: Physical Characteristics and Behavioural Correlates*, Journal of Mammology, Vol.76, No.4(Nov, 1995) pp.1226-1237

sources can damage the auditory structures of fish (soft sensory tissue on the fish's otolith becomes damaged), rupture swim bladders and cause vascular damage.

The American National Marine Fisheries Service (Stadler and Woodbury 2009[32]) noise management criteria for avoidance of tissue damage in fish during marine piling have been adopted for assessment of both pulsed and non-pulsed sound, as reproduced in Table 16.

The criteria for non-pulsed sound exposure are reportedly conservative as these are essentially based upon research data from impact piling. These are recommended until quantitative data specific to the impact of non-pulsed noise exposures on fish becomes available (e.g. vibratory piling or dredging).

Table 16: Criteria for avoidance of tissue injury in fish

Application	Unit of measure	Single or multiple pulses	Non-pulses
All fish	SPL Re: 1μPa (un-weighted Peak)	206dB	206dB
Fish ≥ 2g	SEL Re: 1μPa²-s (un-weighted)	187dB	187dB
Fish < 2g		183dB	183dB

5.3.4 Marine turtles

Marine turtles have an external ear-drum with mechanical connection to the middle-ear. The external acoustic transmission tissue shows adaptations not observed in terrestrial and semi-aquatic turtles (Moein Bartol 2008[33]).

Early research into the auditory response of marine turtles was motivated by the possibility of developing acoustic deterrent devices to keep turtles away from sources of mechanical harm, such as suction dredges (Moein et al 1995[34]). However, little is known about levels of acoustic energy that may harm the auditory function.

The auditory frequency range of marine turtles is significantly lower than that of dolphin and dugong, with estimates for a range of species (including the Green Turtle and Loggerhead Turtle) in the range of 100Hz to 1kHz (Ketten and Moein Bartol 2005[35]) and best sensitivities near 400-1000Hz (Ketten 2008[36]). These estimates were based upon auditory brain stem response studies of live subjects. Ketten notes that little more is currently known about the hearing sensitivity of turtles or their dependency on sound for many facets of survival.

It may be noted that the known auditory frequency range of marine turtles is fully contained between 100Hz and 1kHz, representing a small fraction of the auditory frequency range of mid-frequency cetaceans (refer Figure 5).

In the absence of recommended damage criteria for marine turtles from scientific literature it is proposed to utilise the same criteria as for dolphin species.

---

[32] Stadler J H and Woodbury D P *Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria* National marine Fisheries Service USA, Proceedings Internoise 2009 August 2009 Ottawa, Canada.

[33] Bartol S M *A review of auditory function of sea turtles* Bioacoustics Vol 17(1-3) 57-59 2008

[34] Moein S E, Musick JA, Keinath J A, Barnard D E, Lenhardt M L, and George R *Evaluation of seismic sources for repelling sea turtles from hopper dredges* In *Sea Turtle Research Program: Summary Report* (Ed by L Z Hales) pp.90-93 Technical Report CERC95

[35] Ketten D R and Bartol S M *Functional Measures of Sea Turtle Hearing –Final Report* Woods Hole Oceanographic Institution

[36] Ketten DR *Underwater ears and the physiology of impacts: Comparative Liability for Hearing Loss in Sea Turtles, Birds and Mammals* Bioacoustics 17(103) 315-318 2008

5.4 Baseline marine noise survey

5.4.1 Methodology

Attended underwater noise sampling was conducted on the 17 June and the 24 June 2009, within the vicinity of the proposed pipeline crossing and in the vicinity of existing operational wharfs. Monitoring was conducted to provide historical data for the range of baseline noise levels in the study area and to provide numerical context to the underwater noise metrics utilised for assessment of marine construction noise sources.

All sampling locations within the Port of Gladstone area are illustrated within Figure 7. A detailed view of sampling locations in the general area of The Narrows pipeline crossing site is illustrated on Figure 8.

Sampling was conducted in low-wind conditions with negligible noise from wave-action. This condition is not uncommon in the relatively protected waters of The Narrows where wind-fetch distances for wave generation are relatively short.

The hydrophone was suspended at approximately mid-depth, which was determined from depth-sounder records and depth markers on the hydrophone cable. Sampling was conducted with the boat motor cut while drifting, with the start and finish points of the drift marked by a global positioning system.

Sampling within the vicinity of The Narrows crossing was conducted on 17 June 2009 at around low-tide to minimise tidal turbulence and flow turbulence over the hydrophone. Similarly, sampling on 24 June 2009 was conducted around high-tide to reduce flow turbulence noise.

5.4.2 Instrumentation

The acoustic instrumentation used for testing is summarised in Table 17. The test system was calibrated immediately before commencement of measurements and immediately after measurements, with less than 0.2dB drift in system calibration recorded.

Full sound signals were recorded to enable replay of samples for post-analysis identification of noise sources.

A laser rangefinder was utilised to determine the pass-by distance of vessels and to determine hydrophone separation distance from wharf structures and moored ships.

Table 17: Instrumentation and equipment

Item	Notes
Hydrophone	Single-ended Reson TC4032 low noise with 10dB preamp S/N4307048 Usable frequency range 5 Hz to 120 kHz Linear frequency range 15 Hz to 40 kHz ± 2 dB Receiving sensitivity -170 dB re 1 V/µPa (3mV/Pa)
Extension cable	Reson TL8058 10m extension cable and lemo cable junction box
Sound analyser and data storage	Panasonic CF19 Toughbook incorporating a SINUS Harmonie Type 1 sound analyser, hard-drive digital audio storage, and Samurai control software S/N06268 -40kHz 3201 line

Item	Notes
	FFT, 1µPa reference pressure
Calibrator	Type 1 GRAS 42AA pistonphone S/N91003 with RESON TL8089 coupler S/N1108033

5.4.3 Results

A representative summary of the results of ambient noise sampling are collated in Table 18, cross-referenced to the geographical locations illustrated within Figure 7 and Figure 8 and graphical sound spectral data for specific sound samples, as illustrated in Appendix F.

Sample Numbers 1 to 11 were collected on 17 June 2009, and Sample Numbers 12 to 18 on 24 June 2009. The duration of samples was generally five minutes.

Ambient noise in the vicinity of the pipeline crossing was found to be dominated by the 'crackling' sound of many snapping shrimp, with some relatively low-level noise contribution from distant wharf ship-loader activity at Fisherman's Landing.

Sound from a transient fish chorus was noted in Sample 9, with this type of sound occurring within the general frequency range of 200Hz to 2kHz. This event is described as transient as this sound was not evident at the nearby location of Sample 8 approximately 10 minutes earlier and was not evident at the nearby location of Sample 11 approximately 10 minutes later.

The overall root-mean-square (RMS) sound pressure contribution of shrimp and ship-loader noise were comparable at distances of 250-350m from ship-loading activities.

The peak sound pressures throughout the study area were dominated by snapping shrimp noise[37]. Levels were consistently in the range of 155-165dB$_{(peak)}$ throughout the study area.

Whereas snapping shrimp produce sound energy across a very wide frequency range from around 500Hz to greater than 100kHz, the ambient sound energy associated with ship-loading noise generally occurs at frequencies below approximately 2kHz.

Table 18: Marine ambient noise sample summary

Sample point no. (refer Figure 7 and Figure 8)	Time	Water depth	Dominant noise sources	Peak pressure SPL Re: 1µPa (un-weighted Peak)	RMS pressure SPL Re: 1µPa (Mmf-weighted)
1 (Crossing)	8:35am	14m	Snapping shrimp Distant speedboat Wave-slap	157dB (shrimp)	106–122dB (refer Figure 20)
3 (Crossing)	9:05am	14m	Snapping shrimp Speedboat at 80m	126dB (boat) 155dB (shrimp)	108–124dB (refer Figure 21)
5 to 6	11:20am	15m	Snapping	162dB	114–127dB

[37] generated by water-jet induced cavitation bubble implosion

Sample point no. (refer Figure 7 and Figure 8)	Time	Water depth	Dominant noise sources	Peak pressure SPL Re: 1µPa (un-weighted Peak)	RMS pressure SPL Re: 1µPa (Mmf-weighted)
(Hamilton Point)			shrimp Distant shiploading	(shrimp)	(refer Figure 22)
9 (Crossing)	1:34pm	15m	Snapping shrimp Fish chorus	160dB (shrimp)	105–126dB(M_{mf}) 106–126dB(linear) (refer Figure 23)
12A to 12B (Graham Creek)	12:31pm	9-11m	Snapping shrimp Speedboat at 400m Wave-slap	165dB (shrimp)	103–129dB (refer Figure 24)
13A to 13B (Crossing)	12:45pm	17m	Snapping shrimp Distant shiploading	160dB (shrimp)	114–125dB (refer Figure 25)
15A to 15B (Crossing)	1:03pm	5m	Snapping shrimp Distant shiploading	160dB (shrimp)	104–122dB (refer Figure 26)
17A to 17B (Fisherman's Landing)	1:24pm	9-14m	Shiploading at 350m Snapping shrimp	161dB (shrimp)	118–127dB (refer Figure 27)
18A to 18B (Clinton Wharf)	2:20pm	19m	Shiploading at 250m Snapping shrimp	156dB (shrimp)	121–130dB (refer Figure 28)

5.5 Assessment - marine piling noise

5.5.1 Source underwater noise levels

Marine piling can be a source of high levels of underwater sound, particularly for percussive pile-driving techniques.

Sheet piles are proposed for construction of the MOF, with cylindrical steel pipe piles utilised in construction of the LNG loading jetty. It is likely that the sheet piles would be installed using a vibratory driver and the jetty piles by an impact-driver.

A comprehensive compendium of marine noise levels from underwater piling has been prepared by ICF Jones & Stokes et al 2009[38]. The data includes measurements of

[38] ICF Jones & Stokes, and Illingworth and Rodkin Inc, final report to the California Department of Transportation *Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish* February 2009

underwater piling noise in water depths relevant to the vicinity of the MOF and LNG plant's jetty. Extracts of data relevant to the types of piles that may be utilised in construction of the MOF and LNG jetty are detailed in Table 19.

Table 19: Unattenuated underwater noise at 10m from marine piling (from ICF Jones & Stokes et al 2009)

Noise source	Driving Method	Water depth	Peak pressure SPL Re: 1µPa (un-weighted Peak)	RMS pressure SPL Re: 1µPa (un-weighted)	SEL 1s exposure SPL Re: 1µPa2.s (un-weighted)
0.61m diameter steel pipe pile	single impact	~15m	207dB	194dB	178dB per strike
1m diameter steel pipe pile	single impact	10m-15m	210dB	195dB	180dB per strike
0.6m AZ steel sheet	Vibratory driver	~15m	175-182dB	160-165dB	160-165dB

5.5.2 Options for underwater piling noise mitigation

Proven mitigation measures that are commonly used to reduce underwater noise emissions from impact-driven cylindrical steel jetty piles include pile-head cushion blocks, pile isolation casings and bubble curtains.

A cushion block is made of an energy absorbing material such as wood or nylon to reduce the generation of high-frequency vibrations in the pile during pile impact. Marine noise reductions of 11-26dB are reported for wood blocks and 4-5dB for nylon blocks(ICF Jones & Stokes et al 2009). These attenuations are additive to the noise reductions that may be achieved external to the pile (i.e. bubble curtains and isolation casings).

A bubble-curtain consists of a series of vertical-spaced air-diffuser rings on a frame that is lowered around the pile. The change in water density created by the 'curtain' of air-bubbles around the pile reduces the sound transmission to the surrounding water. An example illustration of a bubble-curtain in operation is shown in Figure 9.

An isolation-casing attenuation system utilises a concentric outer shell around the pile to contain either a complete air-gap or a water-air-bubble layer close to the pile to disrupt sound transmission. An example of an isolation-casing technique bubble-curtain in operation is shown in Figure 10. The advantage of this system over the bubble-curtain is that the 'insulating' layer around the pile is not prone to distortion from cross-currents.

Bubble-curtain and isolation-casing techniques can reliably reduce underwater noise levels from piling by 10-5dB. Noise reductions beyond 10dB-15dB for this technique are generally limited by 'leakage' of sound to the water column via transmission from the driven pile through the sea-bed. This leakage is able to bypass the mitigation treatment.

Total reductions in the range of 20-30dB may be achieved using a combination of cushion blocks and pile isolation methods (air-bubble curtain, isolation casing). A total attenuation of 20dB is considered to be a reliable maximum level of attenuation for preliminary analysis.

5.5.3 Impacts on hearing sensitivity

Impacts are described in terms of a potential impact zone, where a creature could be exposed to levels above defined threshold criteria, if assumptions about the duration of dwell and noise level within that zone are true. The size of this impact zone will vary between types of marine fauna (e.g. fish or dolphin) and the various exposure criteria (peak pressure or SEL). Impact assessment requires consideration of all criteria and marine fauna groups to establish the impact zone that can be considered suitable for harm management purposes.

Peak sound pressure level

The potential for TTS or sudden damage is examined by comparing peak sound pressure levels from piling (refer Table 19) with peak sound pressure level (peak SPL criteria for relevant marine fauna(refer Table 15 and Table 16). Piling noise levels are presented at a nominal distance of 10m, corresponding to the source data presented by ICF Jones & Stokes et al.

A comparison of measured ambient levels, piling peak pressure levels and relevant criteria are presented in Table 20. Peak pressure criteria for dolphin have been utilised for consideration of dugong and turtle in the absence of scientifically recommended criteria. The most stringent instantaneous pressure criterion is 206dB$_{peak}$, relating to fish.

Assuming that noise mitigation would be utilised to achieve at least 10dB of attenuation for impact piling, the predicted potential impacted zone, based upon consideration of peak pressure for fish is a circular area of less than 10m radius from the pile. A much smaller potential impact zone (i.e. much smaller radius than 10m) would apply to dolphin, dugong and turtles. It is considered that there would be a low risk of significant numbers of fish, or any dolphin, dugong or turtle remaining within 10m of all piling operations.

It is concluded that 10dB of mitigation would effectively manage potential peak-pressure impacts from impact-driving of cylindrical piles for the jetty. No attenuation would be needed in respect of peak pressure impacts from vibratory driving of sheet piles.

Table 20: Assessment of peak pressure from piling activities

Quantity	Comment	Source distance	SPL Re: 1µPa (un-weighted peak)
Criterion	Dolphin TTS peak pressure criterion.	n/a	224dB
Criterion	Fish peak pressure criterion for on-set of permanent damage.	n/a	206dB
Ambient	**Ambient peak pressure in vicinity of The Narrows crossing (snapping shrimp).**	**n/a**	**155 -165dB measured**
Impact driven 0.61m diameter steel pipe pile	No attenuation	10m	207dB
	10dB attenuation (e.g. bubble curtain)	10m	197dB
Impact driven 1m diameter steel pipe pile	No attenuation	10m	210dB
	10dB attenuation (e.g. bubble curtain)	10m	200dB
Vibratory driven 0.6m AZ steel sheet	No attenuation	10m	182dB

SEL calculation considerations

The cumulative SEL that a marine creature may experience within the vicinity of piling operations would be dependent upon both the separation distance from the pile and the duration of exposure. Both the exposure distance and duration will vary continuously and are therefore difficult to define. These quantities are inherently dependent upon the behavioural avoidance response of the species to the noise source and any normal migratory movement of fauna, all of which is uncertain. In practise, the SEL is quantified by making conservative 'what-if' assumptions about separation distance and exposure duration to develop plausible upper estimates of exposure.

For impact-driven piles ICF Jones & Stokes et al report that 1m diameter steel pipe piles are typically driven by 600 strikes per pile, at a rate of 1.5 seconds per impact. Vibratory driven sheet piles typically require 5-15 minutes of continuous driving. It is normal for there to be breaks during the driving of a single pile, to judge when the pile is sufficiently founded, however this additional 'down time' does not significantly contribute to the cumulative noise impact (i.e. SEL).

The first assumption that is made to help narrow-down the estimate of possible SEL is that the sound energy from only a single pile will be relevant to an individual. Expressed conversely, it is assumed that any marine fauna will not remain in 'significant' proximity to a piling operation for more than the duration of a single pile. This could be 15 minutes for a vibratory driven sheet pile, or between two hours and a full day for a one metre diameter impact driven steel pipe pile.

Vibratory piling SEL

A comparison of measured ambient levels, source noise levels for vibratory piling and SEL criteria relating to non-pulsed noise sources is presented in Table 21. As for the Peak SPL assessment, SEL criteria for dolphin are utilised for consideration of dugong and turtles.

Table 21: Assessment of cumulative SEL from vibratory piling

Quantity	Comment	Source Distance	SEL Re: 1µPa2.s
Criterion	Dolphin TTS SEL criterion.	n/a	195dB(M_{mf}) non-pulsed
Criterion	Fish SEL criterion for on-set of permanent damage (fish ≥ 2g).	n/a	187dB(linear) non-pulsed
Criterion	Fish SEL criterion for on-set of permanent damage (fish < 2g).	n/a	183dB(linear) non-pulsed
Ambient	**Ambient peak pressure in vicinity of The Narrows crossing - Sample 9 (snapping shrimp).**	**n/a**	**136dB(Mmf) measured (5 minutes)** **160dB(Mmf) calculated (24 hour)** **(Note: linear-weighted ambient SELs are 1dB higher)**
Vibratory driven 0.6m AZ steel sheet pile	No attenuation	10m	165dB (1 second) 193dB (15 minutes ~ 1 pile)

Quantity	Comment	Source Distance	SEL Re: 1µPa2.s
		50m	155dB (1 second) 183dB (15 minutes ~ 1 pile)
Vibratory driven 0.6m AZ steel sheet pile	10dB attenuation	10m	155dB (1 second) 183dB (15 minutes ~ 1 pile)

If no noise mitigation is utilised the potential impacted zone based upon consideration of SEL for small fish is a circular area of less than 50m radius from the pile. A much smaller potential impact zone of approximately 10m radius would apply to dolphin, dugong and turtles. It is considered that there would be a low risk of significant numbers of fish dwelling within a 50m impact zone, or any dolphin, dugong or turtle remaining within a 10m zone, for a period of the order of 15 minutes.

It is concluded that no additional mitigation would be necessary to manage potential SEL impact from vibratory sheet piling for the MOF.

Impact piling SEL

Table 22 presents a comparison of measured ambient levels, source and more distant noise levels for impact piling and criteria for SEL relating to pulsed noise sources. Piling noise is presented for a 1m diameter steel pipe pile. SEL criteria for dolphin are utilised for consideration of dugong and turtles. The M_{mf} criteria have been compared to the un-weighted piling noise data, which may slightly over-estimate the significance of noise impact, depending upon the amount of piling noise energy that lies outside of the functional auditory range of medium frequency cetaceans.

SELs are presented for a range of source distances and degrees of noise mitigation. For this preliminary analysis, 20dB is considered the upper limit of reliable achievable attenuation at the impact piling source. Distance attenuation of underwater piling noise has been modelled as intermediate between cylindrical and hemispherical spreading (4.5dB attenuation per doubling of distance) on the basis of empirical studies presented by ICF Jones & Stokes et al. This study found 4.5dB attenuation per doubling of distance to be the lower bound of attenuations measured experimentally up to 1000m in water depths within the range of 12-16m.

It is concluded that the potential SEL impact zone for unattenuated piling of steel pipes for the jetty would be of the order of 1km in radius for either large marine fauna or small fish. For this scenario the earlier assumption that a creature would only remain in close proximity to piling for the duration of one pile only would appear tenuous, as it is conceivable that marine fauna could remain within 1km of multiple pile drives. It is concluded that some degree of source noise control should be applied.

The potential SEL impact zone could be reduced to approximately 250m radius by applying 10dB of source attenuation, or approximately 50m radius by applying 20dB of source attenuation.

A 250m radius potential SEL impact zone (achieved by applying 10dB of source attenuation) could readily be monitored for the presence of large marine fauna (dolphin, dugong, turtle) however it could be questioned whether or not significant numbers of fish could dwell within 250m of piling works.

A reduced 50m radius potential SEL impact zone (achieved by applying 20dB of source attenuation) would provide a high degree of confidence that large marine fauna (dolphin, dugong, turtle) would be unlikely to suffer TTS from impact piling noise. It is expected that the numbers of small fish that could remain within a 50m radius would be considered an acceptable environmental risk.

Table 22: Assessment of cumulative SEL from impact piling

Quantity	Comment	Source Distance	SEL Re: 1µPa2.s
Criterion	Dolphin TTS SEL criterion	n/a	183dB(M_{mf}) multiple pulses
Criterion	Fish SEL criterion for on-set of permanent damage (fish ≥ 2g)	n/a	187dB(linear) multiple pulses
Criterion	Fish SEL criterion for on-set of permanent damage (fish < 2g)	n/a	183dB(linear) multiple pulses
Ambient	**Ambient peak pressure in vicinity of The Narrows crossing - Sample 9 (Snapping Shrimp)**	**n/a**	**136dB(Mmf) measured (5 minutes)** **160dB(Mmf) calculated (24hour)** **(Note: linear-weighted ambient SELs are 1dB higher)**
1m diameter steel pipe pile	Unattenuated	10m 10m 50m 250m 1km	180dB per strike 208dB per pile (nominal 600 strikes) 198dB per pile 188dB per pile 179dB per pile
1m diameter steel pipe pile	10dB attenuation	10m 50m 250m	198dB per pile (nominal 600 strikes) 188dB per pile 178dB per pile
1m diameter steel pipe pile	20dB attenuation	10m 50m	188dB per pile (nominal 600 strikes) 178dB per pile

5.6 Assessment - dredge and vessel noise

5.6.1 Source underwater noise levels

Marine noise levels have been sampled, for example dredging operations and a range of vessel pass-by events, to provide marine noise level data that is indicative of marine noise generation associated with dredging of inshore areas associated with the MOF and jetty. This previous sampling was conducted while dredges and vessels were operating in protected water passages (Port of Brisbane and Port of Bundaberg) that are similar in water depth, wave conditions and bottom conditions to Laird Point LNG site area.

Noise levels were sampled utilising the instrumentation and methodology as detailed in Section 5.4 for baseline noise monitoring.

A summary of the results of source noise sampling are collated in Table 23.

All noise sources sampled may be described as 'non-pulsed' noise sources for assessment of potential auditory effects on marine creatures. This was concluded from the observation that the impulse-response RMS level for each noise source was no more than 1dB higher than the fast-response RMS level.

Table 23: Sample marine dredging and vessel noise summary

Noise source	Measurement distance	Receiver water depth	Dominant noise sources	Peak pressure SPL Re: 1µPa (un-weighted Peak)	RMS pressure SPL Re: 1µPa (Mmf-weighted)
'Amity' cutter-suction dredge Figure 11 Figure 12	45m beam	14m	Hydraulic drive Suction noise	145dB	128-142 dB
'Brisbane' 2900m^3 trailing-arm suction hopper dredge Figure 13 Figure 14	45m pass-by of stationary observer by traversing dredge	11m	Gravel noise in suction head Engine noise	176dB	147-158dB(M_{mf}) 148-160dB(linear)
Sea-service freighter Figure 15	220m pass-by	7m (source depth ~14m)	Engine and drive noise	<140dB - Shrimp noise dominant	127-135dB
Stolt tanker Figure 16	155m pass-by	3m (source depth ~14m)	Engine and drive noise	<140dB - Shrimp noise dominant	124-136dB
Pilot boat Figure 17	150m pass-by	2m (source depth ~14m)	Engine and propeller cavitation noise	<140dB - Shrimp noise dominant	113-126dB
Passenger ferry Figure 18	200m pass-by	2m (source depth ~14m)	Engine and propeller cavitation noise	<140dB - Shrimp noise dominant	120-133dB
Tug and barge	200m pass-by	2m (source depth ~14m)	Engine and propeller cavitation noise	<140dB - Shrimp noise dominant	113-126dB

The levels of noise associated with the sources in Table 23 at distances less than the measurement distance can be conservatively over-estimated by simplistic modelling[39], by assuming free-field spherical propagation between the source and the measurement position (the level is approximated to increase by 6dB for each halving of distance).

Levels at separation distances beyond the measurement distance can be conservatively over-estimated by assuming cylindrical propagation beyond the measurement position (the level is approximated to decrease by 3dB for each doubling of distance).

5.6.2 Impacts on hearing sensitivity

The potential for TTS is examined by comparing typical levels of marine noise generated by dredging and vessel movements (refer Table 23) with instantaneous peak sound pressure level (peak SPL) and cumulative sound exposure level (SEL) criteria (refer Table 15 and Table 16).

Peak sound pressure level

A comparison of measured ambient levels, source noise levels and criteria for peak SPL is presented in Table 24. Pressure criteria for dolphin have been utilised for consideration of dugong and turtle in the absence of scientifically recommended criteria.

The highest peak acoustic pressures associated with dredging occurs when a suction dredge is lifting rocky material, which generates significant impact noise in the hopper arm (176dB_{peak} at 45m). It is predicted that the most stringent pressure criterion for this operation of 206dB_{peak} (relating to fish) could be reached at distances within 1m to 2m of the suction head. The dolphin criterion of 224dB_{peak} would be reached at distances of less than 1m from the suction head.

It can be concluded that there is low risk of damage to any marine species associated with the peak sound pressure levels from dredging operations, or miscellaneous vessel movements. To put this risk into context, any creature close enough (<1m) for significant sound pressure impact would be at risk of direct mechanical damage from a dredge suction head or boat propeller.

Table 24: Assessment of peak pressure from dredging activities

Quantity	Comment	Source distance	SPL Re: 1μPa (un-weighted peak)
Criterion	Dolphin TTS peak pressure criterion	n/a	224dB
Criterion	Fish peak pressure criterion for on-set of permanent damage.	n/a	206dB
Ambient	**Ambient peak pressure in vicinity of The Narrows crossing**	**n/a**	**155 -165dB measured**

[39] More accurate predictions require detailed modelling of the water depth, wave conditions, the acoustic absorptive properties and profile of the sea-bed, in addition to more detailed account of the directional characteristics and frequency spectrum of the noise source. The sound field at any distance will be a complex composite of direct and multiple surface and bottom-reflected sound paths, with the reflected sound-paths dominating in the far-field. In the far-field where reflected sound-paths dominate, the propagation of low frequency components will also be limited by the water depth, as the water column is unable to support the reflected propagation of soundwaves at wavelengths more than four times the water depth.

Quantity	Comment	Source distance	SPL Re: 1µPa (un-weighted peak)
	(snapping shrimp).		
Cutter-suction dredge	'Amity' cutter-suction dredge.	45m	145dB measured
Trailing-arm suction hopper dredge	'Brisbane' suction hopper dredge.	45m	176dB measured
Vessel pass-bys	Freighters, ferries, workboats Freighters, ferries, workboats	150m 45m	≤140dB measured ≤150dB estimated

Cumulative SEL

The potential cumulative sound exposure level (SEL) that a marine creature may experience within the vicinity of dredging operations would be dependent on both the separation distance from the noise source and the duration of exposure. The exposure distance and duration are difficult to define, as these quantities are inherently dependent upon the behavioural avoidance response of the species in question to the noise source, which is uncertain. In practise, the SEL is quantified by making 'what-if' assumptions about separation distance and exposure duration.

A comparison of measured ambient levels, source noise levels and criteria for cumulative SEL sound pressures is presented in Table 25. As for the Peak SPL assessment, SEL criteria for dolphin are utilised for consideration of dugong and turtles.

Table 25: Assessment of cumulative SEL from dredging activities

Quantity	Comment	Source Distance	SEL Re: 1µPa2.s
Criterion	Dolphin TTS SEL criterion	n/a	195dB(M_{mf}) non-pulsed
Criterion	Fish SEL criterion for on-set of permanent damage (fish ≥ 2g)	n/a	187dB(linear) non-pulsed
Criterion	Fish SEL criterion for on-set of permanent damage (fish < 2g)	n/a	183dB(linear) non-pulsed
Ambient	**Ambient peak pressure in vicinity of The Narrows crossing - Sample 9 (snapping shrimp).**	**n/a**	**136dB(Mmf) measured (5 minutes)** **160dB(Mmf) calculated (24hour)** **(Note: linear-weighted ambient SELs are 1dB higher)**
Trailing-arm suction hopper dredge	'Brisbane' suction hopper dredge lifting sandy material	45m	142dB(M_{mf}) measured (1second) 172dB(M_{mf}) calculated (15 minutes)

Quantity	Comment	Source Distance	SEL Re: 1µPa2.s
			(Note: linear-weighted ambient SELs are 1dB higher)
Trailing-arm suction hopper dredge	'Brisbane' suction hopper dredge lifting rocky material.	45m	158dB(M_{mf}) measured (1second) 173dB(M_{mf}) measured (2 minutes) 182dB(M_{mf}) calculated (15 minutes) (Note: linear-weighted ambient SELs are 1dB higher)
Cutter-suction Dredge	'Amity' cutter-suction dredge in sandy material.	45m	142dB(M_{mf}) measured (1second) 156dB(M_{mf}) measured (2 minutes) 165dB (M_{mf}) calculated (15 minutes) (Note: linear-weighted ambient SELs are 1dB higher)
Vessel pass-bys	Freighters, ferries, workboats	150m	150dB(M_{mf}) measured 90s pass-by
	Freighters, ferries, workboats	45m	≤160dB(M_{mf}) estimated 90s pass-by

The highest SEL associated with dredging would occur if a suction dredge encountered pebbly or rocky material, which generates significantly more additional noise emission from the hopper arm. It is predicted that the most stringent SEL criterion for this operation of 183dB(lin) relating to small fish (<2g) could be exceeded at distances within 50m of the suction head if an individual fish remained in the area for longer than 15 minutes, which is considered unlikely. Much lower SELs would result if the dredge was operating over sandy material.

The SEL criterion of 195dB(M_{mf}) for dolphin species[40] is predicted to be exceeded if an individual remained for longer than five hours within 50m of the suction head lifting rocky material, which is unlikely.

The marine sound energy levels associated with the cutter-suction dredge and vessel pass-by noise levels are not significant in relation to the SEL criteria. Hundreds of vessel pass-

[40] also simplistically used in this assessment as a guideline for Dugong and turtles in the absence of recommended criteria

bys each day within 50m of an individual creature would be necessary for the sound exposure to become significant.

5.7 Behavioural impacts

In theory, the behavioural response of marine creatures to anthropogenic noise is dependent on both instinctive responses (e.g. flight) and cognitive responses (curiosity, understanding of danger, irritation).

Data is not available for the behavioural response of marine species to underwater piling noise. It is conservatively assumed that marine life would likely try to avoid noise from impact or vibratory piling, given the opportunity. To facilitate this assumed response, it is recommended that piling processes commence at low impact or vibratory energy levels and ramp-up to full driving levels during a suitable period of time to provide opportunity for fauna to vacate the area. This is generally referred to as the 'soft-start' technique.

Dolphin species exhibit a high degree of cognition of marine sounds and are very mobile. Dolphin may temporarily be driven by curiosity to venture closer to dredging. Research literature indicates no significant adverse behavioural response (in the context of survival) to vessel noise and this is also expected to be the case for dredging noise.

The inclusion of turtle-excluding design features on modern dredge suction-heads indicates that turtles (unfortunately) may not exhibit a significant behavioural avoidance response to marine dredging noise. The problems of boat-strike with turtles suggest that there is also not a strong behavioural avoidance response to vessel noise.

The behavioural response of dugong to marine dredging noise is unknown. The history of mortality from boat-strike and scientific literature about the auditory response of dugong may suggest that cognition of dredging noise as a threat may be low.

6.0 Conclusions

6.1 Airborne noise impacts

Construction noise

With the exception of possible impact piling noise associated with constructing LNG storage tanks and jetty structures, construction noise would not be significant at existing residential receptors during the day or night due to the large separation distance between the construction site and residential receptors.

Noise impacts from piling of the jetty and LNG tank foundations could potentially produce sleep disturbance in the Targinie area and at Fisherman's Road if conducted at night. Noise from piling of the LNG tank foundations may also be found to be excessive at the construction camp during the evening and at night.

The specific details for noise management will need to be established when particulars of actual piling methods, piling schedule and rig capacities are known.

Road traffic

A Noise Management Plan will be prepared to minimise the noise impact of the buses and delivery trucks on surrounding residences. The most significant factor of noise control of these movements is anticipated to be the control of the time of operations. The scheduling, volumes involved and the route to be taken would all require careful consideration during the detailed design of the project for inclusion in the Noise Management Plan.

Marine traffic

There are only two isolated dwellings on Tide Island and Witt Island on the east side of the north-south shipping channel that may be potentially affected by increased vessel traffic associated with construction and operation phases of the project. While the frequency of additional vessel noise pass-bys would be noticeable during the project construction phase, individual pass-by events would be no more intrusive than existing vessel traffic. During the operational phase, bulk LNG freighter noise would be comparable to existing bulk freighter noise movements.

Operational noise from proposed LNG plant

For the purpose of noise modelling assessment it has been assumed that the LNG plant will run with both trains operating at 100% capacity, 24 hours per day, seven days a week.

The predicted level of noise plant noise at the construction camp is compatible with air-conditioned dwelling facilities, which would be expected given the camp proximity to the plant.

At all existing locations the predicted levels comply with the critical night-time planning noise levels.

Significant levels of low frequency noise are not expected at any of the existing residential receivers which are located relatively remote from the site. However, the data required to test this expectation is not yet available. It is therefore recommended that the detailed design phase includes a requirement to conduct analysis of the low frequency noise utilising the criteria discussed in Section 3.2.3.

In the unlikely event of short term major ground flaring (equivalent to two process trains), overall LNG plant noise levels inclusive of flare noise would be acceptable during the day or night.

Cumulative operational noise from future projects in the locality

The noise contribution from the Project may be significant at residential receptors in the Targinie area and at South End. At these locations the predicted cumulative noise from the proposal and other proposed industrial facilities would comply with the Project's noise goals.

At other receptor locations the noise contribution from the Project would not be significant in the context of the cumulative noise emission from other projects.

6.2 Vibration impacts

Significant vibration impacts from piling activities are not anticipated at either the project construction camp, or at a construction camp of an adjoining project, due to the large expected separation distance (at least 800m) between piling locations and camp sites.

Vibration impacts associated with any blasting for the initial earthworks could conceivably be significant at the proposed construction camp for this project, or at an adjoining LNG plant construction project. It is very unlikely that blasting would be of a scale that would be regarded as significant at South End.

If blasting is required, the blast should be designed to achieve vibration and air-blast levels that will comply with the statutory criteria in Section 4.2 and with regard to any specific vibration requirements or sensitivities of structures associated with any adjoining LNG plant (including habitable construction camps).

Vibration impacts to fauna associated with marine piling are addressed in the underwater noise analysis[41].

6.3 Marine noise impacts

Underwater noise levels associated with anticipated vibratory sheet-piling for the MOF would pose a low risk of harm to marine fauna.

Impact-piling of steel pipe piles for the LNG loading jetting will likely require noise mitigation to achieve an acceptably low risk of harm to marine fauna. A preliminary analysis of the degree of noise control that may be required has been based upon assumptions of 1m diameter steel pipe piles and 600 pile-strikes per pile. With these assumptions, approximately 20dB of source mitigation is recommended to restrict the zone of potential noise impact to within 50 metres of the driven pile. This level of source noise mitigation can be achieved by proven mitigation measures, utilising a combination of an air-bubble curtain system (either confined by an outer shell casing or an unconfined system of stacked air-diffuser rings) and a cushion block at the pile head.

It is recommended that piling processes commence at low impact or vibratory energy levels and ramp-up to full driving levels during a suitable period of time to provide opportunity for fauna to vacate the area. This is generally referred to as the 'soft-start' technique.

Whilst the exact extent and nature of marine piling is not known in detail, it can be concluded that marine noise emissions can be effectively managed to an acceptable

[41] Assessment of marine vibration impacts in water is synonymous with the assessment of acoustic pressure impacts

standard by utilising proven mitigation methods. Detailed mitigation planning should be developed when the actual details of proposed piling are known.

Quantitative assessment of typical noise levels associated with dredging and vessel movements indicates that dredging operations in the vicinity of the MOF and jetty would result in low risk of harm to marine fauna.

Significant adverse behavioural responses of marine animals to dredging noise or vessel noise are not anticipated.

Figures

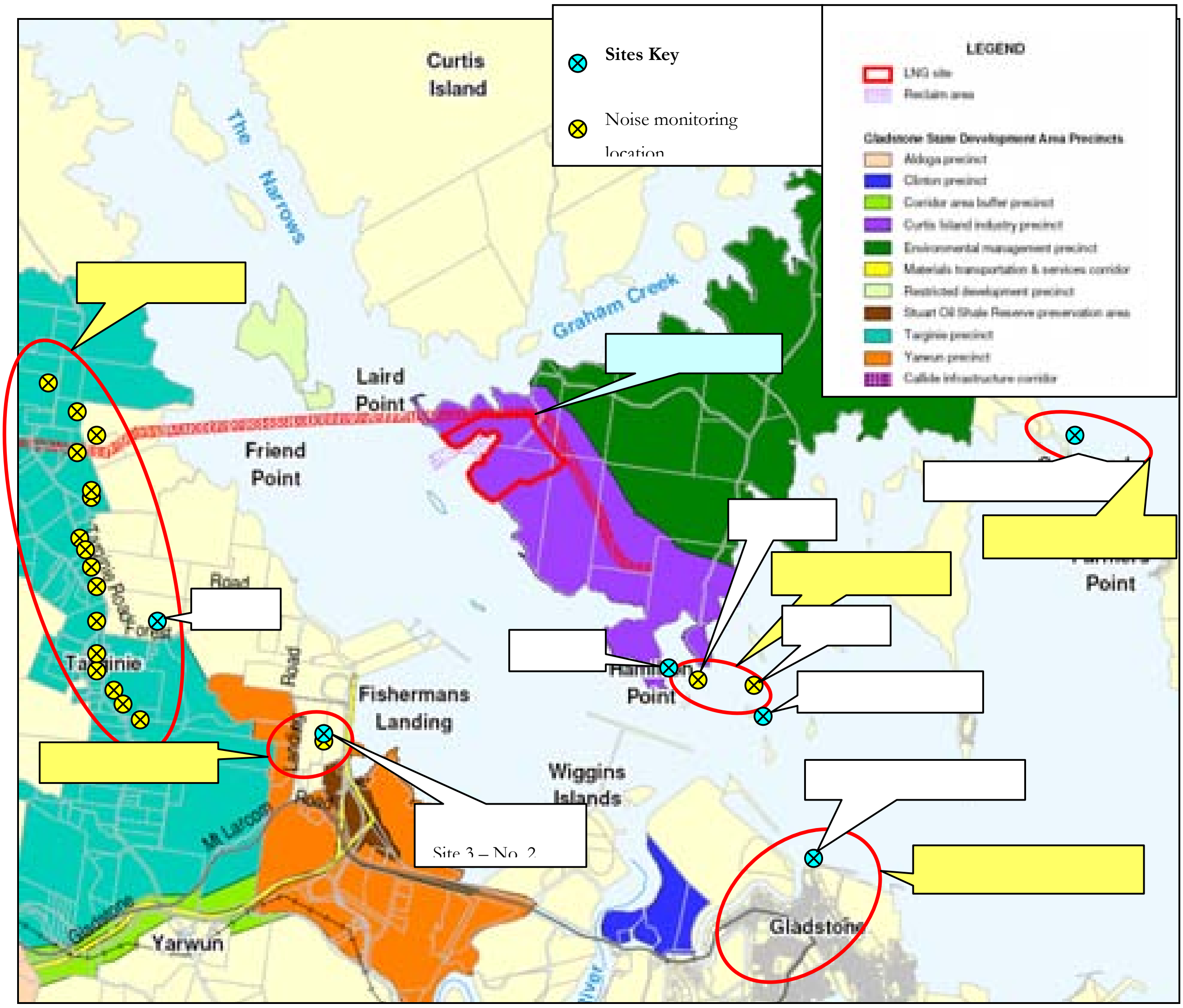


Figure 1: Nearest dwellings and baseline noise monitoring locations

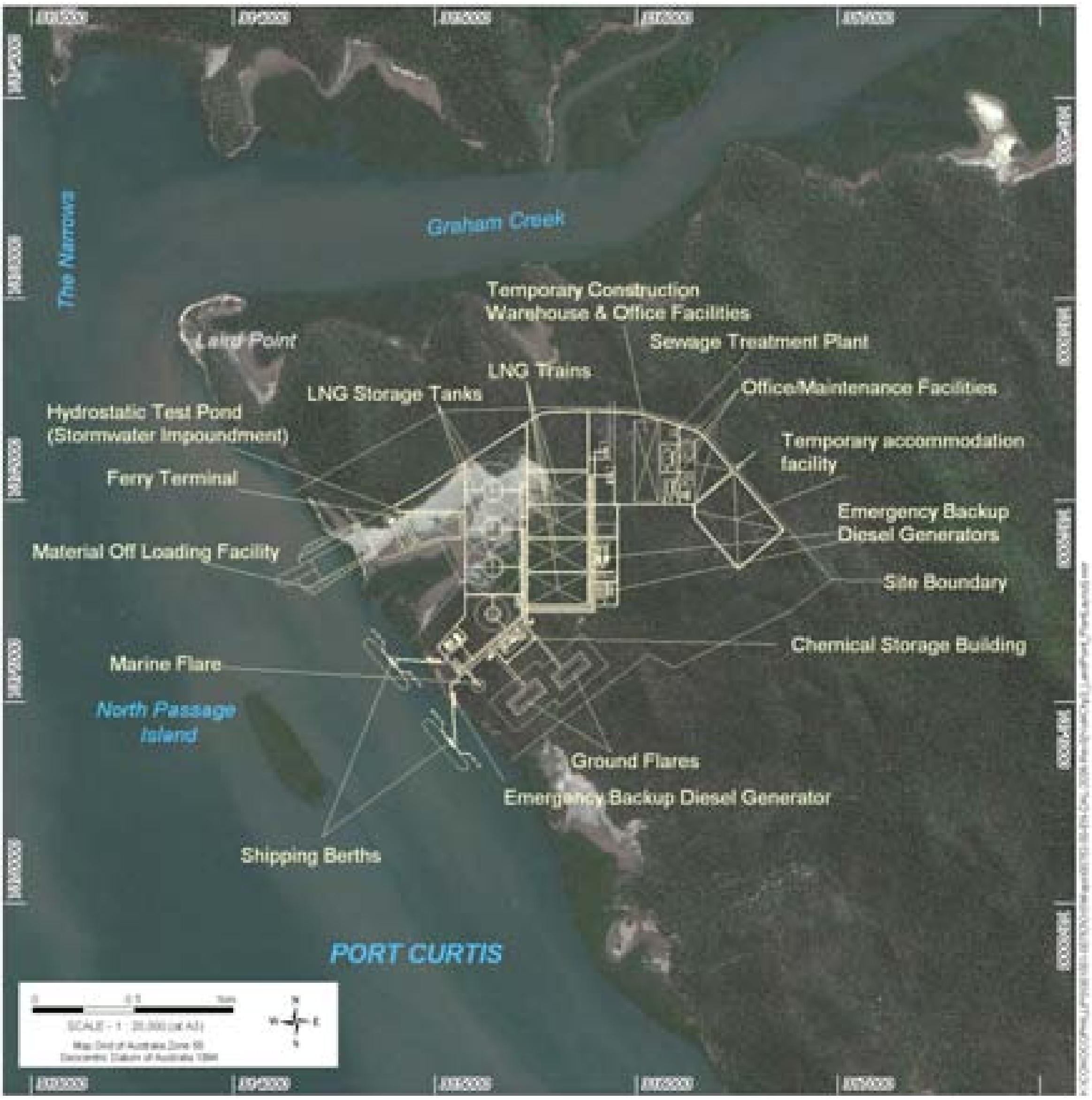


Figure 2: Indicative LNG plant layout

Figure 3: Artist's impression of LNG plant

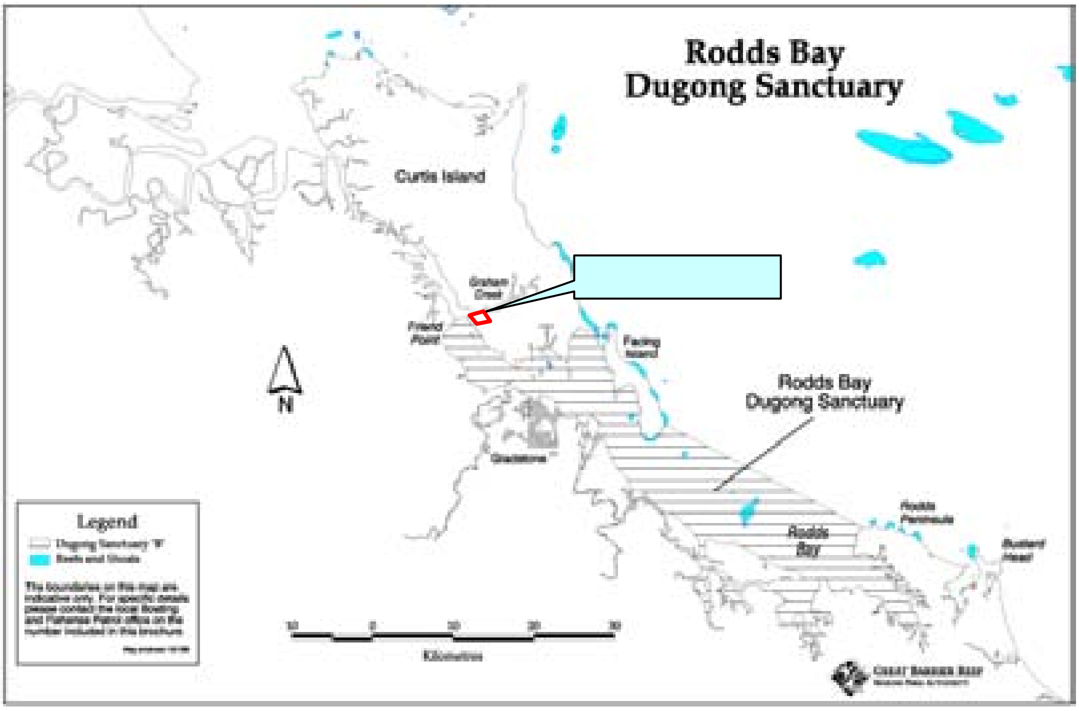


Figure 4 Rodds Bay dugong protection area and proposed LNG site

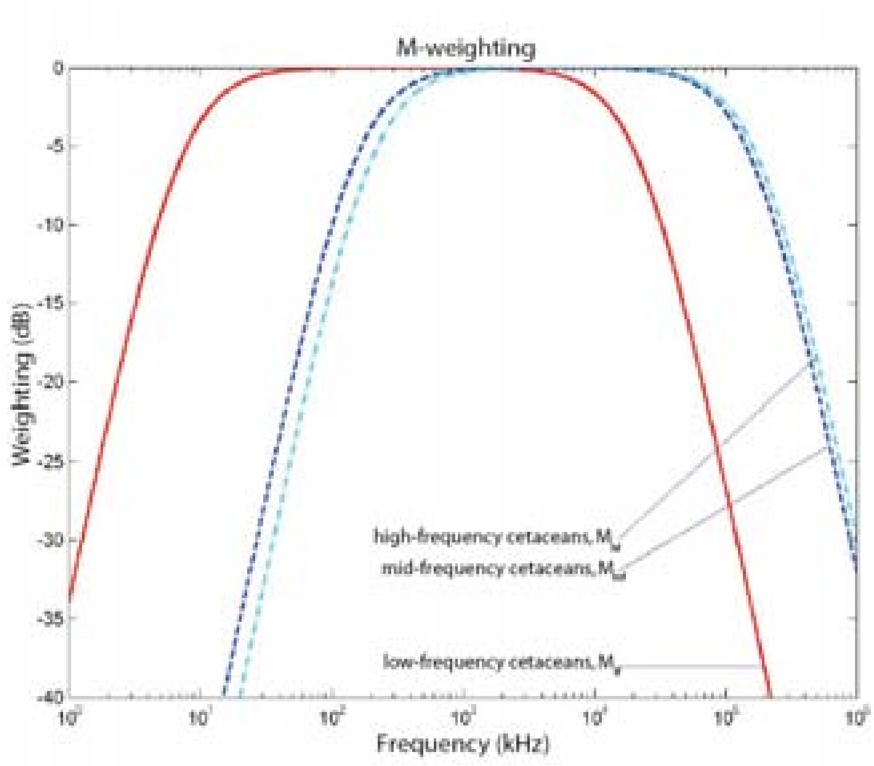


Figure 5 M-weighting curves reproduced from Southall et al.2007[42]

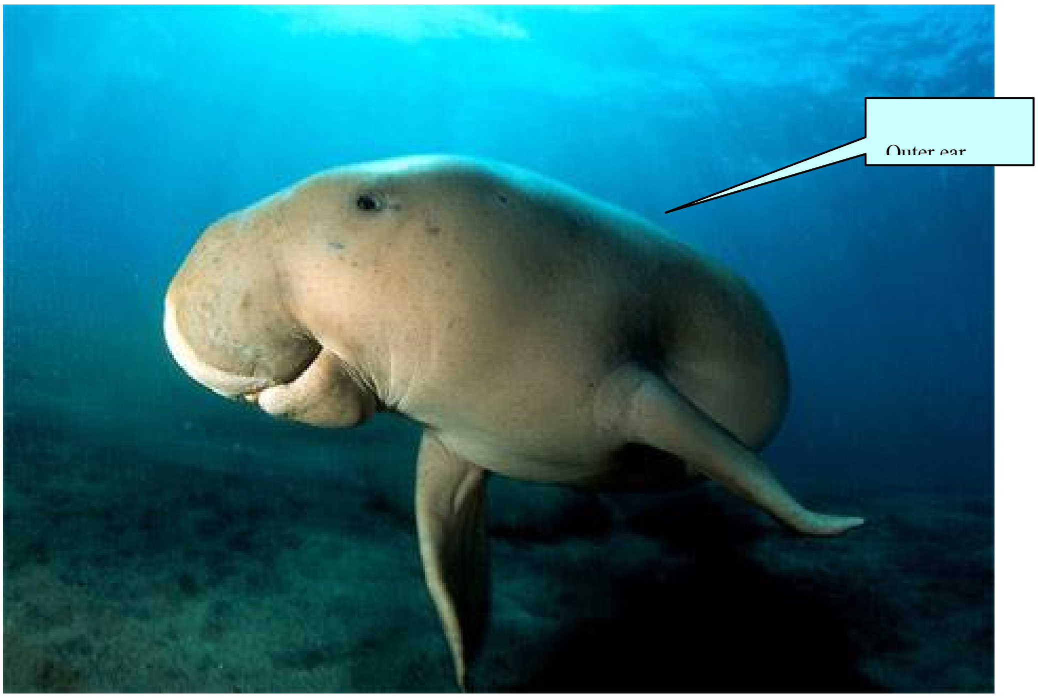


Figure 6 Dugong (*Dugong Dugon*) [43]

[42] Southall B L; Bowles A E; Ellison W T; Finneran J J; Gentry R L; Green C R; Kastak D; Ketten D R; Miller J H; Nactigall P E; Richardson W J; Thoas J A; and Tyack P L. *Marine Mammal Noise Exposure Criteria* Aquatic Mammals, Volume 33(4) 2007.

[43] Source: http://animals.nationalgeographic.com/staticfiles/NGS/Shared/StaticFiles/animals/images/primary/dugong.jpg

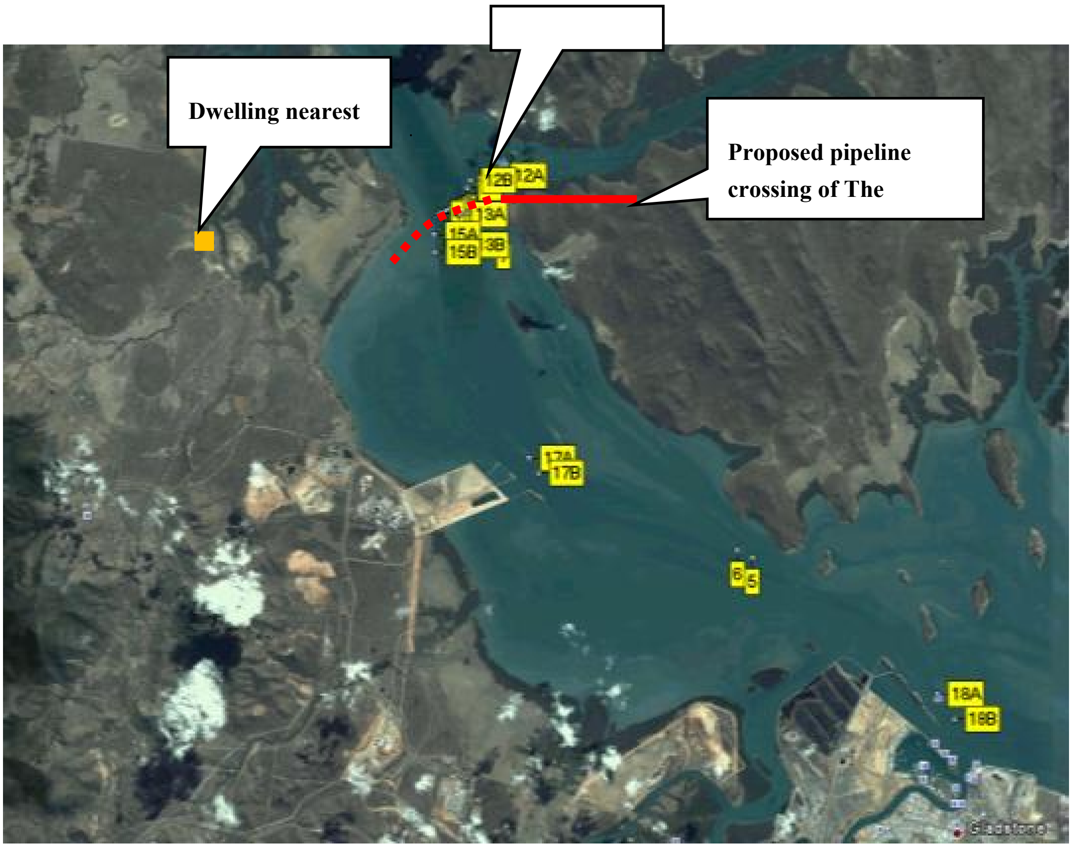


Figure 7: Whole harbour baseline marine noise sampling locations

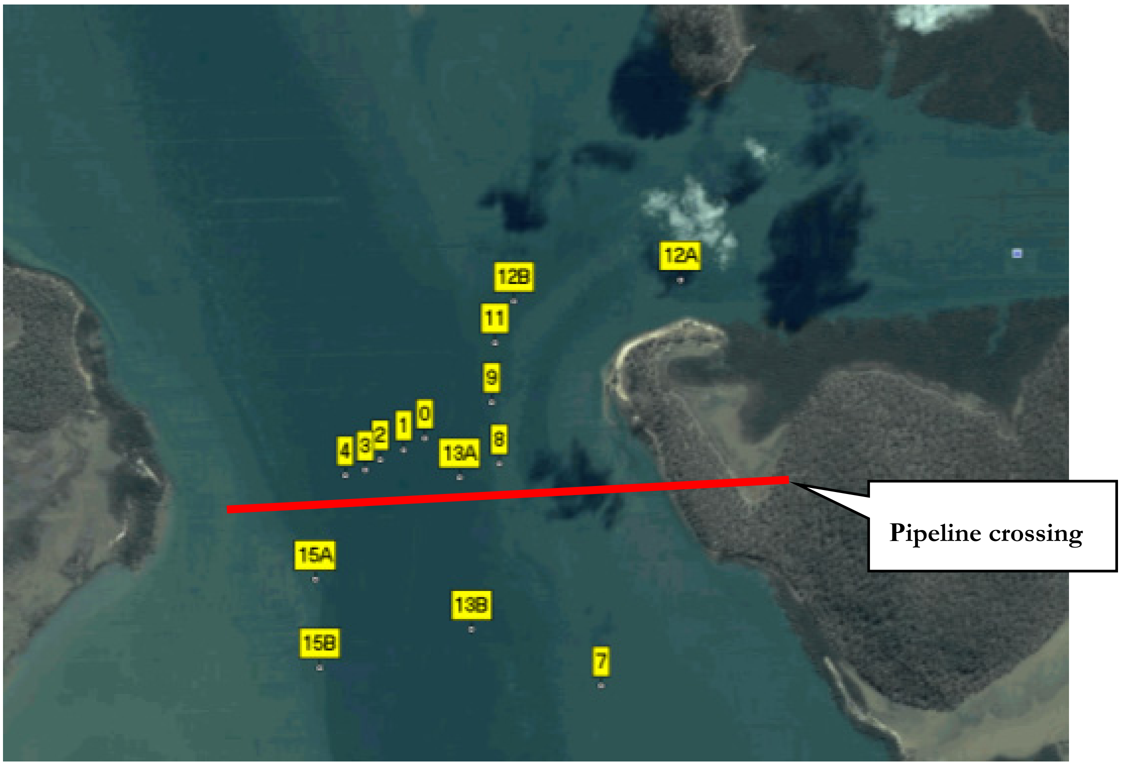


Figure 8: The Narrows area baseline marine noise sampling locations

Figure 9: Air-bubble curtain in-situ and raised (source: ICF Jones & Stokes et al 2009)

Figure 10: Casing (confined air-bubble) mitigation raised and in-situ (source: ICF Jones & Stokes et al 2009)

Figure 11: 'Amity' cutter-suction dredge

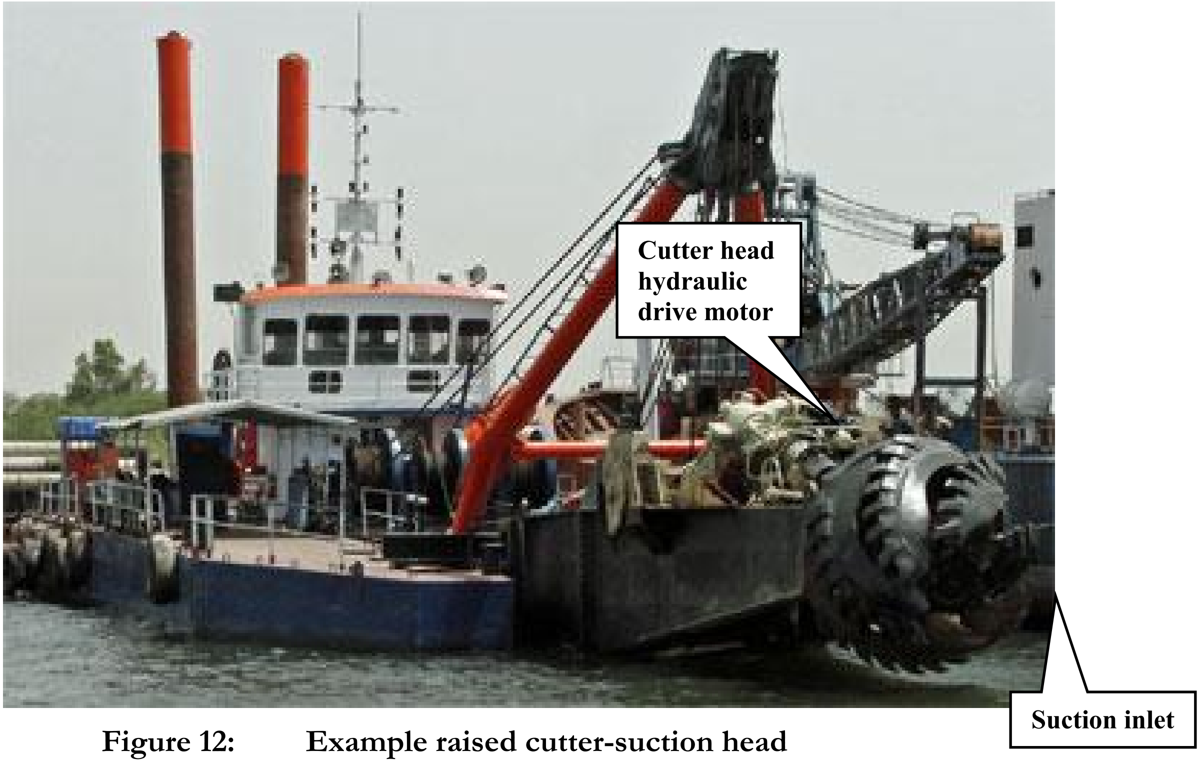


Figure 12: Example raised cutter-suction head

Figure 13: 'Brisbane' trailing-arm suction dredge

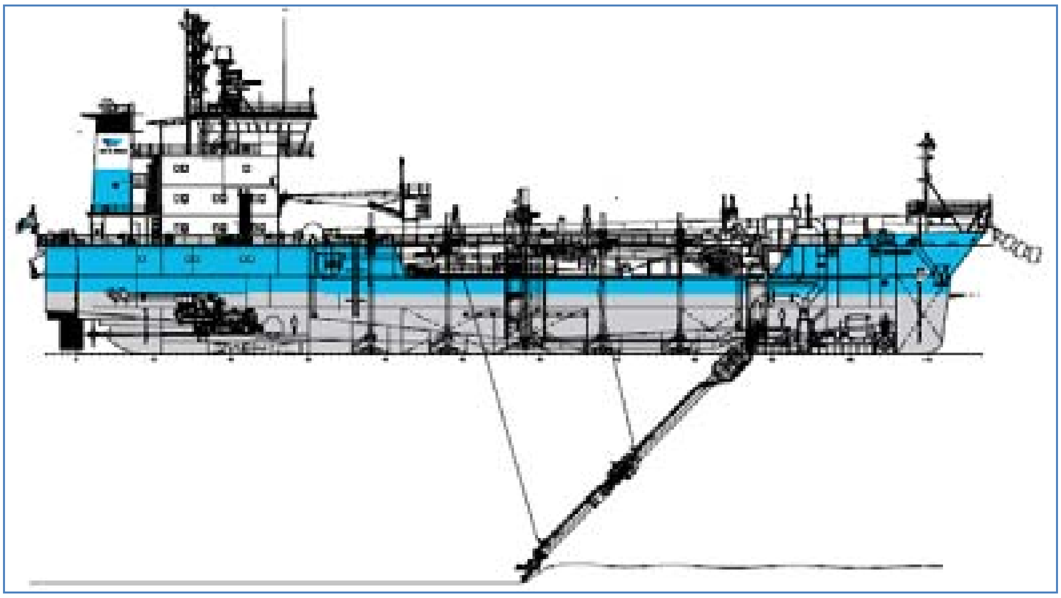


Figure 14: 'Brisbane' trailing-suction dredge schematic

Figure 15: Sea-service freighter (246m x 42m)

Figure 16: **Stolt tanker**

Figure 17: **Pilot boat**

Figure 18: Tangalooma Flyer high speed passenger ferry

Figure 19: Riverside marine tug and barge

Appendix A – Derivation of guideline planning levels

A.1 Control of Background Noise Creep

To prevent the background noise levels (for day, evening and night periods) from gradually increasing with the establishment of new developments in an area, the guideline describes a methodology for determining the design emission limits for each new development (or industry) based upon 'recommended' and 'rating' (existing) outdoor background noise levels (min LA90, 1hour2). The recommended background noise levels depend upon the nature of the surrounding land use, being lower for green-field areas, and higher for recognised industrial areas, as detailed in Table 26.

Table 26: Queensland DERM guideline – recommended background levels

Receiver land use	Receiver area dominant land use	Recommended background noise level minLA90,1hour (dBA)[44]		
		Day (7am-6pm)	Evening (6pm-10pm)	Night (10pm-7am)
Purely residential	Very rural	35	30	25
	Rural residential, church, hospital	40	35	30
	Shop or commercial office	45	40	35
	Light industry	50	45	40
Residential area on a busy road, or near an industrial or commercial area	Rural residential, church, hospital	45	40	35
	Shop or commercial office	50	45	40
	Light industry	55	50	45
Industrial area	Rural residential, church, hospital	50	45	40
	Shop or commercial office	55	50	45
	Factory office or factory	60	60	60
Passive recreation area	Picnic grounds, public beaches, bush walks,	35	35	35

[44] $minL_{A90,1hour}$ is defined as the rating background level in accordance with the methodology defined in the Planning for Noise Control guideline

Receiver land use	Receiver area dominant land use	Recommended background noise level minLA90,1hour (dBA)44		
		Day (7am-6pm)	Evening (6pm-10pm)	Night (10pm-7am)
	public gardens, etc.			

To control and prevent cumulative increase of the rating (actual) background level above the recommended background levels in Table 26, the planning background levels (minLA90, 1hour) applicable for a new development are determined from the recommended background levels (from Table 26) and the rating (existing) background Levels in accordance with Table 27.

Table 27: Queensland DERM guideline- planning background levels

Classification of rating background level at receptor	Planning background level (minLA90, 1 hour)
A. above the recommended level in Table 26	At least 10 dBA below Table 26 recommended level
B. at recommended level	10 dBA below Table 26 recommended level
C. below recommended level by:	Set Planning background Level:
1 dB	9 dB below Recommended level
2 dB	5 dB below Recommended level
3 dB	3 dB below Recommended level
4 dB	2 dB below Recommended level
5 dB	2 dB below Recommended level
6 dB or more	5 dB above Existing background level

The planning equivalent noise level for a new development that is based upon consideration of background creep (PNLBg,) is determined using the planning background level (minLA90, 1 hour) from Table 27 in the following equation:

$PNL_{Bg,}$ = Planning $min.L_{A90,1\ hour}$ + 3 dB – K1 – K2

The adjustments K1 and K2 are required by the Guideline to account for tonal and impulsive noise characteristics of a development. If present, these characteristics increase the subjective audibility of sound and the resulting PNLBg, is lowered accordingly. The required adjustments to the PNLBg, to adjust for tonal and impulsive characteristics are summarised in Table 28.

Table 28: Guideline corrections to PNLBg for audible characteristics

Audible characteristic	Criterion	Correction
Tonality	Subjectively just detectable	K1 = 2 - 3dB
	Subjectively prominent (clearly audible)[45]	K1 = 5 - 6 dB
Impulsivity	Subjectively detectable[46]	K2 = 2 dB

Planning equivalent levels (PNLBg,) have been determined in accordance with the methods of the Guideline for the five receptor locations based upon the ambient noise monitoring data presented in Section 5.0, the town planning designation and current land use. The recommended background for each area based upon the descriptions and levels in Table 26 are shown below in Table 29.

Table 29: Recommended background levels for project receptors

Area	Receiver Land Use by Zoning (Ref. Gladstone State Development Area Map Dated 27/01/08)	Receiver Area Dominant Land Use	Recommended Background (minLA90,1 hour) from Table 26		
			Day (7am-6pm)	Evening (6pm-10pm)	Night (10pm-7am)
Targinie area (residences inside GSDA Industrial Precinct)	Industrial area	Rural Residential	45	40	35
Passage Islands	Industrial area	Residential	50	45	40
Gladstone city	Residential area	Residential and commercial	45	40	35
Fisherman's Road	Industrial area	Residential and industrial	55	50	45
South End	Residential area	Residential	40	35	30

The analysis for the Targinie area, the north-south band of rural residential dwellings west and north of Site 4 (Forest Road), is presented in Table 30. The analysis for the Passage area, comprising the dwellings on small passage islands (Witt Island and Tide Island) is presented in Table 31. The analysis for the Gladstone city area is presented in

[45] The objective test of tonality is as per AS1055.1 Clause 6.6.3

[46] The objective test of impulsive characteristics is as per AS1055.1 Clause 6.6.4

Table 32. The analysis for Site 3 on Fisherman's Road is presented in Table 33. The analysis for South End is presented in Table 34.

Given the substantial separation distances between the proposed LNG site and sensitive receptors it is considered unlikely that tonal or impulsive noise characteristics would be discernible at any receptor locations. Accordingly penalties should not be assumed in the derivation of PNLBg values for receptor locations. The PNLs should therefore be expressed as adjusted levels (LAeq 1 hour, adj)47.

Table 30: Planning level derivation (background methodology) – Targinie area

Parameter	Source	Sound pressure level, dBA		
		Day (7am–6pm)	Evening (6pm–10pm)	Night (10pm–7am)
Recommended background ($minL_{A90,1\ hour}$)	Table 26	45	40	35
Rating background ($minL_{A90,1\ hour}$)	Site 4	30	32	31
Planning background ($minL_{A90,1\ hour}$)	Table 27	35 (Rating+5)	37 (Rating +5)	33 (Recommended - 2)
Tonality correction K_1	Table 28	0	0	0
Impulsivity correction K_2	Table 28	0	0	0
Planning noise level ($PNL_{Bg,}$) ($L_{Aeq,1hour}$)	Planning BG + 3 – K_1- K_2	38	40	36

Table 31: Planning level derivation (background methodology) – Witt and Tide Islands

Parameter	Source	Sound pressure level (dBA)		
		Day (7am – 6pm)	Evening (6pm – 10pm)	Night (10pm – 7am)
Recommended background ($minL_{A90,1\ hour}$)	Table 26	50	45	40
Rating background ($minL_{A90,1\ hour}$)	Sites 1 & 2	41	44	45
Planning background ($minL_{A90,1\ hour}$)	Table 27	46 (Rating+5)	36 (Rec.-9)	35 (Rating-10)

[47] For other projects, the presumption of a tonal correction in deriving the PNLs has caused confusion in the specification of licensed levels. It is more appropriate and accurate that the determination of adjustments for tonal and impulse corrections is performed when emissions from a specific source at a given distance are assessed.

Parameter	Source	Sound pressure level (dBA)		
		Day (7am – 6pm)	Evening (6pm – 10pm)	Night (10pm – 7am)
Tonality correction K_1	Table 28	0	0	0
Impulsivity correction K_2	Table 28	0	0	0
Planning noise level ($PNL_{Bg,}$) ($L_{Aeq,1hour}$)	Planning BG + 3 – K_1- K_2	49	39	38

Table 32: Planning level derivation (background methodology) – Gladstone city

Parameter	Source	Sound pressure level (dBA)		
		Day (7am – 6pm)	Evening (6pm – 10pm)	Night (10pm – 7am)
Recommended background (min$L_{A90,1\ hour}$)	Table 26	45	40	35
Rating background (min$L_{A90,1\ hour}$)	Site 5	42	42	37
Planning background (min$L_{A90,1\ hour}$)	Table 27	42 (Rec.-3)	32 (Rating-10)	27 (Rating-10)
Tonality correction K_1	Table 28	0	0	0
Impulsivity correction K_2	Table 28	0	0	0
Planning noise level (PNL_{Bg}) ($L_{Aeq,1hour}$)	Planning BG + 3 – K_1- K_2	45	35	30

Table 33: Planning level derivation (background methodology) – Fisherman's Road

Parameter	Source	Sound pressure level (dBA)		
		Day (7am–6pm)	Evening (6pm–10pm)	Night (10pm–7am)
Recommended background (min$L_{A90,1\ hour}$)	Table 26	55	50	45
Rating background (min$L_{A90,1\ hour}$)	Site 3	40	39	40
Planning background (min$L_{A90,1\ hour}$)	Table 27	53 (Rec'd-2)	44 (Rating+5)	43 (Rec'd-2)
Tonality correction K_1	Table 28	0	0	0
Impulsivity correction K_2	Table 28	0	0	0
Planning noise level (PNL_{Bg}) ($L_{Aeq,1hour}$)	Planning BG + 3 – K_1- K_2	56	47	46

Table 34: Planning level derivation (background methodology) - South End

Parameter	Source	Sound pressure level (dBA)		
		Day (7am–6pm)	Evening (6pm–10pm)	Night (10pm–7am)
Recommended background ($minL_{A90,1\ hour}$)	Table 26	40	35	30
Rating background ($minL_{A90,1\ hour}$)	Site 6	32	35	27
Planning background ($minL_{A90,1\ hour}$)	Table 27	37 (Rating+5)	25 (Rec'd-10)	27 (Rec'd-3))
Tonality correction K_1	Table 28	0	0	0
Impulsivity correction K_2	Table 28	0	0	0
Planning noise level ($PNL_{Bg,}$) ($L_{Aeq,1hour}$)	Planning BG + 3 – K_1- K_2	40	28	30

A.2 Management of variable noise

To ensure that the derived PNL adequately contains levels of transient or variable noises from new developments (e.g. transportation noise or noise from cyclic industrial processes), the Guideline describes a methodology for determining an alternative PNL. This methodology depends upon the relationship between the baseline minimum LAeq,1hour values in each time period and the recommended maximum PNLs advised in the guideline. The guideline advises that the recommended maximum PNLs are intended to help protect against impacts such as "speech interference, community annoyance and, to some extent, sleep disturbance".

The guideline recommended maximum PNLs depend upon the nature of the surrounding land use, being lower for green-field areas and higher for recognised commercial/industrial areas and areas with more transportation noise sources, as defined in Table 35.

Table 35: Guideline recommended maximum PNLs

Noise area category	Description of neighbourhood[48]	Recommended maximum PNL[49], (LAeq,1hour - dBA)

[48] Where transportation noise is present, the minimum of the hourly L_{Aeq} values for transportation noise in the appropriate time period is taken, or the corresponding guideline value from Table 35, whichever is the greater. Guidance in selecting the appropriate hourly L_{Aeq} values for premises adjoining roadways carrying more than 100 vehicles per hour is given in the guideline.

[49] Recommended levels are estimated 4m from the facade of a building.

		Day (7am–6pm)	Evening (6pm–10pm)	Night (10pm– 7am)
Z1	Very rural, purely residential. Less than 40 vehicles/hour	40	35	30
Z2	Negligible transportation. Less than 80 vehicles/hour	50	45	40
Z3	Low-density transportation. Less than 200 vehicles/hour	55	50	45
Z4	Medium density transportation (less than 600 vehicles/hour) or some commerce or industry	60	55	50
Z5	Dense transportation (less than 1200 vehicles/hour) or some commerce or industry	65	60	55
Z6	Very dense transportation (less than 3000 vehicles/hour) or in commercial or bordering industrial districts	70	65	60
Z7	Extremely dense transportation (3000 or greater vehicles/hour) or within predominantly industrial districts	75	70	65

The procedure for determining the PNLEq considers both the 'Baseline' minimum LAeq,1hour values and the maximum recommended PNL's as summarised in Table 36.

Table 36: Guideline determination of PNLEq to contain variable noise

Comparison of baseline LAeq,1hour at receptor with recommended PNL (Table 35)	PNLEq for new sources (LAeq, 1 hour – dBA)
Baseline ≥ Recommended + 2 dB	If Baseline $L_{Aeq,1hour}$ is likely to decrease in future, 10 dB below recommended If Baseline $L_{Aeq,1hour}$ is likely to increase in future, 10 dB below baseline
Baseline = Recommended + 1 dB	Recommended – 9 dB
Baseline = Recommended	Recommended – 8 dB
Baseline = Recommended -1 dB	Recommended – 6 dB
Baseline = Recommended -2 dB	Recommended – 4 dB
Baseline = Recommended -3 dB	Recommended – 3 dB
Baseline = Recommended -4 dB	Recommended – 2 dB
Baseline = Recommended -5 dB	Recommended – 2 dB
Baseline = Recommended -6 dB	Recommended – 1 dB
Baseline < Recommended -6 dB	Recommended

A.3 Design PNL

After determining the PNLEq and PNLBg these values are compared and the lower value used as the design PNL (PNLDesign). This analysis is summarised in Table 37, Table 38, Table 39, Table 40, and Table 41. All receiver areas are subject to minimal road traffic noise. The Passage Area is subject to significant transportation noise in the form of shipping and powered recreational boating. The dwelling at 2 Fisherman's Road (Site 3) is remote from significant road noise, but is within the vicinity of a significant conveyor corridor which is considered to represent transportation noise.

Table 37: Design PNL derivation – Targinie area

Parameter	Source	Sound pressure level (LAeq,1hour – dBA)		
		Day (7am – 6pm)	Day (7am – 6pm)	Day (7am – 6pm)
Recommended maximum PNL	Table 35 (z2)	50	45	40
Baseline minimum $L_{Aeq,1hour}$	Site 4	37	48	38
PNL_{Eq} ($L_{Aeq,1hour}$)	Table 36	50 (recomm'd)	38 (Baseline-10)	36 (Rec.-4)
PNL_{Bg} ($L_{Aeq,1hour}$)	Table 30	38	40	36
PNL_{Design} ($L_{Aeq,1hour}$)	lesser of PNL_{Eq} and PNL_{Bg}	38	38	36

Table 38: Design PNL derivation – Passage area

Parameter	Source	Sound pressure level (LAeq,1hour – dBA)		
		Day (7am – 6pm)	Day (7am – 6pm)	Day (7am – 6pm)
Recommended maximum PNL	Table 35 (z4)	60	55	50
Baseline minimum $L_{Aeq,1hour}$	Sites 1 & 2	44	49	48
PNL_{Eq} ($L_{Aeq,1hour}$)	Table 36	60 (Rec.)	55 (Rec.)	46 (Rec.-4)
PNL_{Bg} ($L_{Aeq,1hour}$)	Table 31	49	39	38
PNL_{Design} ($L_{Aeq,1hour}$)	lesser of PNL_{Eq} and PNL_{Bg}	49	39	38

Table 39: Design PNL derivation – Gladstone city

Parameter	Source	Sound pressure level (LAeq,1hour – dBA)		
		Day (7am–6pm)	Day (7am–6pm)	Day (7am–6pm)
Recommended maximum PNL	Table 35 (z3)	55	50	45
Baseline minimum $L_{Aeq,1hour}$	Site 5	47	47	40
PNL_{Eq} ($L_{Aeq,1hour}$)	Table 36	55 (Rec.)	47 (Rec.-3)	43 (Rec.-2)
PNL_{Bg} ($L_{Aeq,1hour}$)	Table 32	45	35	30
PNL_{Design} ($L_{Aeq,1hour}$)	lesser of PNL_{Eq} and PNL_{Bg}	45	35	30

Table 40: Design PNL derivation – Fisherman's Road

Parameter	Source	Sound pressure level (LAeq,1hour – dBA)		
		Day (7am–6pm)	Day (7am–6pm)	Day (7am–6pm)
Recommended maximum PNL	Table 35 (z3)	55	50	45
Baseline minimum $L_{Aeq,1hour}$	Site 3	45	46	44
PNL_{Eq} ($L_{Aeq,1hour}$)	Table 36	55 (Rec.)	48 (Rec.-2)	39 (Rec.-6)
PNL_{Bg} ($L_{Aeq,1hour}$)	Table 33	56	47	46
PNL_{Design} ($L_{Aeq,1hour}$)	lesser of PNL_{Eq} and PNL_{Bg}	55	47	39

Table 41: Design PNL derivation – South End

Parameter	Source	Sound pressure level (LAeq,1hour – dBA)		
		Day (7am–6pm)	Day (7am–6pm)	Day (7am–6pm)
Recommended maximum PNL	Table 35 (z2)	50	45	40
Baseline minimum $L_{Aeq,1hour}$	Site 6	46	40	38
PNL_{Eq} ($L_{Aeq,1hour}$)	Table 36	48 (Rec'd-2)	43 (Rec'd.-2)	36 (Rec'd-4)
PNL_{Bg} ($L_{Aeq,1hour}$)	Table 33	40	28	30
PNL_{Design} ($L_{Aeq,1hour}$)	lesser of PNL_{Eq} and PNL_{Bg}	40	28	30

Appendix B – Site 1 ambient noise records

Coordinates: 23.79864°S,151.22476E | Site description: Hamilton Point

Instrument: CESVA310 + C130 mic. | Serial No: T226274 (Logger 1)

Calibrator: RION NC-73 | Serial No: 10486582

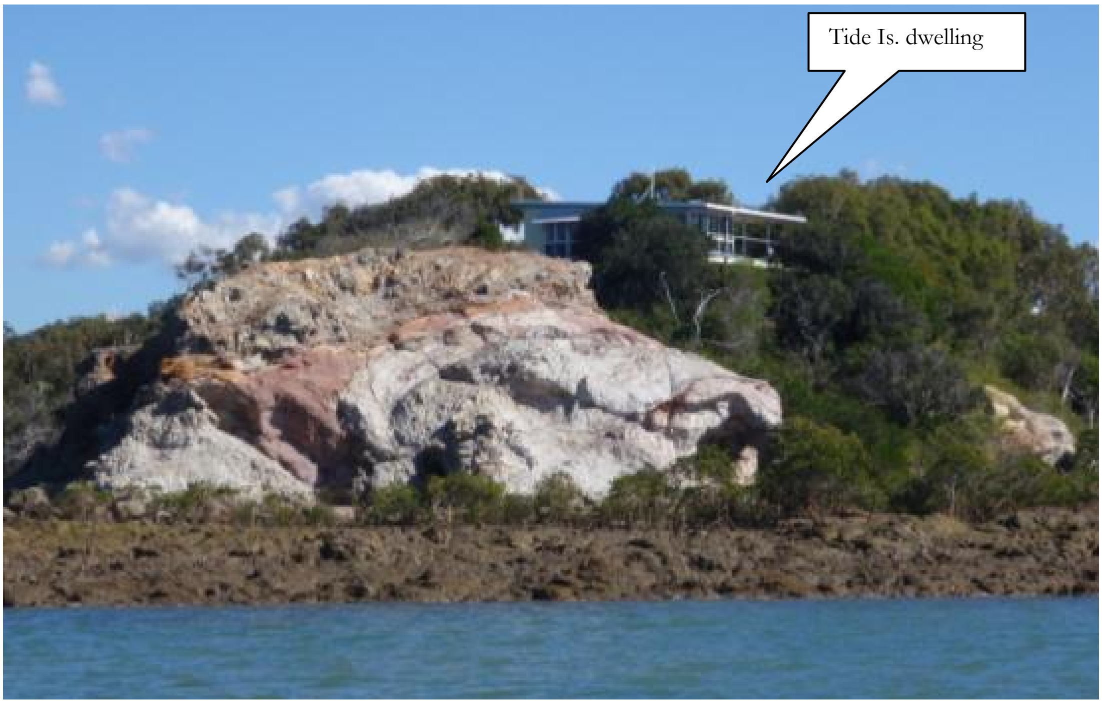
Reference weather station: | Gladstone BOM Station 39123

Logging period: Wednesday, 17 June 2009 to Wednesday, 24 June 2009

Comments:

- Bureau of Meteorology radar station weather records from 75m above sea level substantially over-estimate the wind-speed at the microphone level (approximately 4m above high tide level).
- Evening insect noise is evidenced by 2.5 kHz and 3.15 kHz banding in the spectral records. This is significant to overall levels in the early evening (i.e. typically 6-9pm) but not later at night.
- Industrial noise in bands between 250 Hz and 1.6 kHz dominates when breezes from southerly around to westerly enhance the propagation of existing industrial noise sources on the mainland (Fisherman's Landing and Gladstone wharves and refineries) towards this monitoring location. This usually occurs at night.

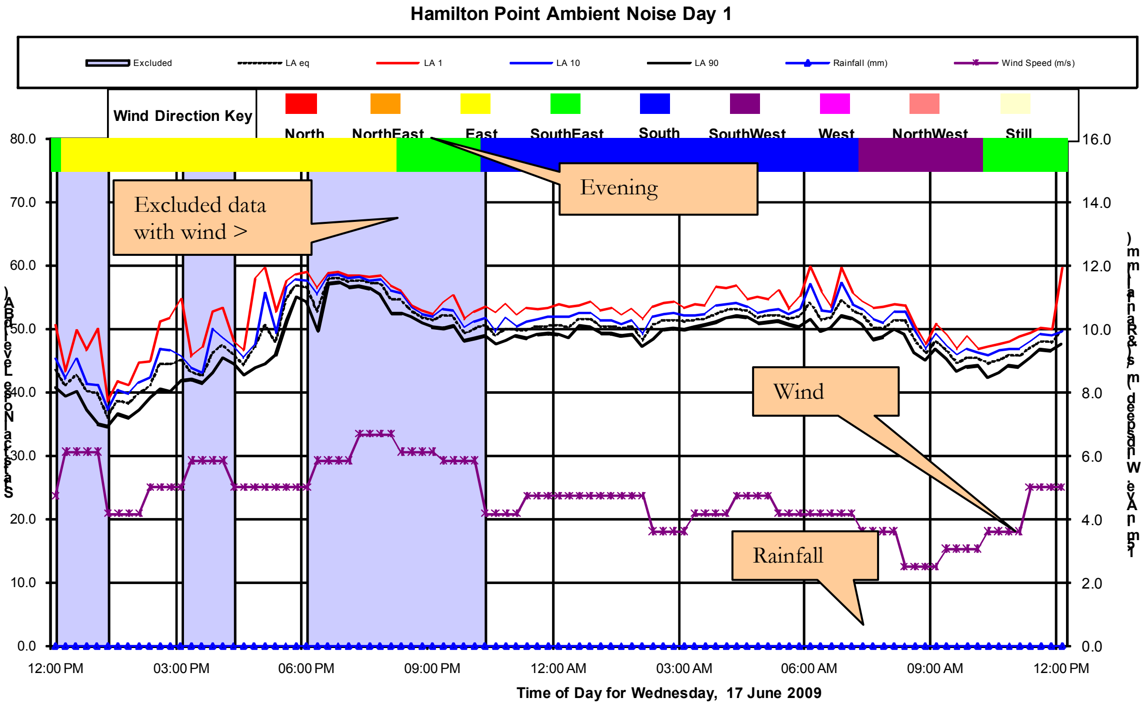

Noise Monitoring
Site 1- Hamilton Pt.
Tide Is. dwelling

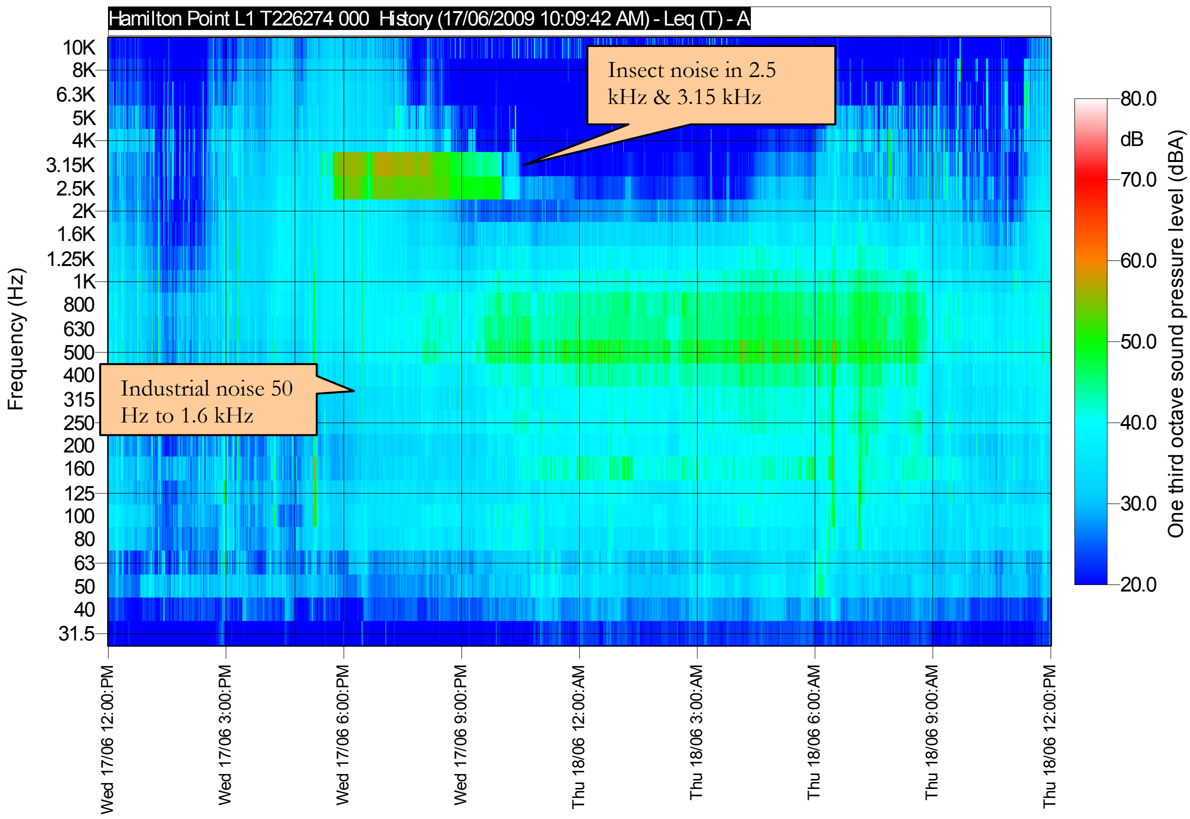

Tide Is. dwelling

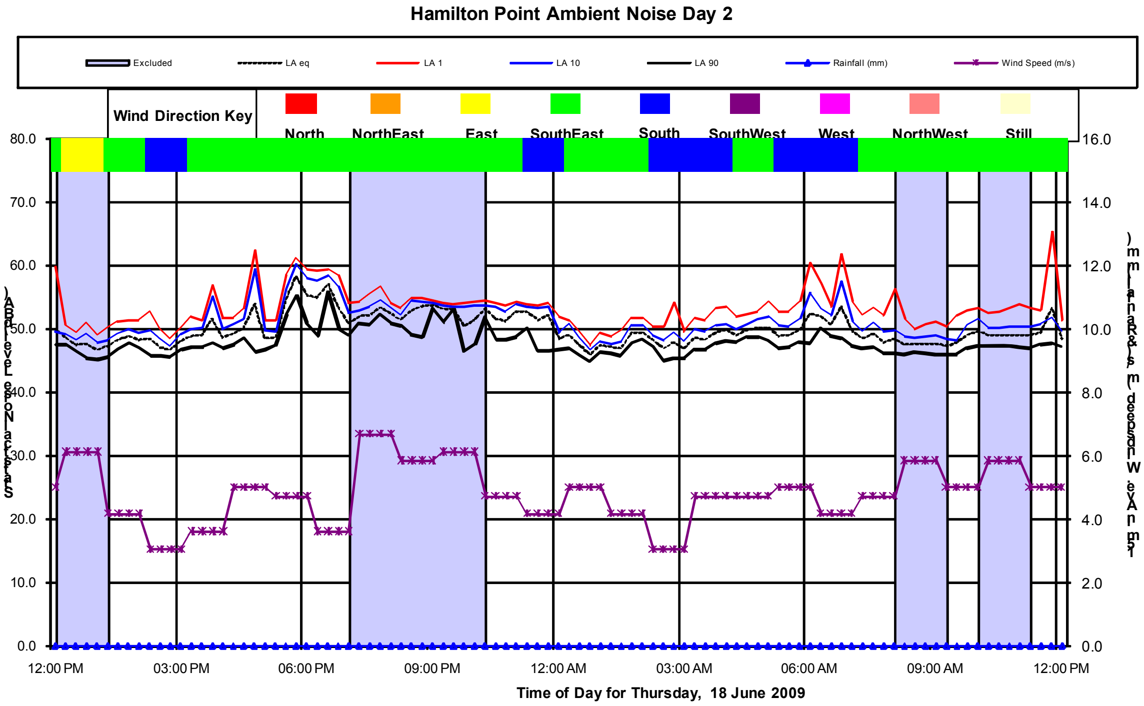
Summary - Rating LA90									
	Raw Data						Filtered Data		
Date	6am to 6pm	Fill	6pm to 10pm	Fill	10pm to 6am	Fill	6am to 6pm	6pm to 10pm	10pm to 6am
	Day	%	Evening	%	Night	%	Day	Evening	Night
Wed, 17 Jun 2009	36.7	50%	54.2	6%	48.3	97%			
Thu, 18 Jun 2009	44.1	92%	48.9	31%	45.4	97%			
Fri, 19 Jun 2009	46.1	35%	47.9	94%	47.0	100%			
Sat, 20 Jun 2009	40.2	100%	46.4	75%	48.2	88%			
Sun, 21 Jun 2009	42.5	83%	36.2	31%	39.7	34%			
Mon, 22 Jun 2009	37.0	92%	41.7	100%	43.0	100%			
Tue, 23 Jun 2009	40.6	100%	39.2	100%	42.3	100%			
Wed, 24 Jun 2009	38.7	52%							
Median RBL	40.4		46.4		45.4				

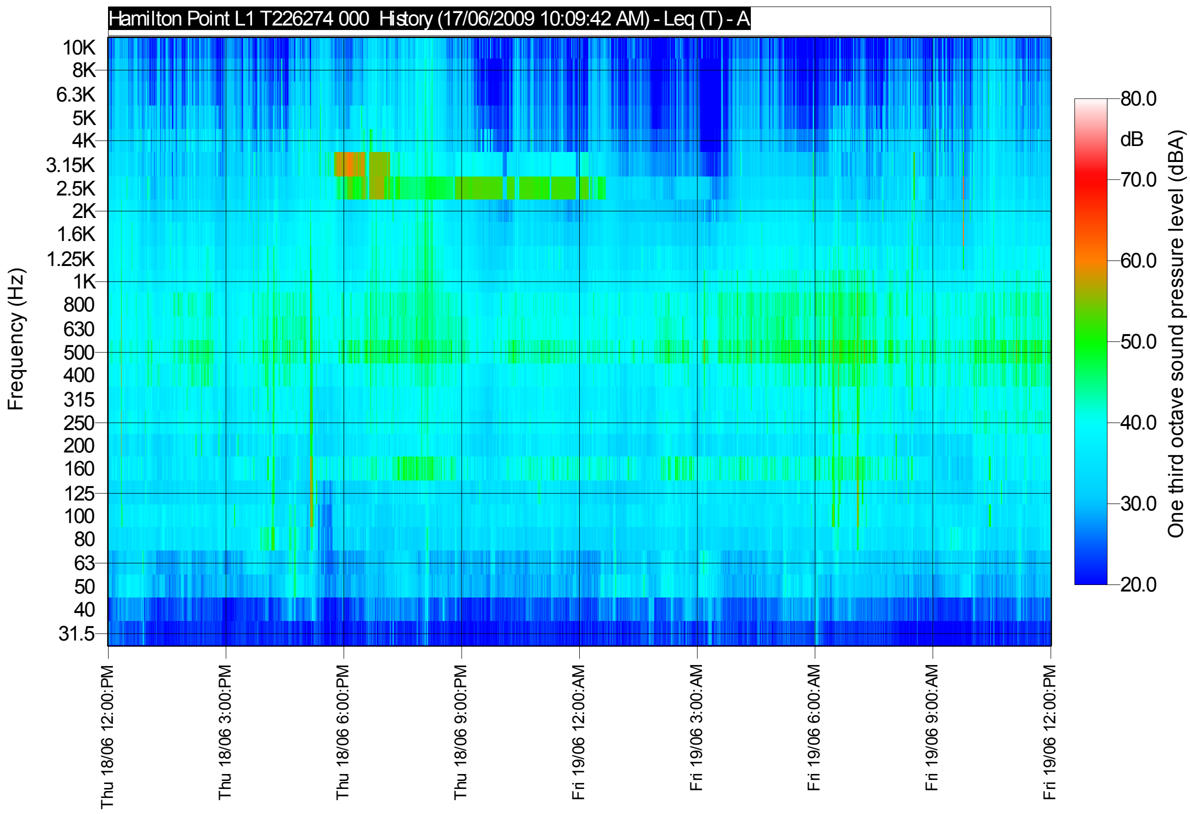
Summary - Minimum 1 Hour LAeq									
	Raw Data						Filtered Data		
Date	6am to 6pm	Fill	6pm to 10pm	Fill	10pm to 6am	Fill	6am to 6pm	6pm to 10pm	10pm to 6am
	Day	%	Evening	%	Night	%	Day	Evening	Night

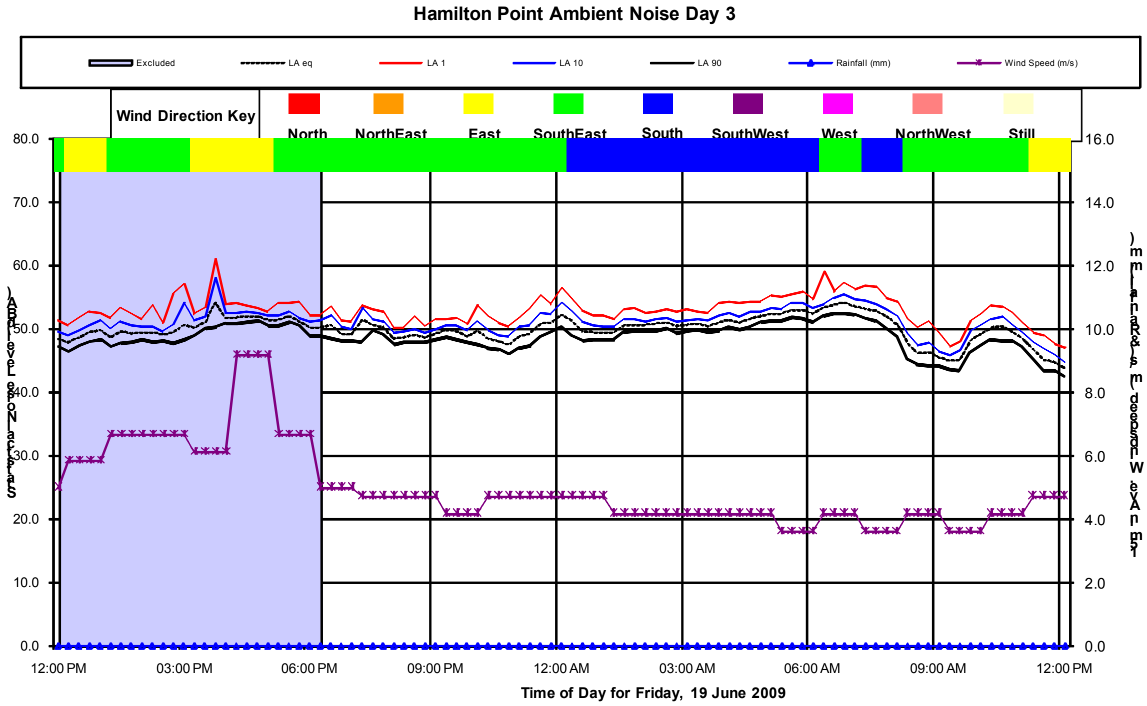
Summary - Minimum 1 Hour LAeq									
	Raw Data						Filtered Data		
Date	6am to 6pm	Fill	6pm to 10pm	Fill	10pm to 6am	Fill	6am to 6pm	6pm to 10pm	10pm to 6am
	Day	%	Evening	%	Night	%	Day	Evening	Night
Wed, 17 Jun 2009	40.7	50%	56.4	6%	49.8	97%			
Thu, 18 Jun 2009	46.3	92%	55.4	31%	48.1	97%			
Fri, 19 Jun 2009	50.0	35%	49.8	94%	48.4	100%			
Sat, 20 Jun 2009	42.8	100%	48.9	75%	50.4	88%			
Sun, 21 Jun 2009	46.1	83%	43.2	31%	43.0	34%			
Mon, 22 Jun 2009	42.5	92%	47.5	100%	46.1	100%			
Tue, 23 Jun 2009	44.8	100%	45.7	100%	46.1	100%			
Wed, 24 Jun 2009	41.9	52%							
Median Level	43.8		48.9		48.1				

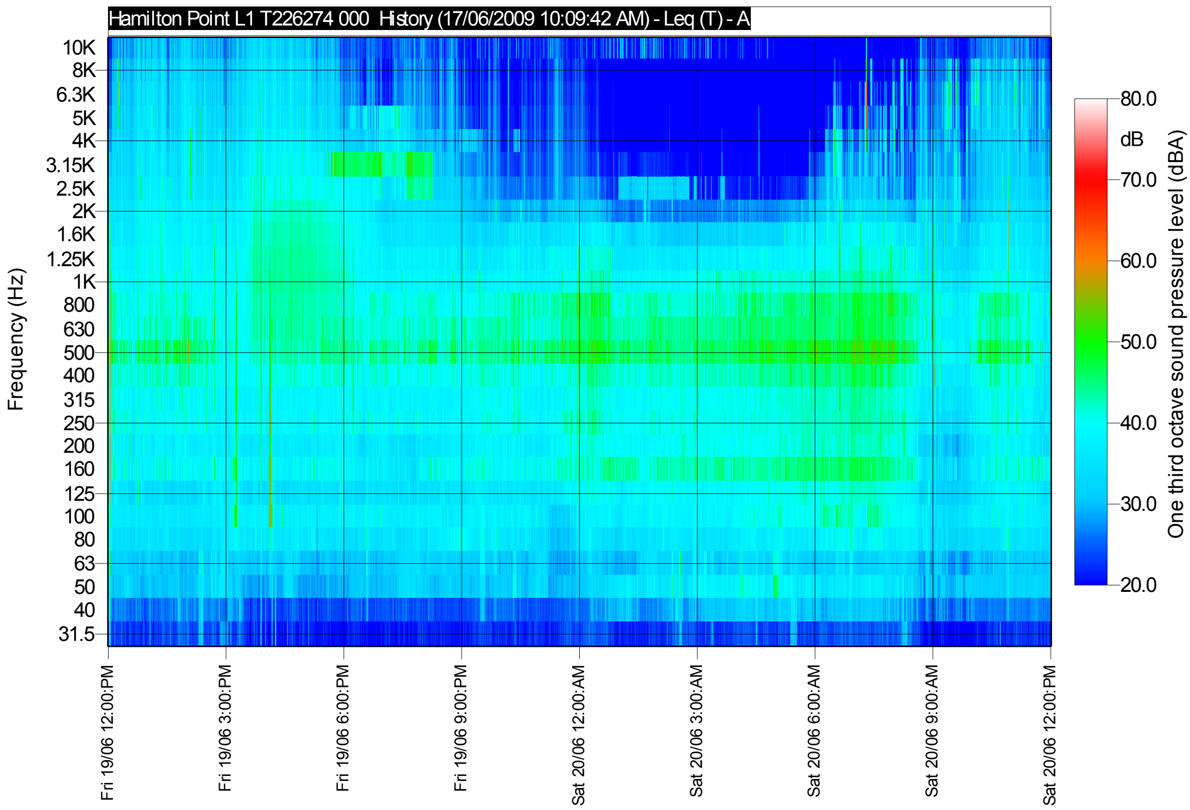

Hamilton Point Ambient Noise Day 1
Excluded
LA eq
LA 1
LA 10
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Excluded data with wind >
Evening
Wind
Rainfall
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM
Time of Day for Wednesday, 17 June 2009

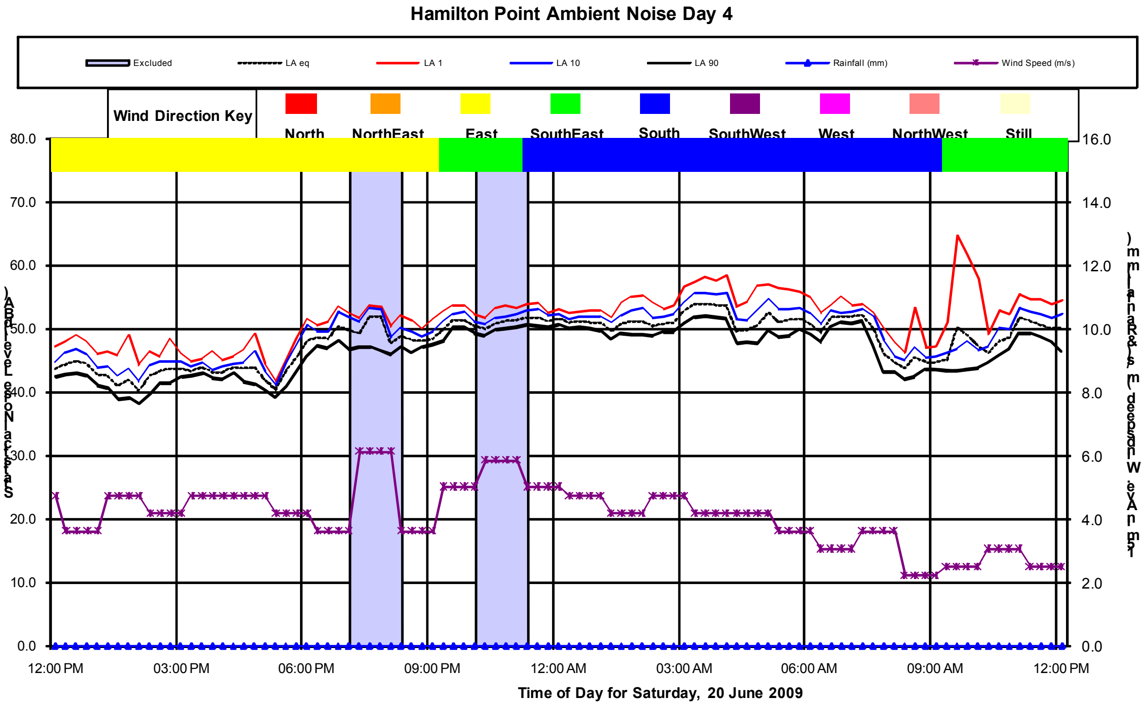

Hamilton Point L1 T226274 000 History (17/06/2009 10:09:42 AM) - Leq (T) - A
Insect noise in 2.5 kHz & 3.15 kHz
Industrial noise 50 Hz to 1.6 kHz
Frequency (Hz)
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
80.0
dB
70.0
60.0
50.0
40.0
30.0
20.0
One third octave sound pressure level (dBA)
Wed 17/06 12:00:PM
Wed 17/06 3:00:PM
Wed 17/06 6:00:PM
Wed 17/06 9:00:PM
Thu 18/06 12:00:AM
Thu 18/06 3:00:AM
Thu 18/06 6:00:AM
Thu 18/06 9:00:AM
Thu 18/06 12:00:PM

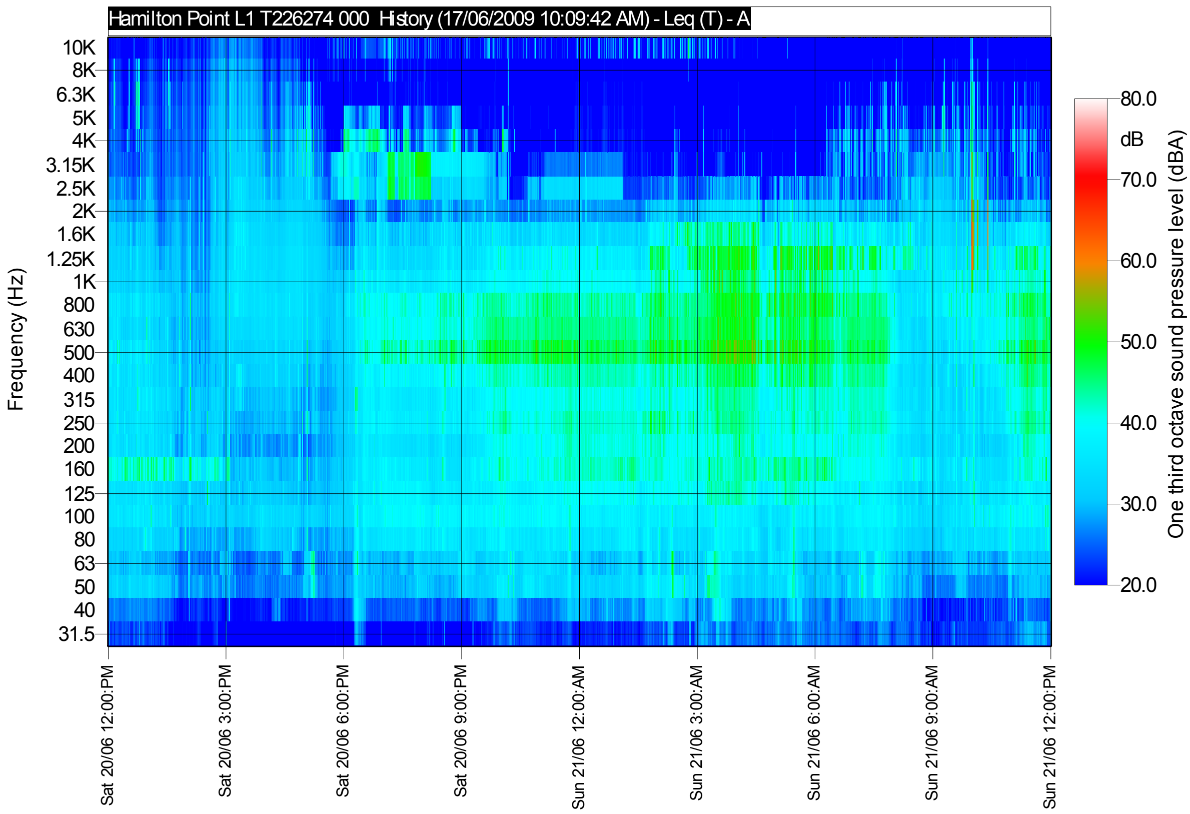

Hamilton Point Ambient Noise Day 2
Excluded
LA eq
LA 1
LA 10
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
Time of Day for Thursday, 18 June 2009

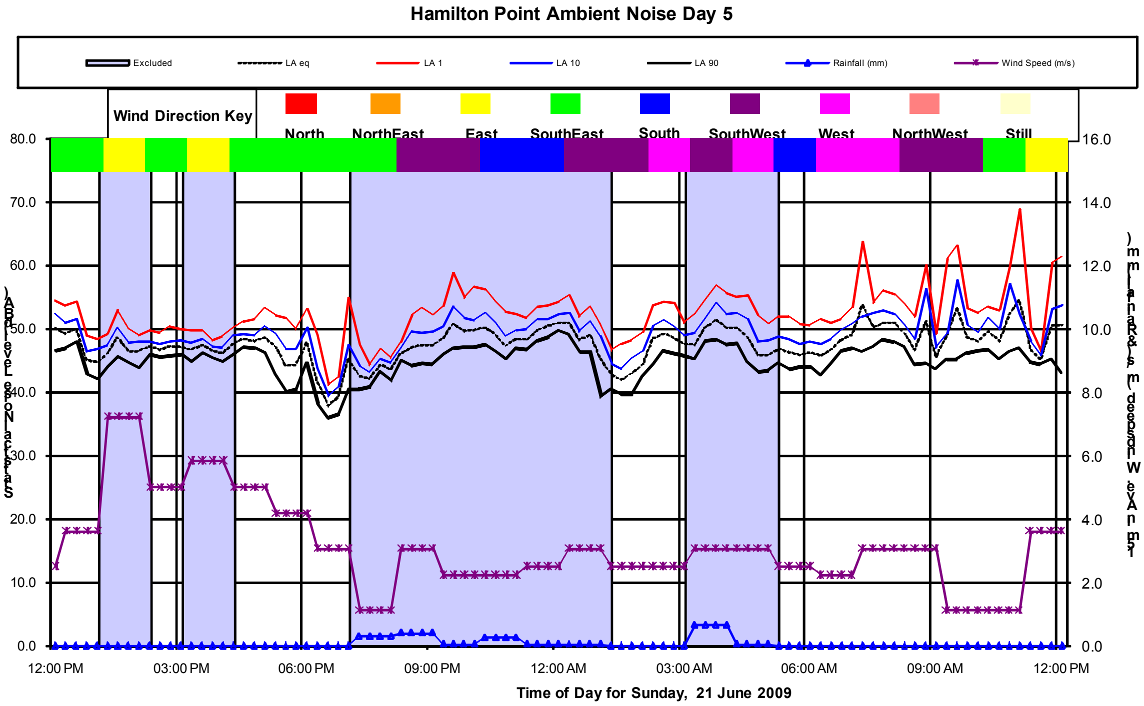

Hamilton Point L1 T226274 000 History (17/06/2009 10:09:42 AM) - Leq (T) - A
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
Frequency (Hz)
80.0
dB
70.0
60.0
50.0
40.0
30.0
20.0
One third octave sound pressure level (dBA)
Thu 18/06 12:00:PM
Thu 18/06 3:00:PM
Thu 18/06 6:00:PM
Thu 18/06 9:00:PM
Fri 19/06 12:00:AM
Fri 19/06 3:00:AM
Fri 19/06 6:00:AM
Fri 19/06 9:00:AM
Fri 19/06 12:00:PM

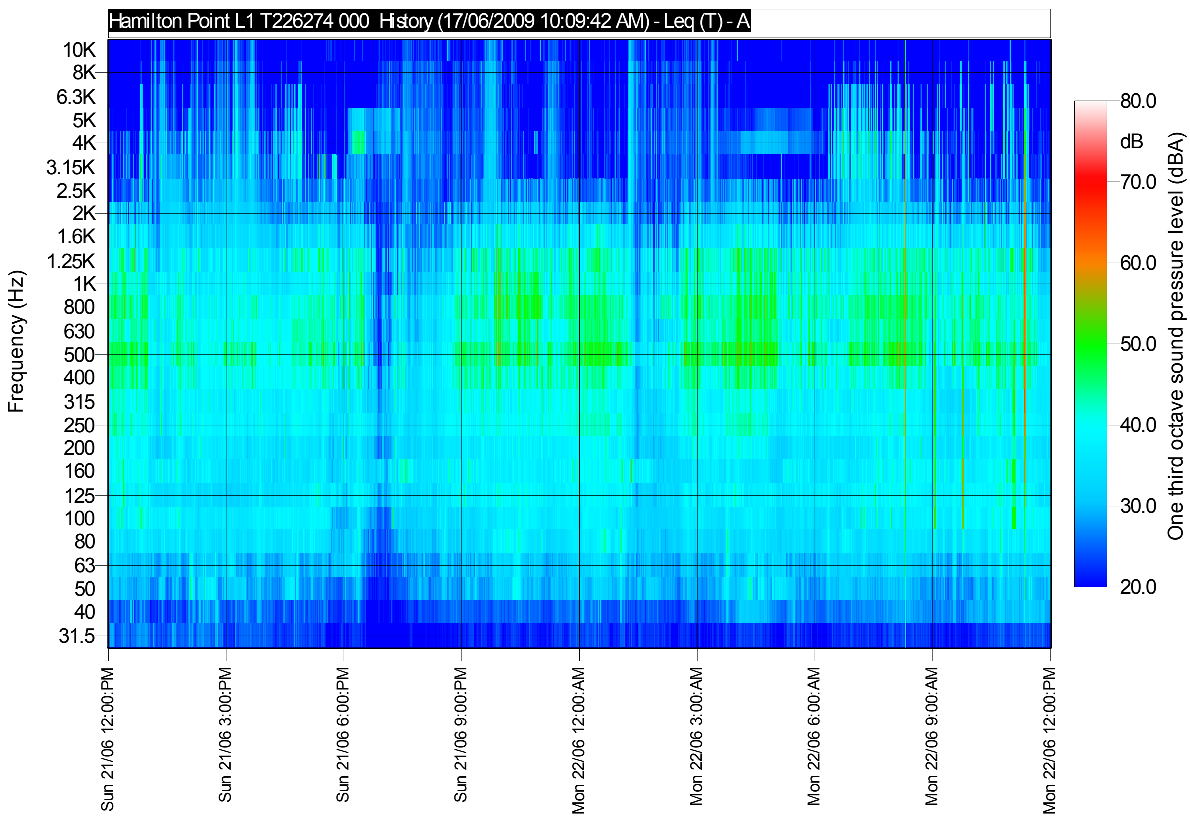

Hamilton Point Ambient Noise Day 3
Excluded
LA eq
LA 1
LA 10
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
Time of Day for Friday, 19 June 2009

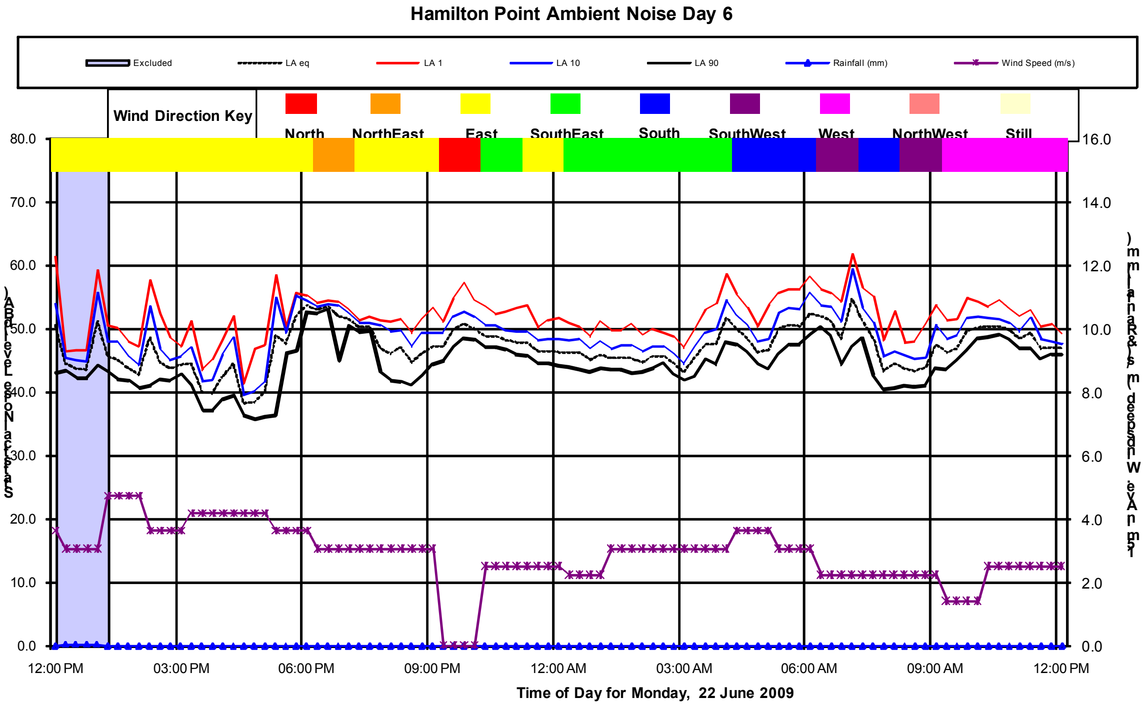

Hamilton Point L1 T226274 000 History (17/06/2009 10:09:42 AM) - Leq (T) - A
Frequency (Hz)
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
80.0
dB
70.0
60.0
50.0
40.0
30.0
20.0
One third octave sound pressure level (dBA)
Fri 19/06 12:00:PM
Fri 19/06 3:00:PM
Fri 19/06 6:00:PM
Fri 19/06 9:00:PM
Sat 20/06 12:00:AM
Sat 20/06 3:00:AM
Sat 20/06 6:00:AM
Sat 20/06 9:00:AM
Sat 20/06 12:00:PM

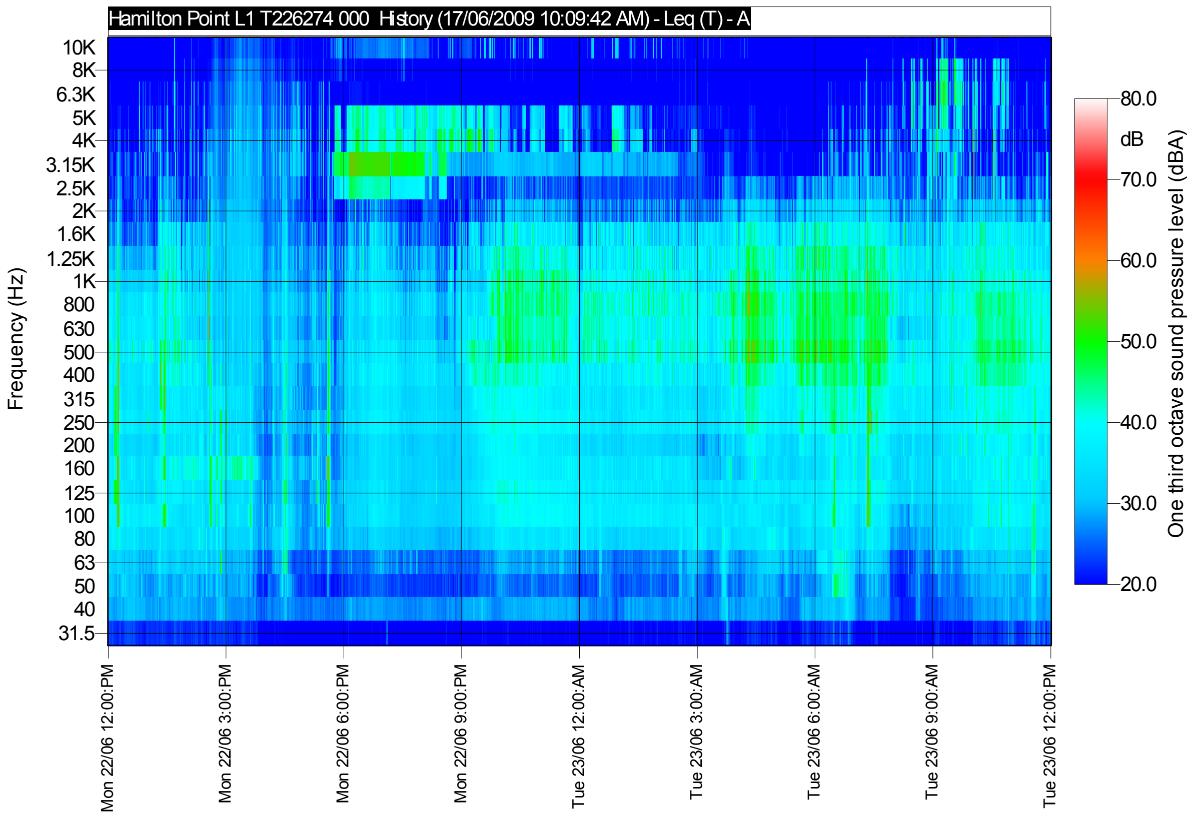

Hamilton Point Ambient Noise Day 4
Excluded
LA eq
LA 1
LA 10
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
Time of Day for Saturday, 20 June 2009


Hamilton Point L1 T226274 000 History (17/06/2009 10:09:42 AM) - Leq (T) - A
Frequency (Hz)
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
80.0
dB
70.0
60.0
50.0
40.0
30.0
20.0
One third octave sound pressure level (dBA)
Sat 20/06 12:00:PM
Sat 20/06 3:00:PM
Sat 20/06 6:00:PM
Sat 20/06 9:00:PM
Sun 21/06 12:00:AM
Sun 21/06 3:00:AM
Sun 21/06 6:00:AM
Sun 21/06 9:00:AM
Sun 21/06 12:00:PM

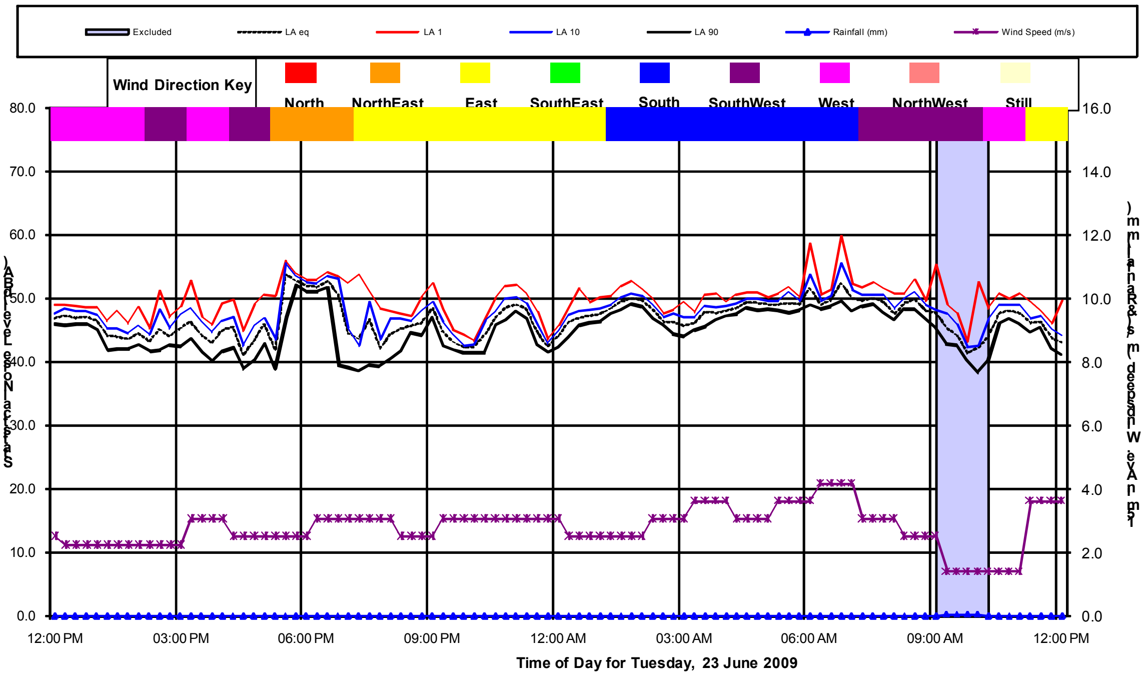

Hamilton Point Ambient Noise Day 5
Excluded
LA eq
LA 1
LA 10
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Time of Day for Sunday, 21 June 2009

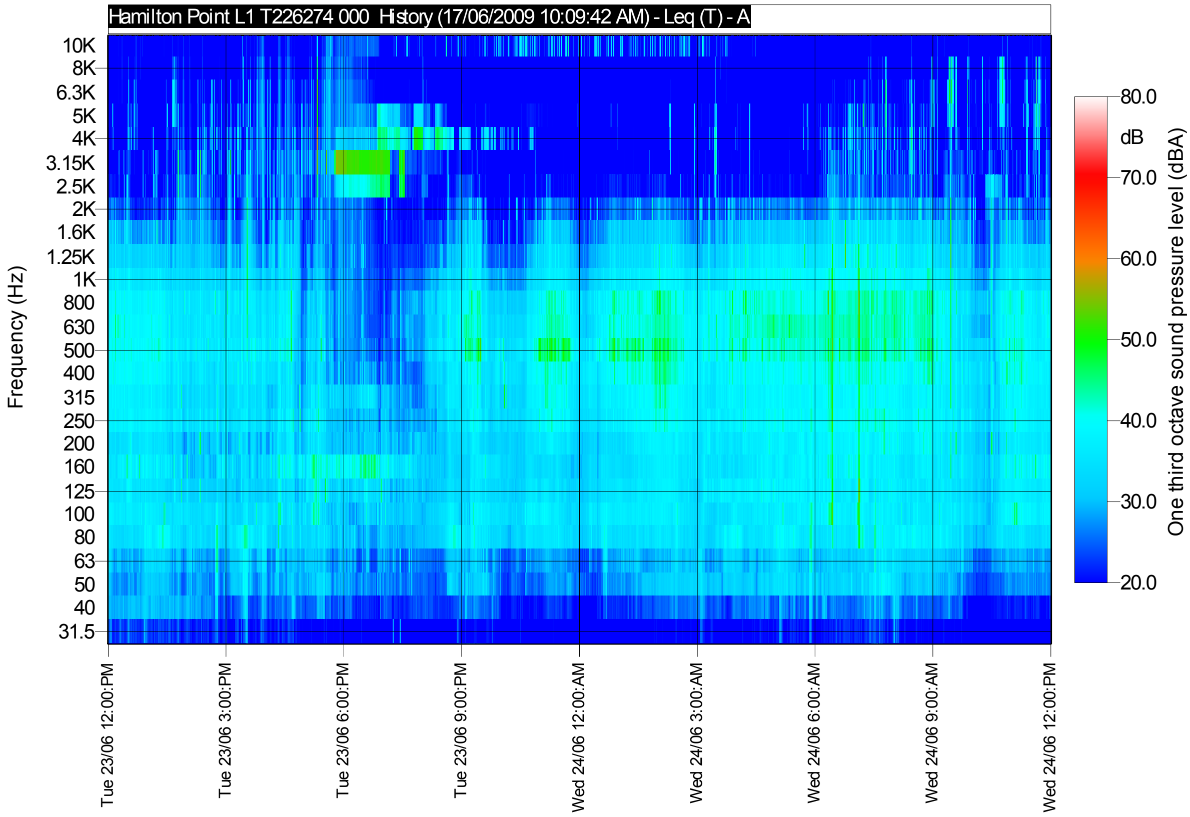

Hamilton Point L1 T226274 000 History (17/06/2009 10:09:42 AM) - Leq (T) - A
Frequency (Hz)
One third octave sound pressure level (dBA)
dB


Hamilton Point Ambient Noise Day 6
Excluded
LA eq
LA 1
LA 10
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM
Time of Day for Monday, 22 June 2009


Hamilton Point L1 T226274 000 History (17/06/2009 10:09:42 AM) - Leq (T) - A
Frequency (Hz)
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
80.0
dB
70.0
60.0
50.0
40.0
30.0
20.0
One third octave sound pressure level (dBA)
Mon 22/06 12:00:PM
Mon 22/06 3:00:PM
Mon 22/06 6:00:PM
Mon 22/06 9:00:PM
Tue 23/06 12:00:AM
Tue 23/06 3:00:AM
Tue 23/06 6:00:AM
Tue 23/06 9:00:AM
Tue 23/06 12:00:PM

Hamilton Point Ambient Noise Day 7





Appendix C – Site 2 ambient noise records

Coordinates: 23.80830°S,151.24512E — Site description: Picnic Island

Instrument: CESVA310 + C130 mic. — Serial No: T226531 (Logger 2)

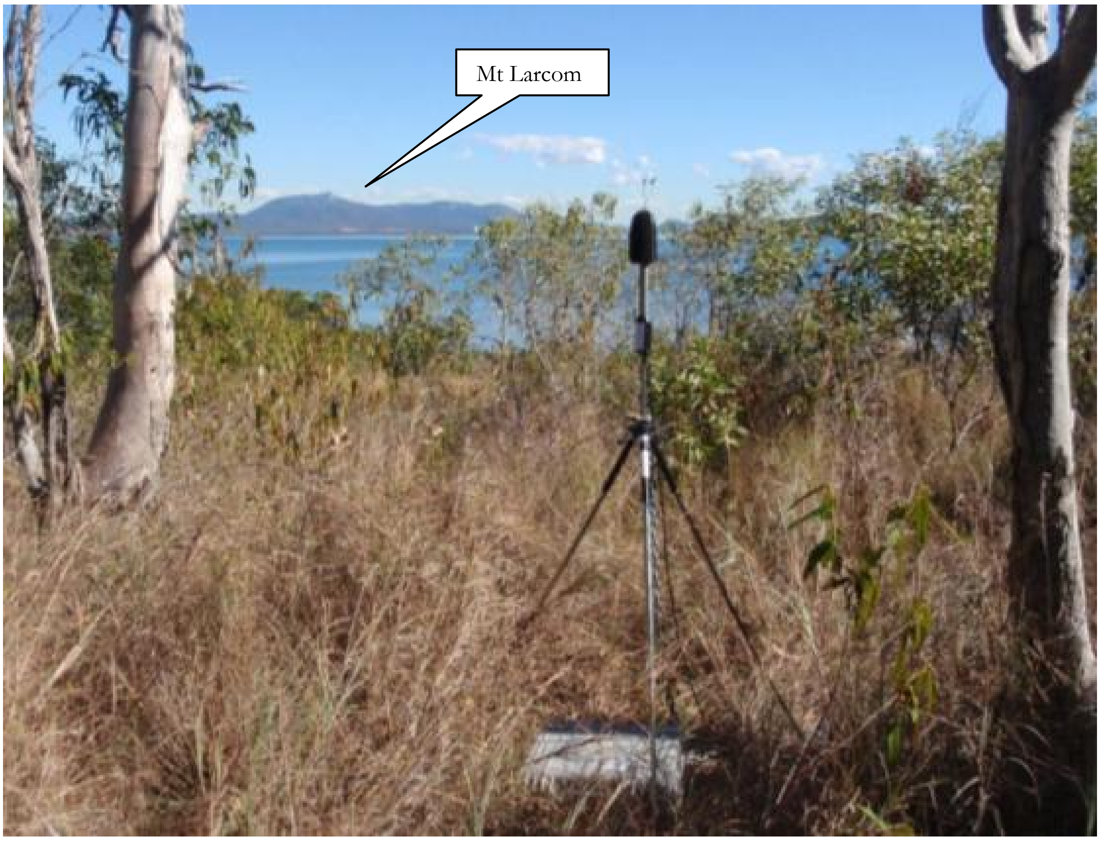
Calibrator: RION NC-73 — Serial No: 10486582

Reference weather station: Gladstone BOM Station 39123

Logging period: Wednesday, 17 June 2009 to Wednesday, 24 June 2009

Comments:

- Bureau of Meteorology radar station weather records from 75m above sea level substantially over-estimate the wind-speed at the microphone level (approximately 4m above high tide level).
- Evening insect noise is evidenced by 2.5 kHz, 3.15 kHz, 8 kHz and 10 kHz banding in the spectral records. This is significant to overall levels in the early evening (i.e. typically 6pm to 9pm) but not later at night.
- Industrial noise in bands between 250 Hz and 1.6 kHz dominates when breezes from southerly around to westerly enhance the propagation of existing industrial noise sources on the mainland (Fisherman's Landing and Gladstone wharves and refineries) towards this monitoring location. This usually occurs at night.



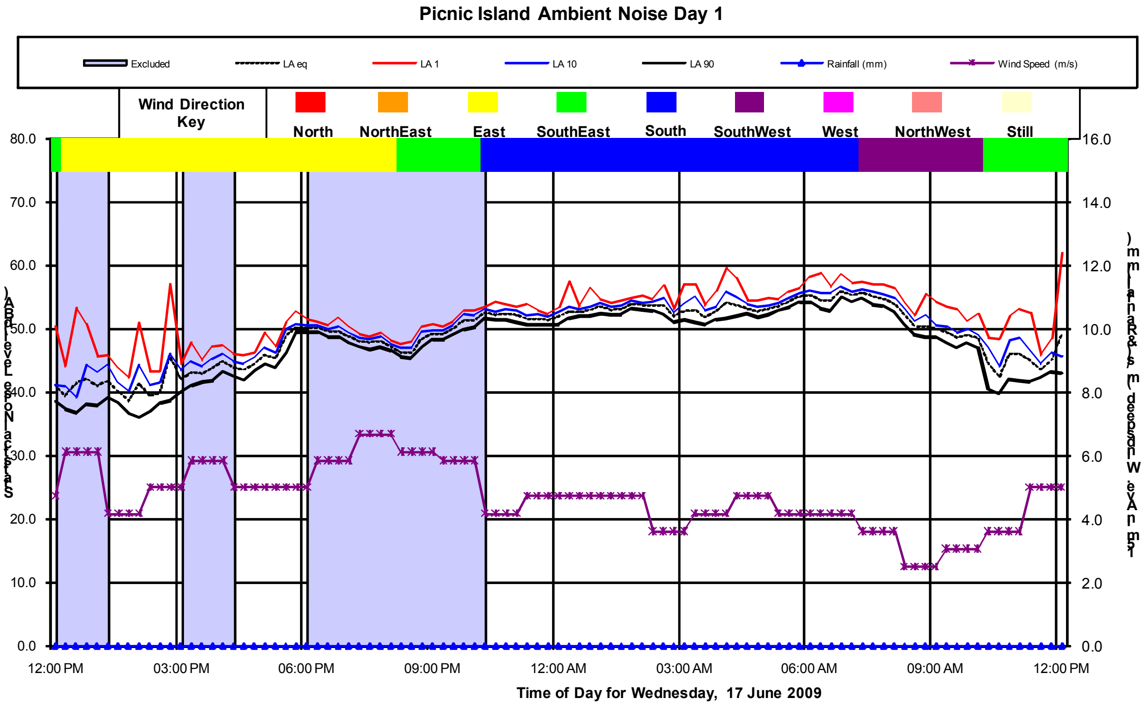

Witt Is. dwelling
Noise Monitoring
Site 2- Picnic Is.

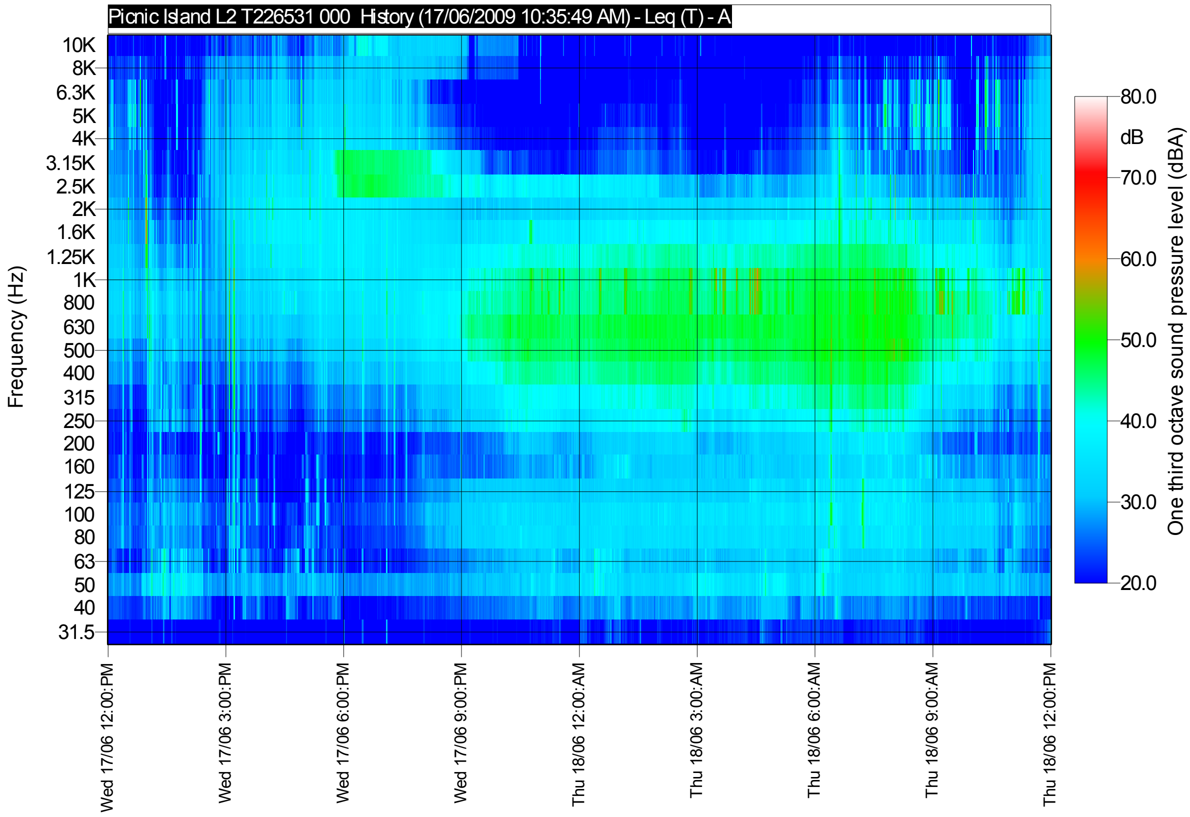

Witt Is. dwelling

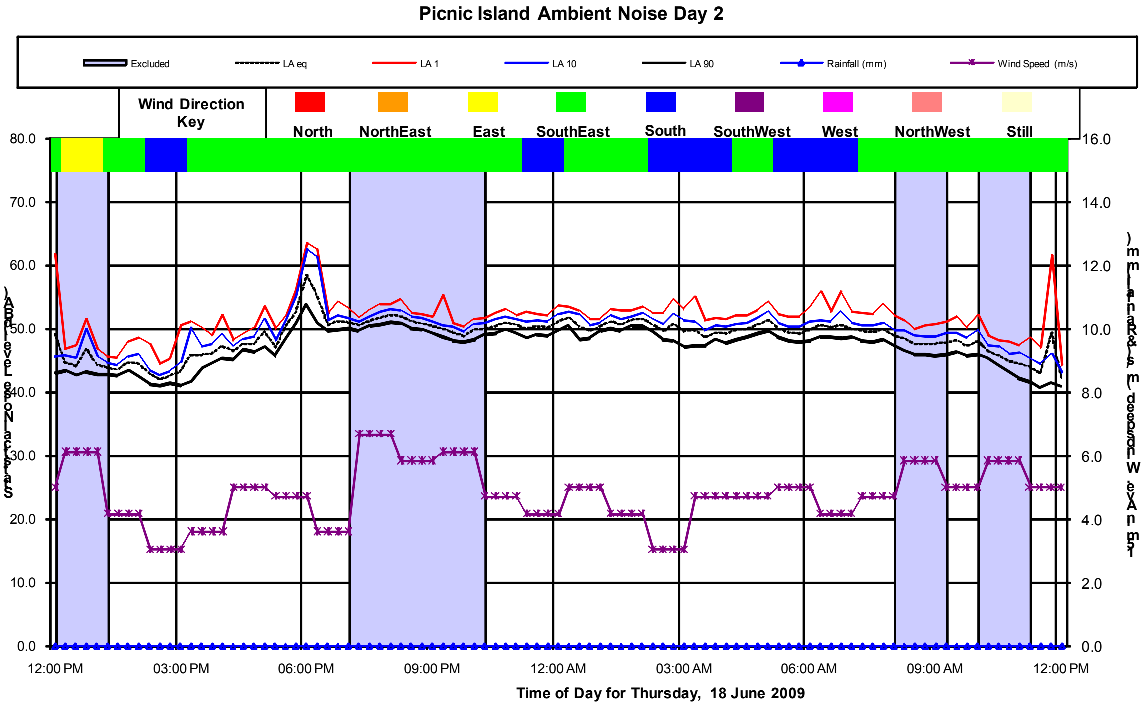
Summary - Rating LA90									
	Raw Data						Filtered Data		
Date	6am to 6pm	Fill	6pm to 10pm	Fill	10pm to 6am	Fill	6am to 6pm	6pm to 10pm	10pm to 6am
	Day	%	Evening	%	Night	%	Day	Evening	Night
Wed, 17 Jun 2009	37.1	46%	49.5	6%	50.7	97%			
Thu, 18 Jun 2009	41.4	92%	49.8	31%	47.8	97%			
Fri, 19 Jun 2009	41.2	35%	46.3	94%	44.4	100%			
Sat, 20 Jun 2009	38.2	100%	43.4	75%	45.2	88%			
Sun, 21 Jun 2009	40.0	83%	39.7	31%	46.0	34%			
Mon, 22 Jun 2009	35.9	92%	39.2	100%	41.8	100%			
Tue, 23 Jun 2009	38.5	100%	38.1	100%	42.9	100%			
Wed, 24 Jun 2009	36.7	54%							
Median RBL	38.3		43.4		45.2				

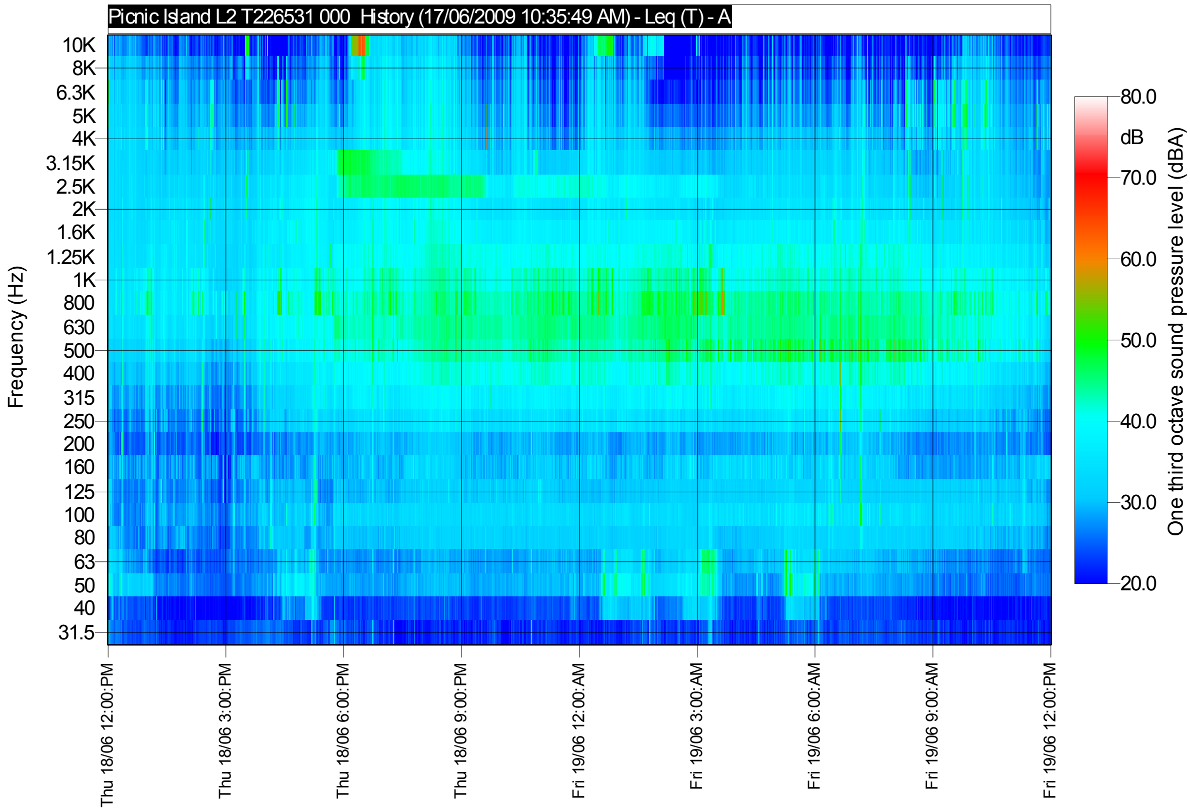
Summary - Minimum 1 Hour LAeq									
	Raw Data						Filtered Data		
Date	6am to 6pm	Fill	6pm to 10pm	Fill	10pm to 6am	Fill	6am to 6pm	6pm to 10pm	10pm to 6am

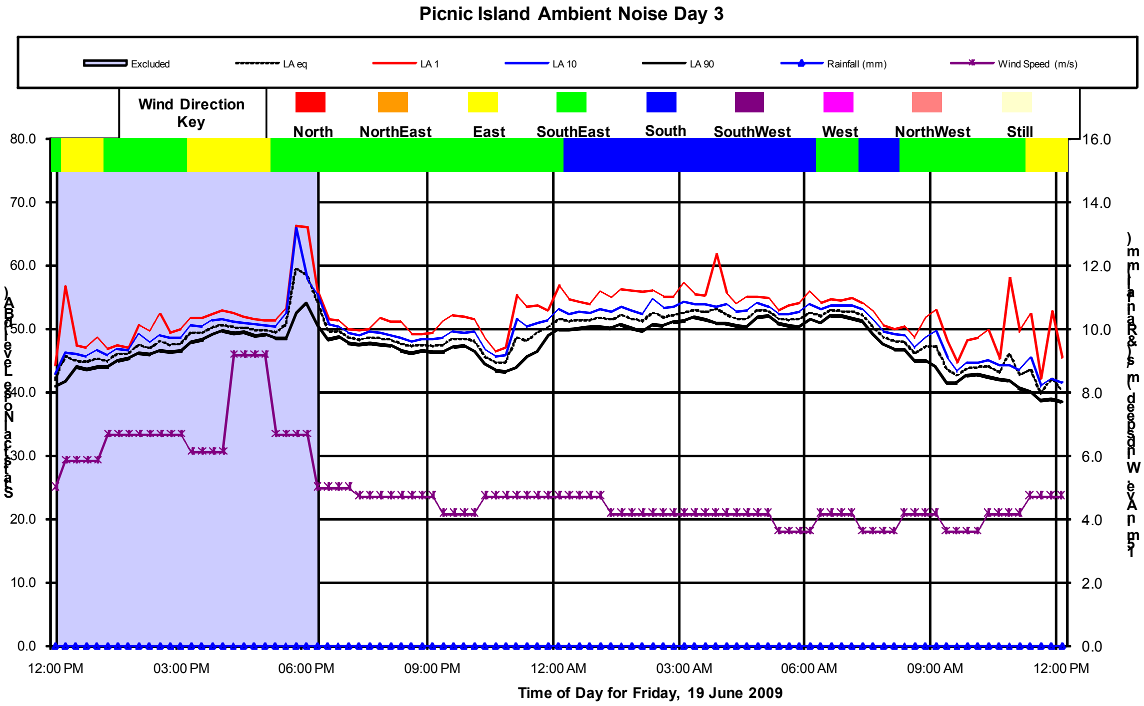
	Day	%	Evening	%	Night	%	Day	Evening	Night
Wed, 17 Jun 2009	41.2	46%	50.1	6%	52.2	97%			
Thu, 18 Jun 2009	44.0	92%	53.2	31%	50.5	97%			
Fri, 19 Jun 2009	47.5	35%	48.7	94%	46.0	100%			
Sat, 20 Jun 2009	40.7	100%	46.9	75%	47.7	88%			
Sun, 21 Jun 2009	43.2	83%	46.4	31%	47.7	34%			
Mon, 22 Jun 2009	39.7	92%	46.1	100%	45.1	100%			
Tue, 23 Jun 2009	44.8	100%	42.5	100%	42.8	100%			
Wed, 24 Jun 2009	40.0	54%							
Median Level	42.2		46.9		47.7				

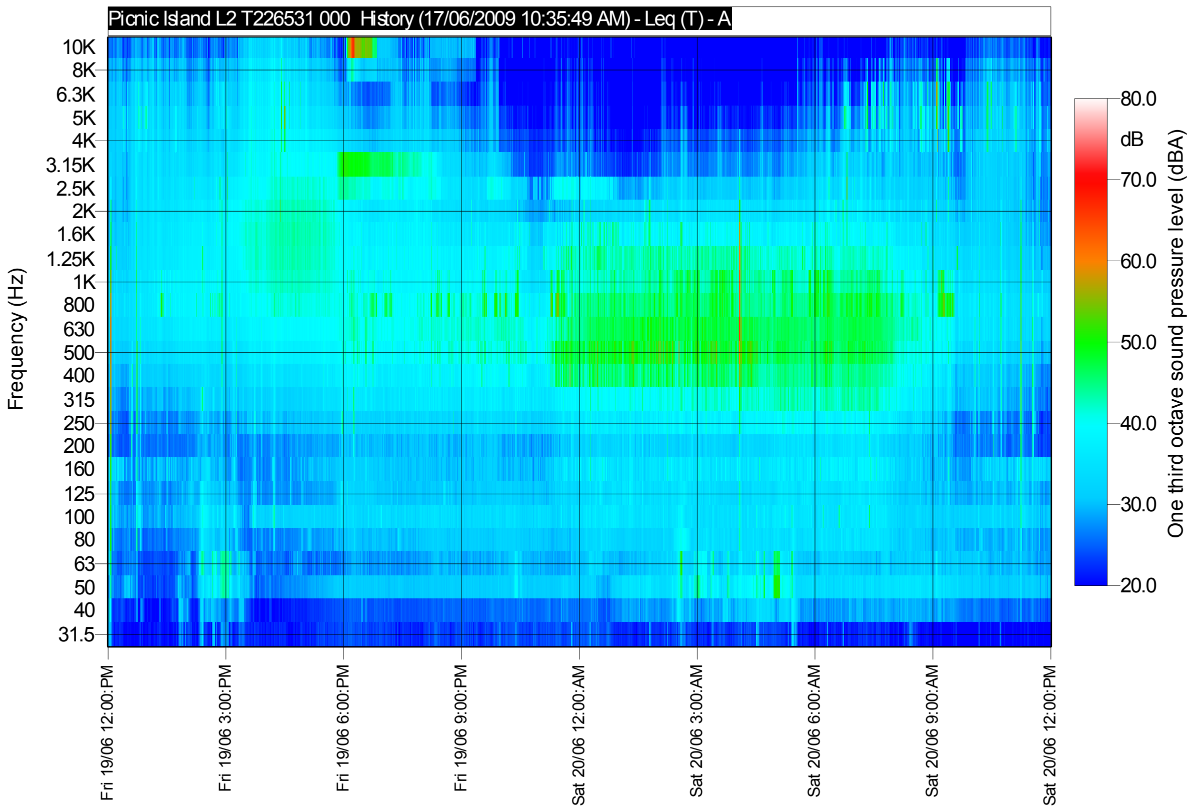

Picnic Island Ambient Noise Day 1
Excluded
LA eq
LA 1
LA 10
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM
Time of Day for Wednesday, 17 June 2009

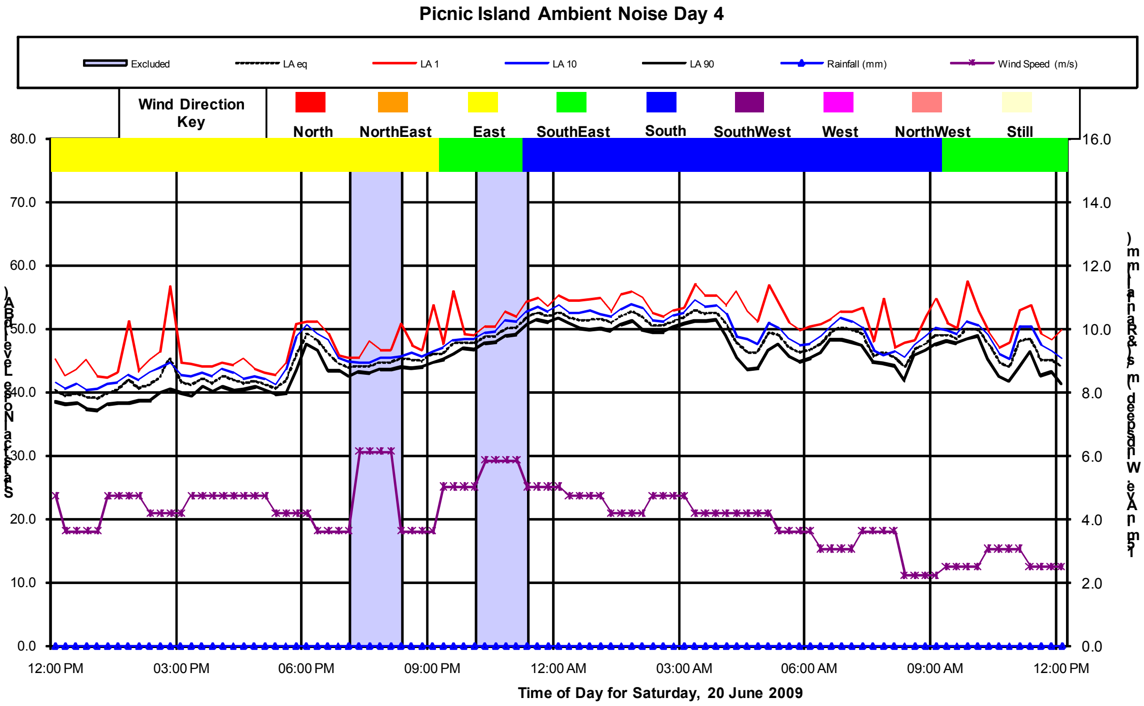

Picnic Island L2 T226531 000 History (17/06/2009 10:35:49 AM) - Leq (T) - A
Frequency (Hz)
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
80.0
dB
70.0
60.0
50.0
40.0
30.0
20.0
One third octave sound pressure level (dBA)
Wed 17/06 12:00:PM
Wed 17/06 3:00:PM
Wed 17/06 6:00:PM
Wed 17/06 9:00:PM
Thu 18/06 12:00:AM
Thu 18/06 3:00:AM
Thu 18/06 6:00:AM
Thu 18/06 9:00:AM
Thu 18/06 12:00:PM

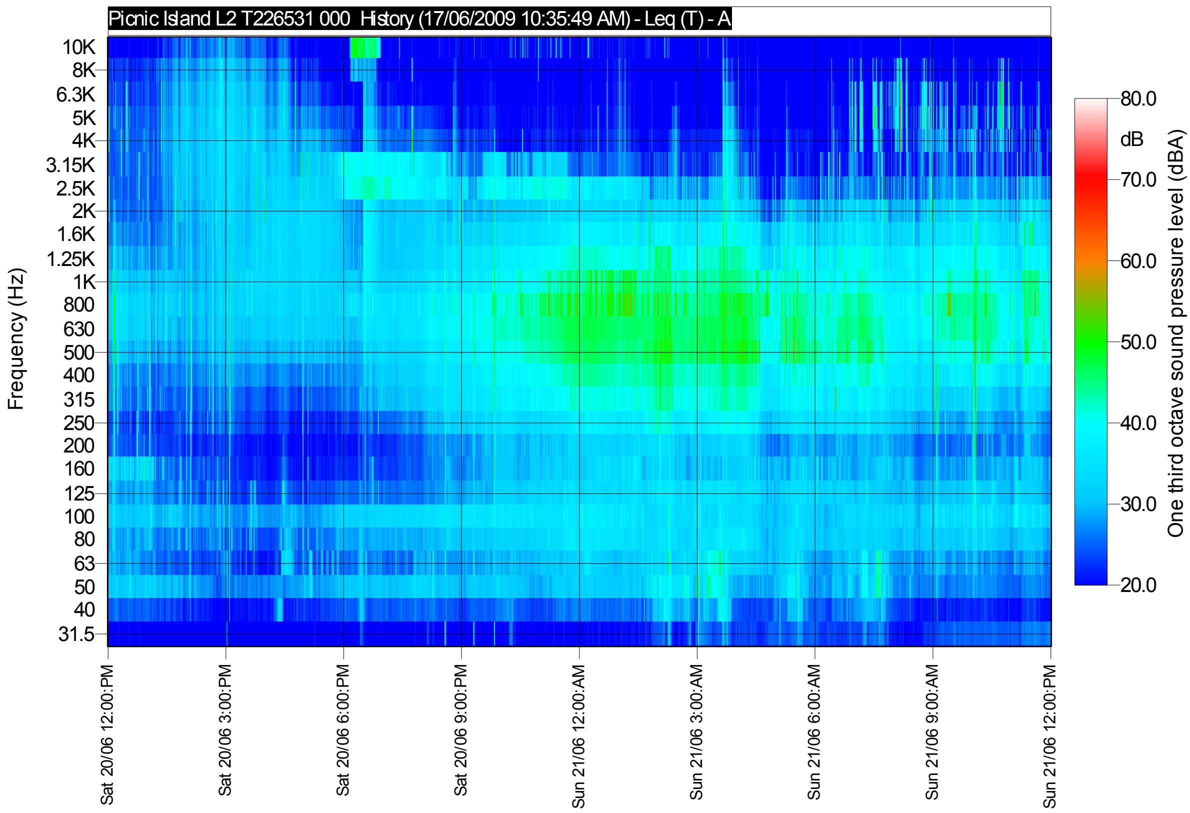

Picnic Island Ambient Noise Day 2
Excluded
LA eq
LA 1
LA 10
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM
Time of Day for Thursday, 18 June 2009


Picnic Island L2 T226531 000 History (17/06/2009 10:35:49 AM) - Leq (T) - A
Frequency (Hz)
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
80.0
dB
70.0
60.0
50.0
40.0
30.0
20.0
One third octave sound pressure level (dBA)
Thu 18/06 12:00:PM
Thu 18/06 3:00:PM
Thu 18/06 6:00:PM
Thu 18/06 9:00:PM
Fri 19/06 12:00:AM
Fri 19/06 3:00:AM
Fri 19/06 6:00:AM
Fri 19/06 9:00:AM
Fri 19/06 12:00:PM

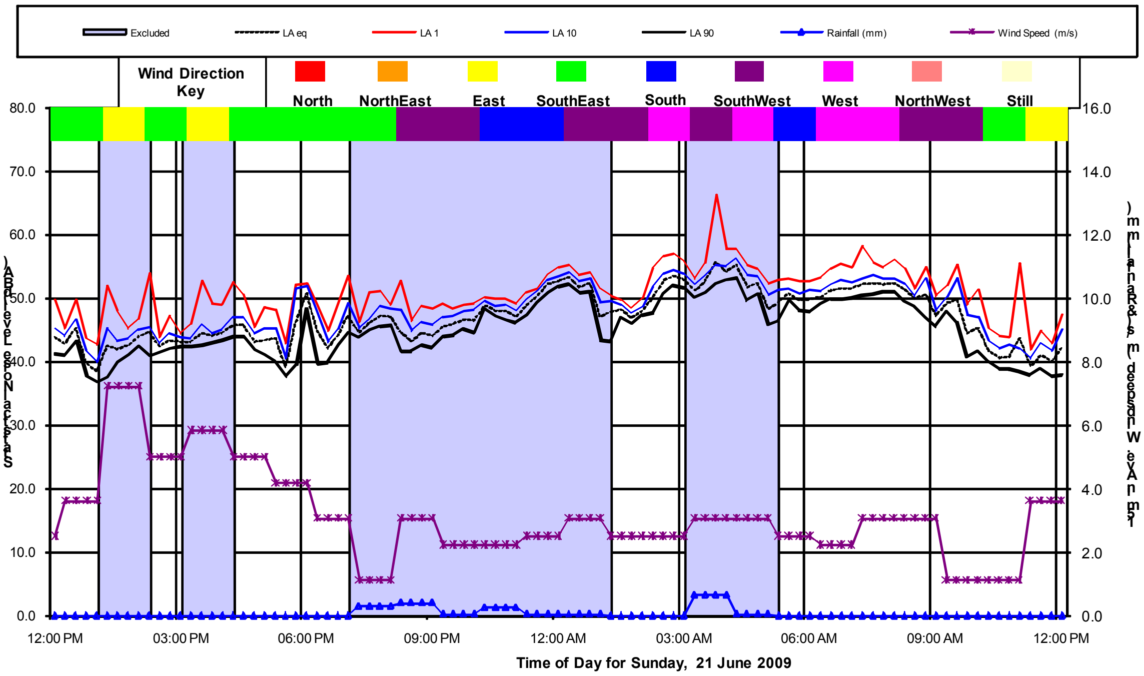

Picnic Island Ambient Noise Day 3
Excluded
LA eq
LA 1
LA 10
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Time of Day for Friday, 19 June 2009

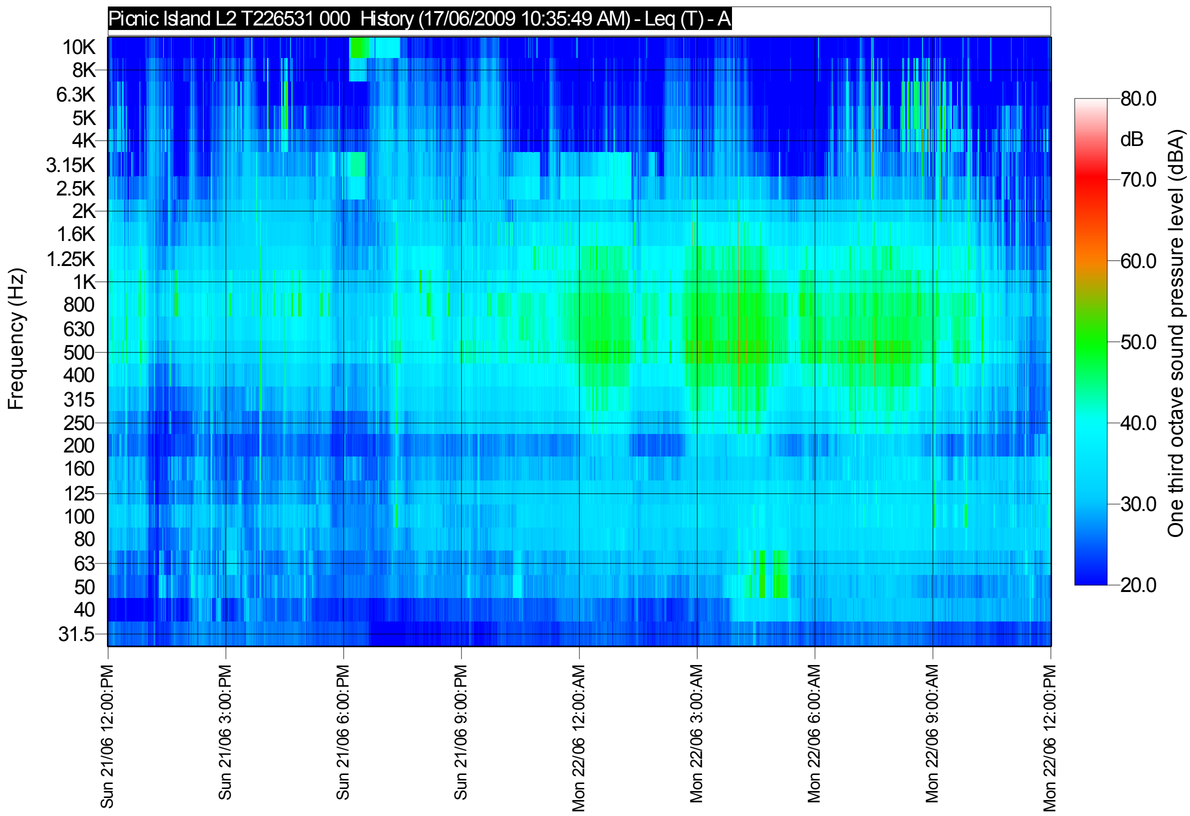

Picnic Island L2 T226531 000 History (17/06/2009 10:35:49 AM) - Leq (T) - A
Frequency (Hz)
One third octave sound pressure level (dBA)
dB

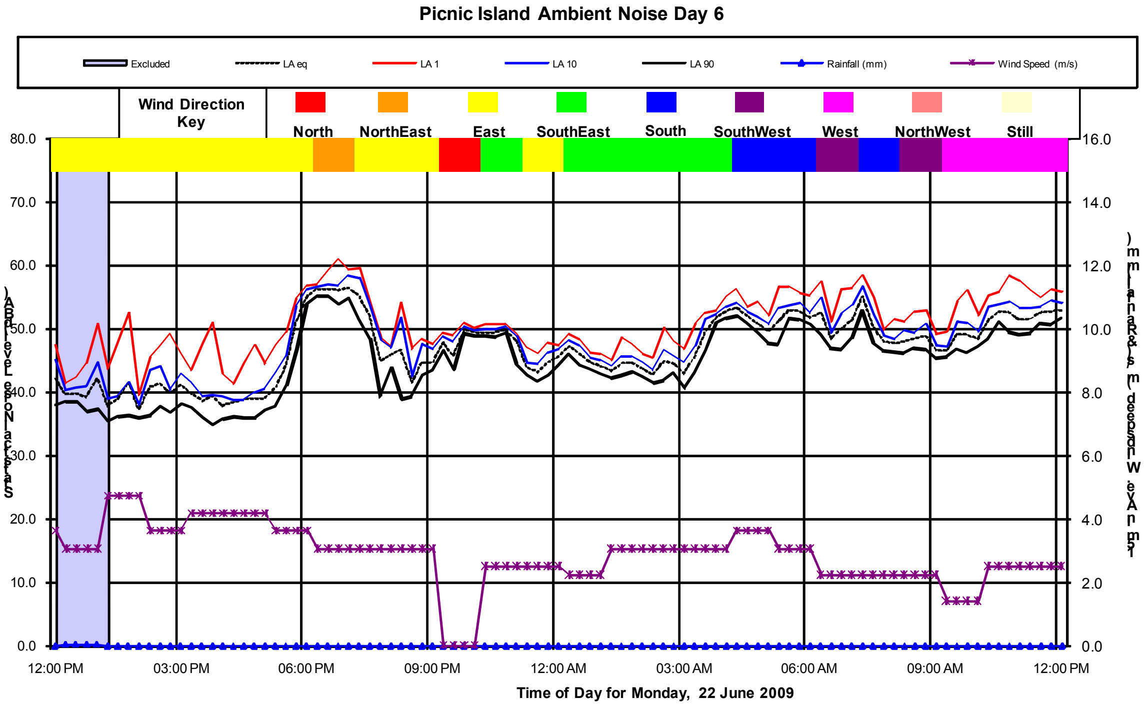

Picnic Island Ambient Noise Day 4
Excluded
LA eq
LA 1
LA 10
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM
Time of Day for Saturday, 20 June 2009

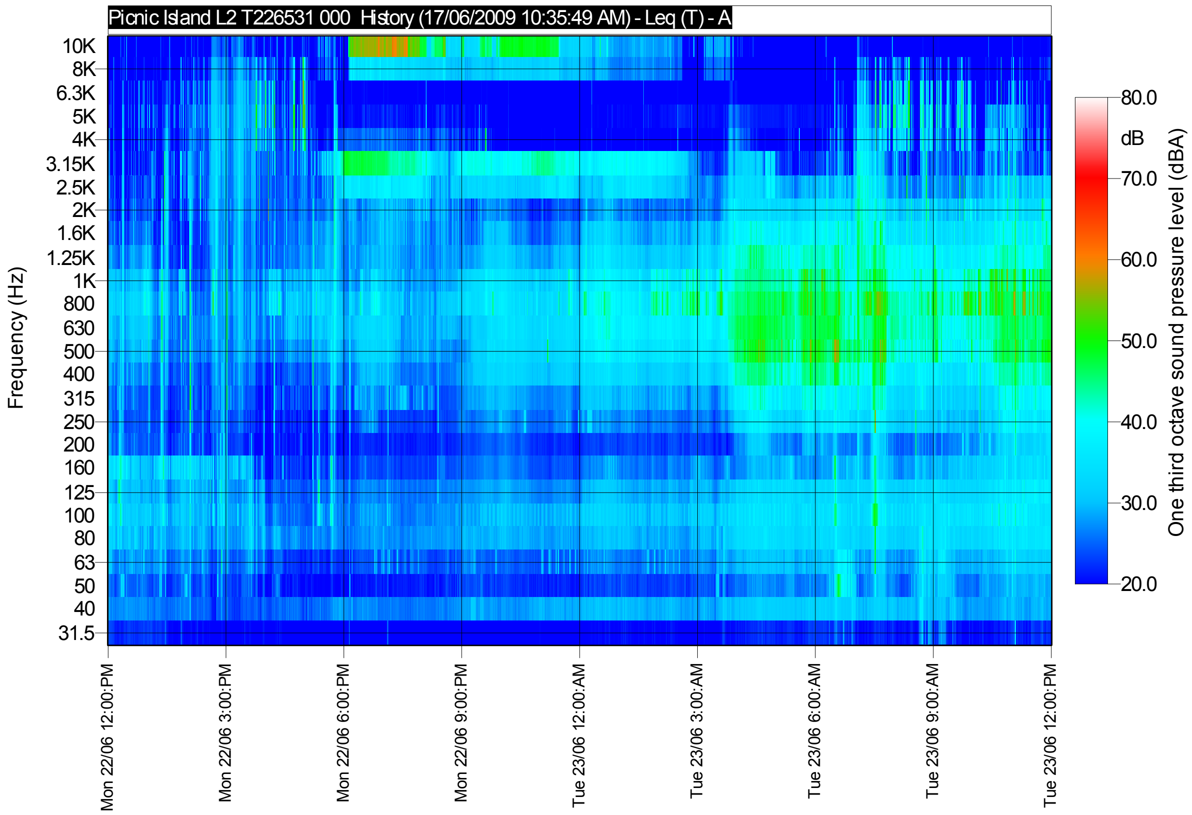

Picnic Island L2 T226531 000 History (17/06/2009 10:35:49 AM) - Leq (T) - A
Frequency (Hz)
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
80.0
dB
70.0
60.0
50.0
40.0
30.0
20.0
One third octave sound pressure level (dBA)
Sat 20/06 12:00:PM
Sat 20/06 3:00:PM
Sat 20/06 6:00:PM
Sat 20/06 9:00:PM
Sun 21/06 12:00:AM
Sun 21/06 3:00:AM
Sun 21/06 6:00:AM
Sun 21/06 9:00:AM
Sun 21/06 12:00:PM

Picnic Island Ambient Noise Day 5

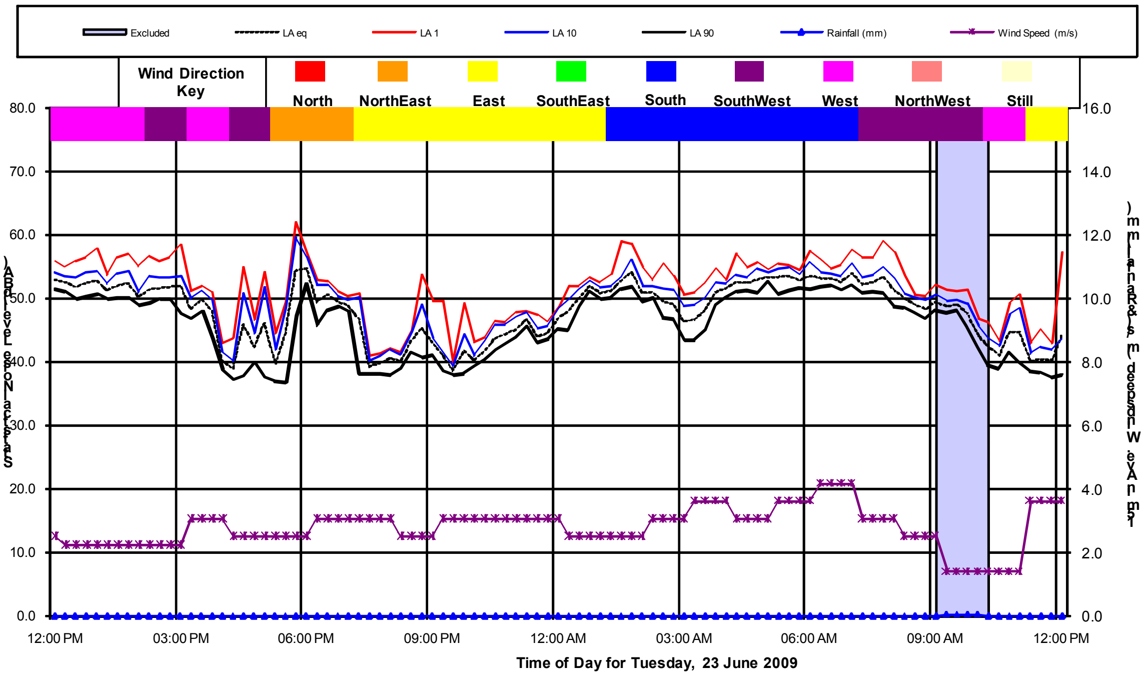


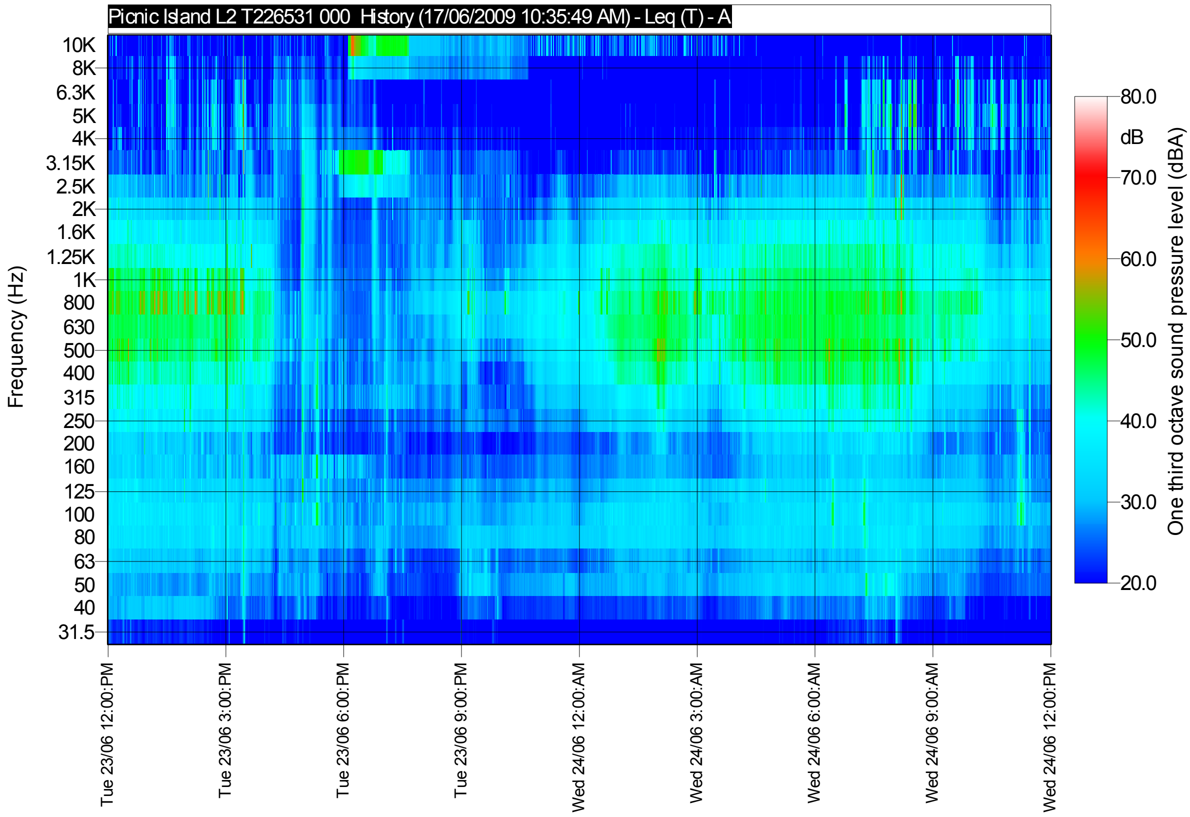



Picnic Island Ambient Noise Day 6
Excluded
LA eq
LA 1
LA 10
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM
Time of Day for Monday, 22 June 2009


Picnic Island L2 T226531 000 History (17/06/2009 10:35:49 AM) - Leq (T) - A
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
Frequency (Hz)
80.0
dB
70.0
60.0
50.0
40.0
30.0
20.0
One third octave sound pressure level (dBA)
Mon 22/06 12:00:PM
Mon 22/06 3:00:PM
Mon 22/06 6:00:PM
Mon 22/06 9:00:PM
Tue 23/06 12:00:AM
Tue 23/06 3:00:AM
Tue 23/06 6:00:AM
Tue 23/06 9:00:AM
Tue 23/06 12:00:PM

Picnic Island Ambient Noise Day 7





Appendix D – Site 3 ambient noise records

Coordinates: 23.81251°S,151.154408E

Site description: No. 2 Fishermans Road

Instrument: CESVA310 + C130 mic.

Serial No: T226545 (Logger 5)

Calibrator: Bruel & Kjaer Type 4231

Serial No: 2463922

Reference weather station:

Reinhardt MWS 5MV SN1013342

Logging period: Saturday, 12 April 2008 to Sunday, 20 April 2008

Comments:

- The noise logger and weather station were positioned approximately 30m north-east of the residential dwelling at 2 Fisherman's Road, Yarwun. This site is approximately 470m west of the Rio Tinto Yarwun Alumina Refinery conveyor, 1500m north of the Rio Tinto Yarwun Alumina Refinery, 900m east of the Transpacific Industries waste management and recycling facility and 2200mm south of the Cement Australia plant.
- Evening insect noise is evidenced by 3.15 kHz, 4 kHz, 8 kHz and 10 kHz banding in the spectral records. This is significant to overall levels in the early evening (i.e. typically 6pm to 9pm) but not later at night.
- Industrial noise is relatively steady resulting in little difference between day, evening and night Rating Background Levels

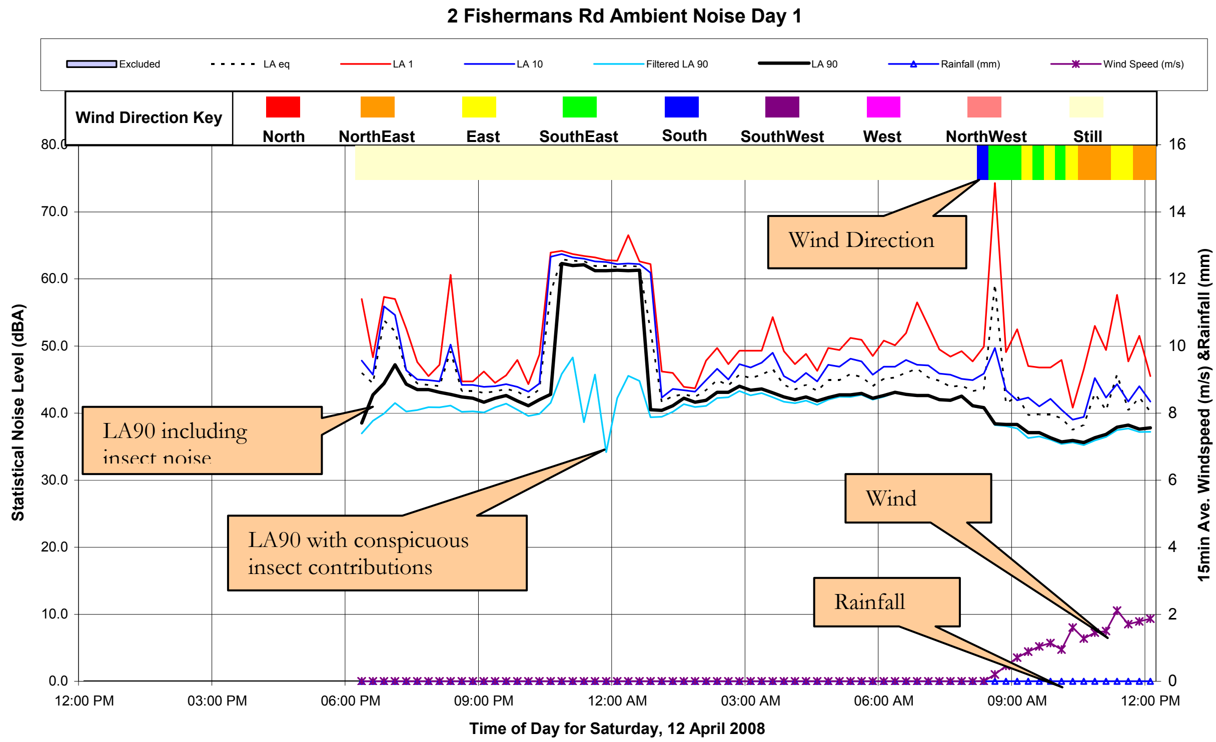
ABL Summary - LA90									
	Raw Data						Filtered Data (insects excluded)		
Date	**6am to 6pm** Day	**Fill** %	**6pm to 10pm** Evening	**Fill** %	**10pm to 6am** Night	**Fill** %	**6am to 6pm** Day	**6pm to 10pm** Evening	**10pm to 6am** Night
Sat, 12 Apr 2008	Nil	0%	41.7	94%	41.2	100%	Nil	39.3	39.4
Sun, 13 Apr 2008	35.7	100%	39.4	100%	41.0	100%	35.0	36.8	40.0
Mon, 14 Apr 2008	36.9	100%	39.4	100%	40.4	100%	36.2	37.2	39.5
Tue, 15 Apr 2008	40.2	100%	43.1	100%	41.8	100%	39.6	40.6	40.5
Wed, 16 Apr 2008	43.1	100%	42.0	100%	39.8	100%	42.7	39.4	38.8
Thu, 17 Apr 2008	41.3	100%	40.0	100%	39.1	100%	40.9	39.3	38.5
Fri, 18 Apr 2008	41.0	92%	43.5	100%	42.1	100%	40.8	41.3	40.7
Sat, 19 Apr 2008	39.8	98%	42.4	100%	41.6	100%	39.5	40.3	40.5

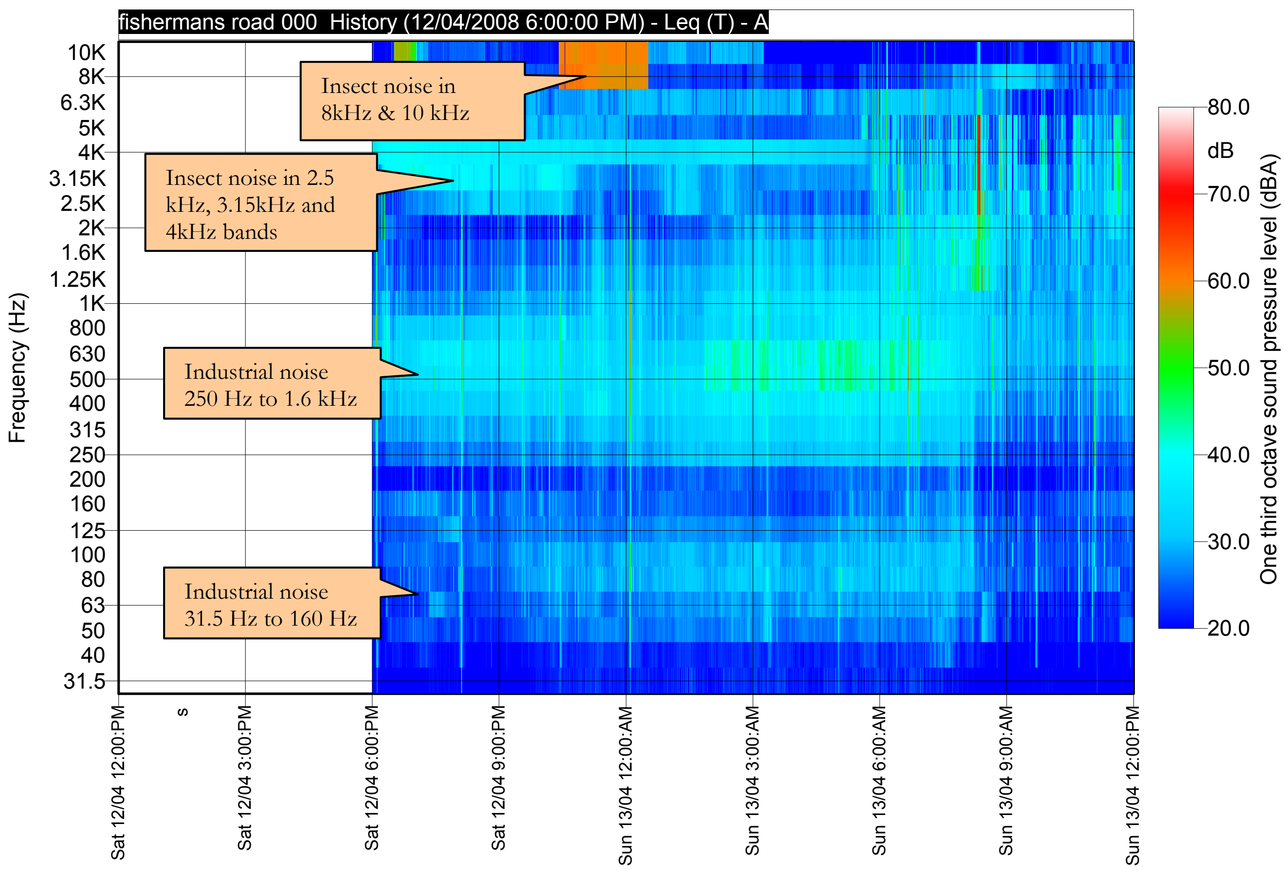
ABL Summary - LA90									
	Raw Data						Filtered Data (insects excluded)		
Date	6am to 6pm Day	Fill %	6pm to 10pm Evening	Fill %	10pm to 6am Night	Fill %	6am to 6pm Day	6pm to 10pm Evening	10pm to 6am Night
Sun, 20 Apr 2008	40.3	100%	44.1	100%	41.7	59%	40.0	40.0	40.1
RBL	40.3		42.0		41.2		39.8	39.4	40.0

Filters Exclude:
3.15 kHz 4 kHz
8 kHz 10 khz

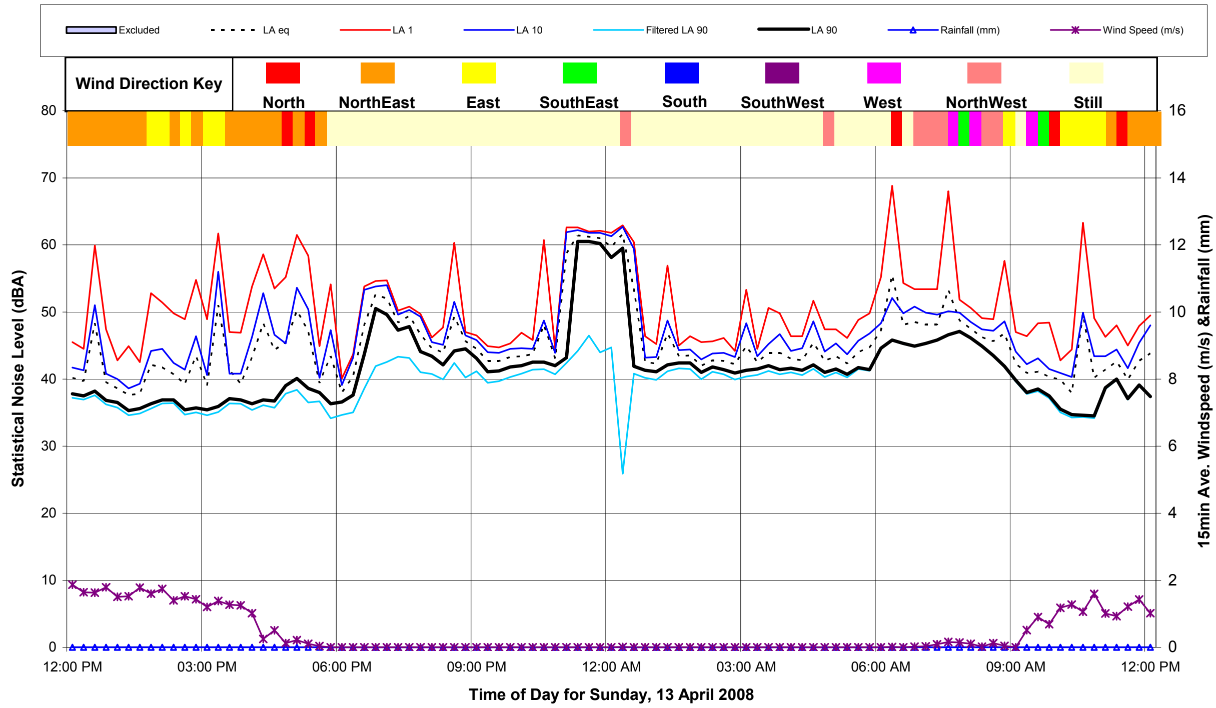
Summary - Minimum 1 Hour LAeq									
	Raw Data						Filtered Data		
Date	6am to 6pm Day	Fill %	6pm to 10pm Evening	Fill %	10pm to 6am Night	Fill %	6am to 6pm Day	6pm to 10pm Evening	10pm to 6am Night
Sat, 12 Apr 2008	46.0	2%	44.4	94%	45.0	100%			
Sun, 13 Apr 2008	40.3	100%	44.5	100%	43.8	100%			
Mon, 14 Apr 2008	41.5	100%	47.1	100%	43.1	100%			
Tue, 15 Apr 2008	45.4	100%	45.9	100%	43.8	100%			
Wed, 16 Apr 2008	47.1	100%	45.6	100%	42.4	100%			
Thu, 17 Apr 2008	47.2	100%	43.7	100%	40.2	100%			
Fri, 18 Apr 2008	45.3	92%	46.1	100%	43.8	100%			

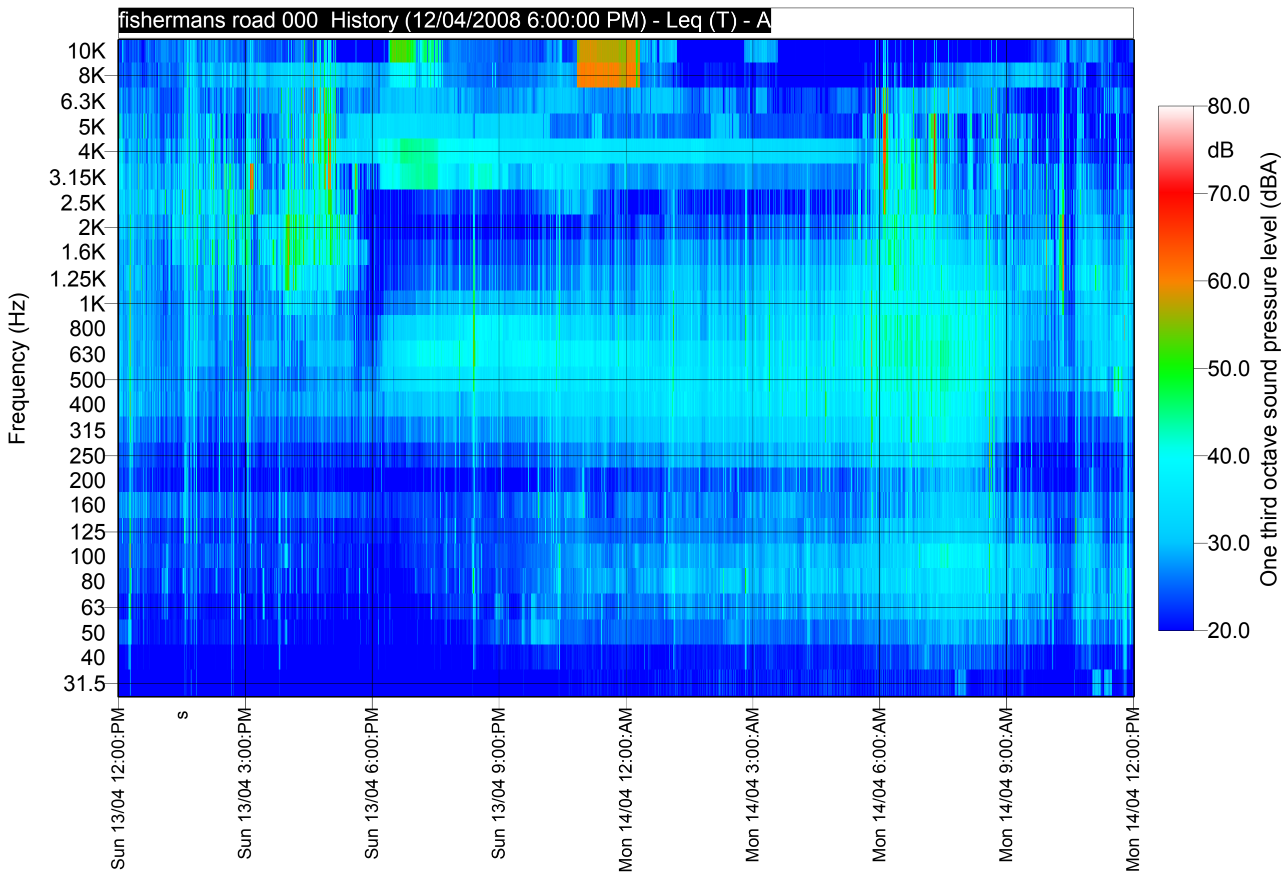
Summary - Minimum 1 Hour LAeq									
	Raw Data						Filtered Data		
Date	6am to 6pm Day	Fill %	6pm to 10pm Evening	Fill %	10pm to 6am Night	Fill %	6am to 6pm Day	6pm to 10pm Evening	10pm to 6am Night
Sat, 19 Apr 2008	43.3	98%	45.6	100%	44.1	100%			
Sun, 20 Apr 2008	44.0	100%	46.9	100%	44.5	56%			
Median Level	45.3		45.6		43.8				

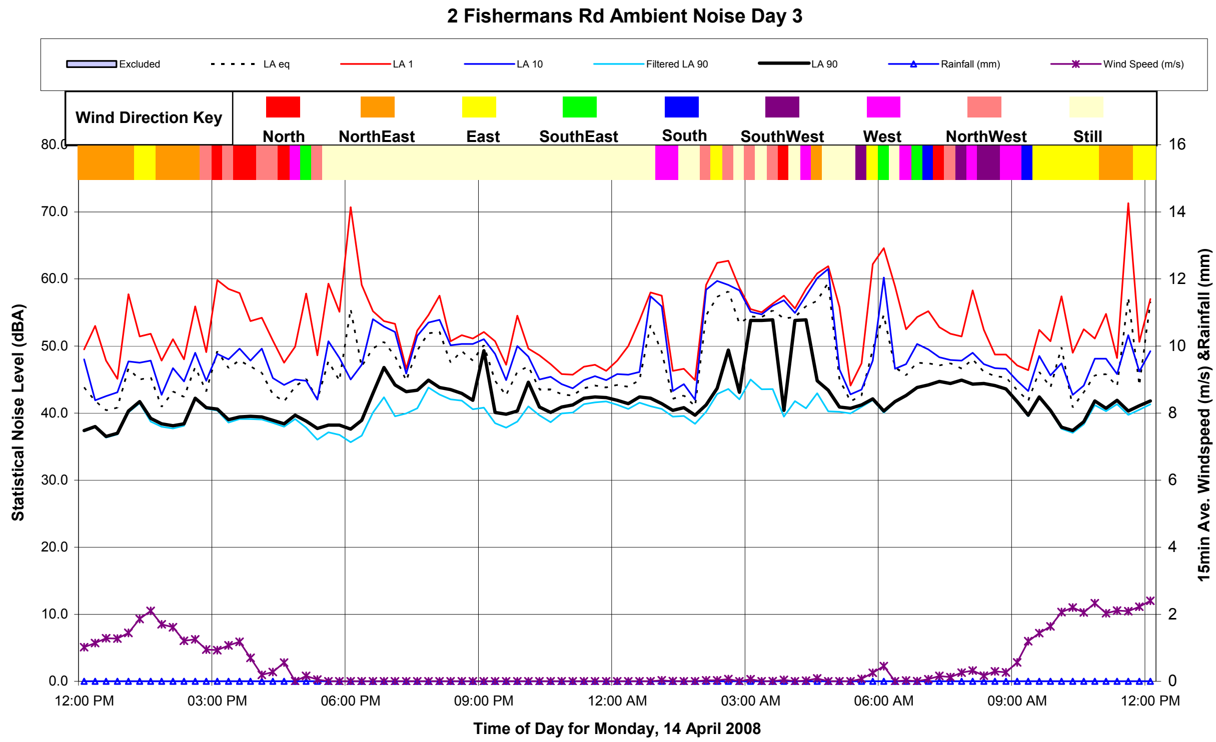

2 Fishermans Rd Ambient Noise Day 1
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Wind Direction
LA90 including insect noise
LA90 with conspicuous insect contributions
Wind
Rainfall
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
Time of Day for Saturday, 12 April 2008

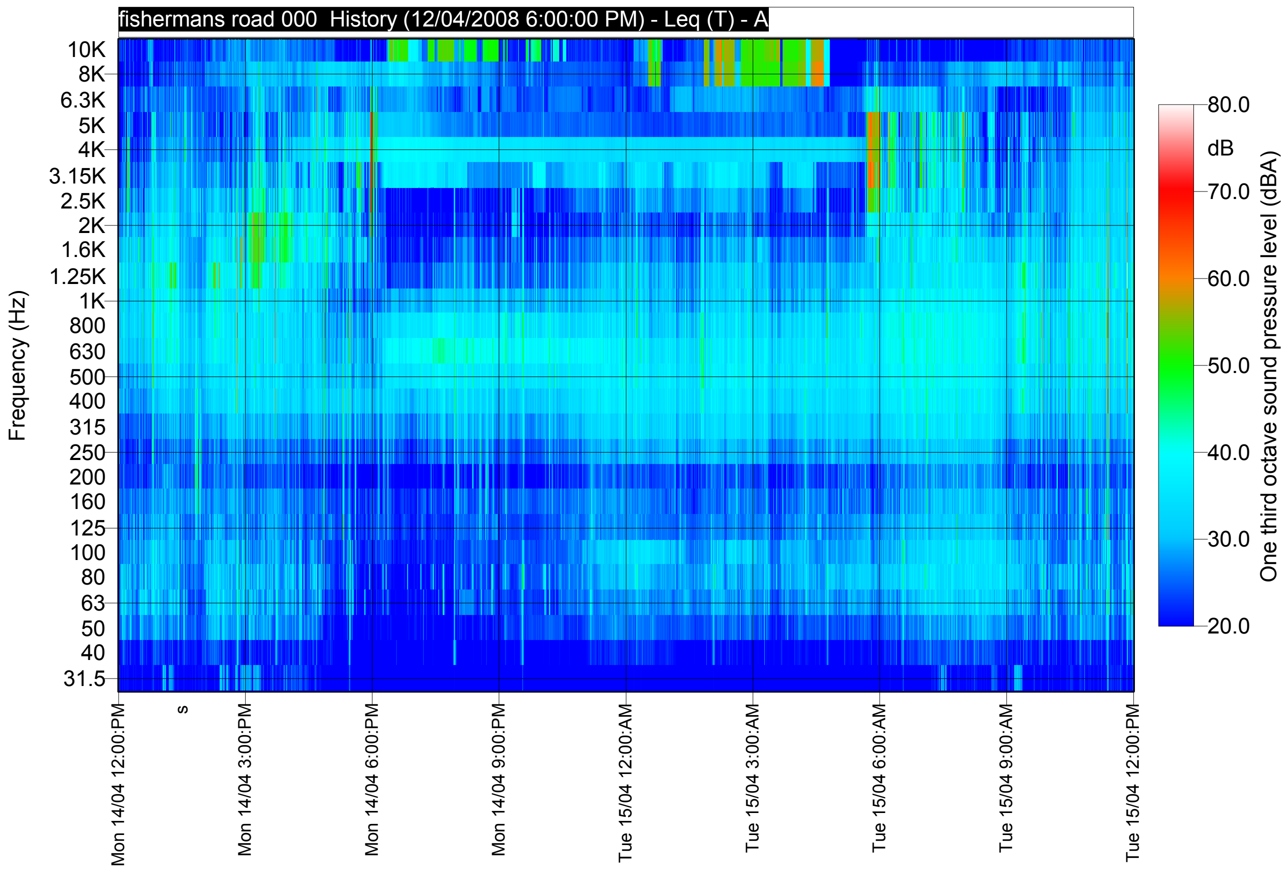

fishermans road 000 History (12/04/2008 6:00:00 PM) - Leq (T) - A
Insect noise in 8kHz & 10 kHz
Insect noise in 2.5 kHz, 3.15kHz and 4kHz bands
Industrial noise 250 Hz to 1.6 kHz
Industrial noise 31.5 Hz to 160 Hz
Frequency (Hz)
One third octave sound pressure level (dBA)
dB
Sat 12/04 12:00:PM
Sat 12/04 3:00:PM
Sat 12/04 6:00:PM
Sat 12/04 9:00:PM
Sun 13/04 12:00:AM
Sun 13/04 3:00:AM
Sun 13/04 6:00:AM
Sun 13/04 9:00:AM
Sun 13/04 12:00:PM

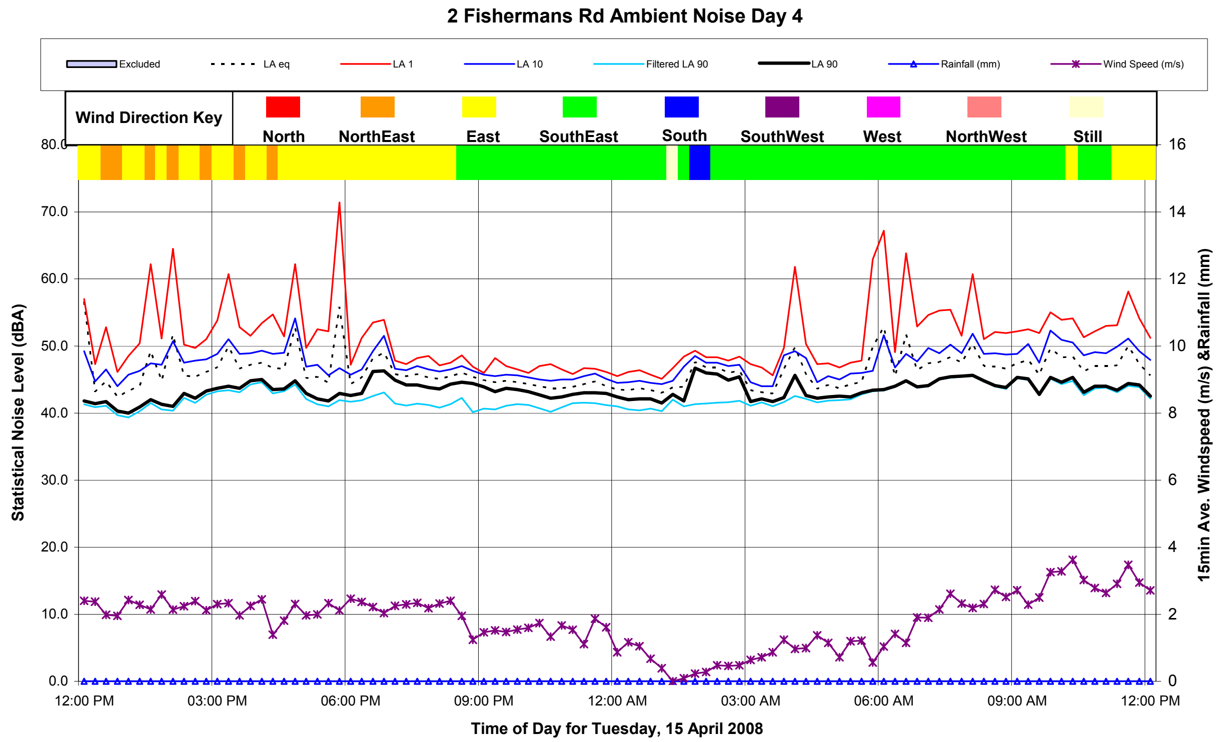
2 Fishermans Rd Ambient Noise Day 2

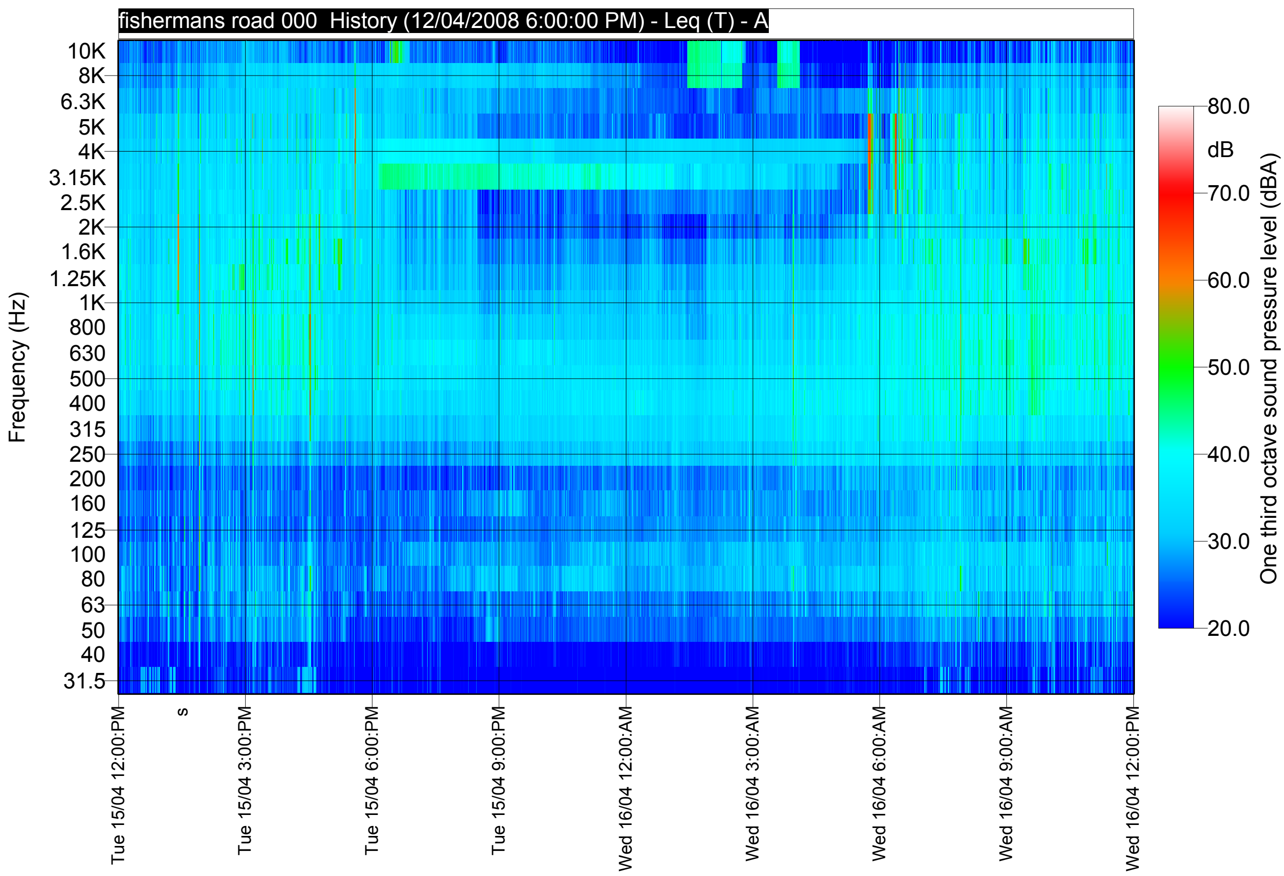




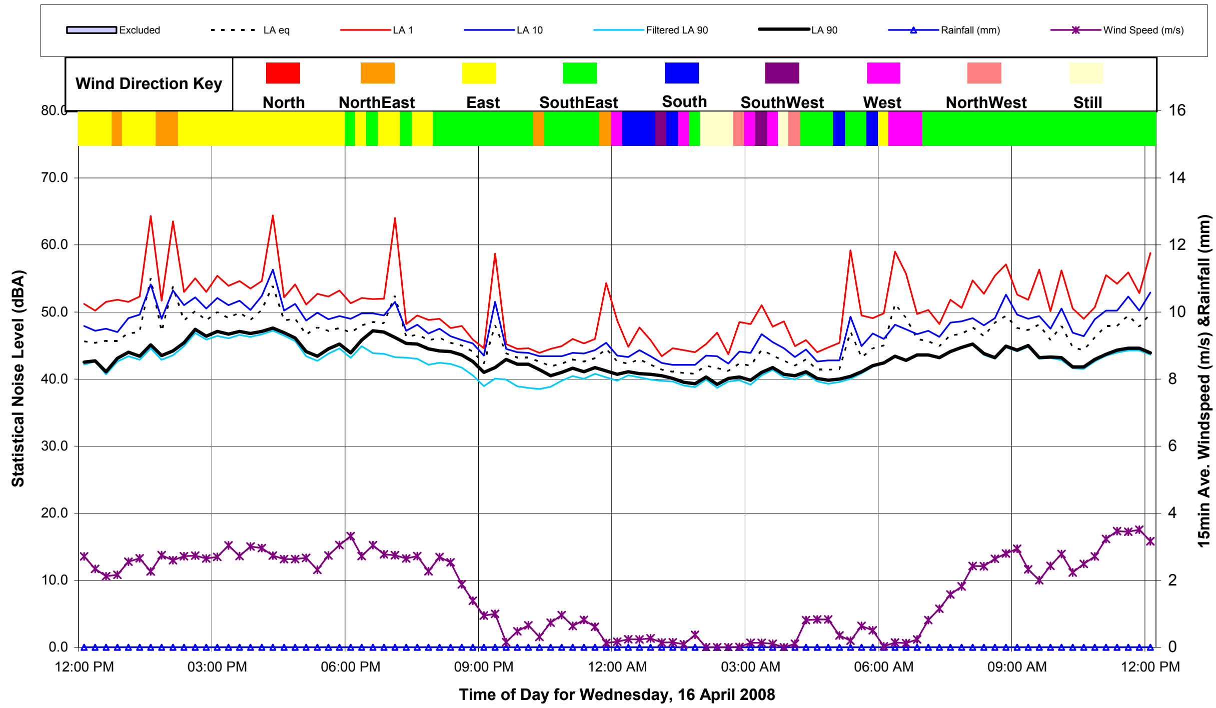

2 Fishermans Rd Ambient Noise Day 3
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
Time of Day for Monday, 14 April 2008

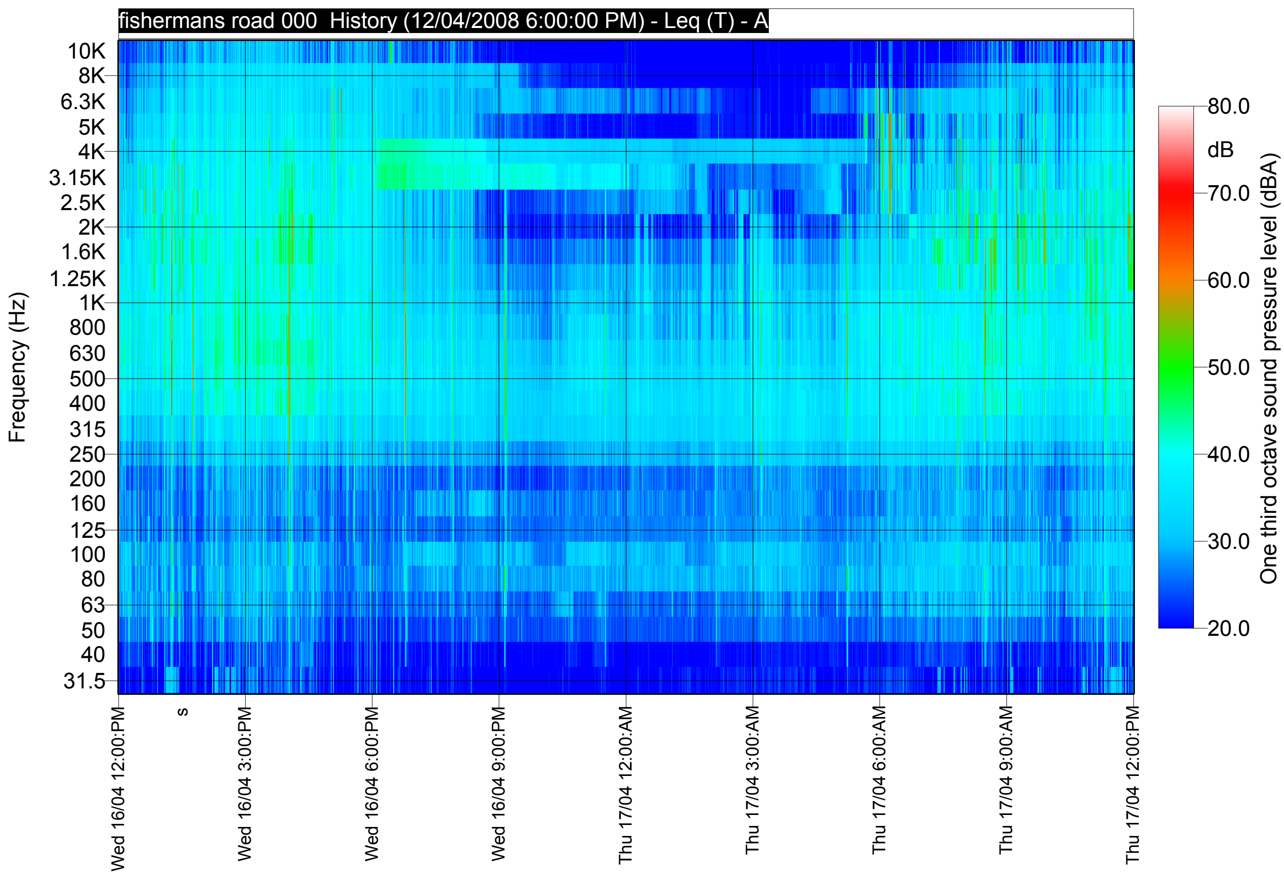

fishermans road 000 History (12/04/2008 6:00:00 PM) - Leq (T) - A
Frequency (Hz)
One third octave sound pressure level (dBA)
dB
Mon 14/04 12:00:PM
Mon 14/04 3:00:PM
Mon 14/04 6:00:PM
Mon 14/04 9:00:PM
Tue 15/04 12:00:AM
Tue 15/04 3:00:AM
Tue 15/04 6:00:AM
Tue 15/04 9:00:AM
Tue 15/04 12:00:PM

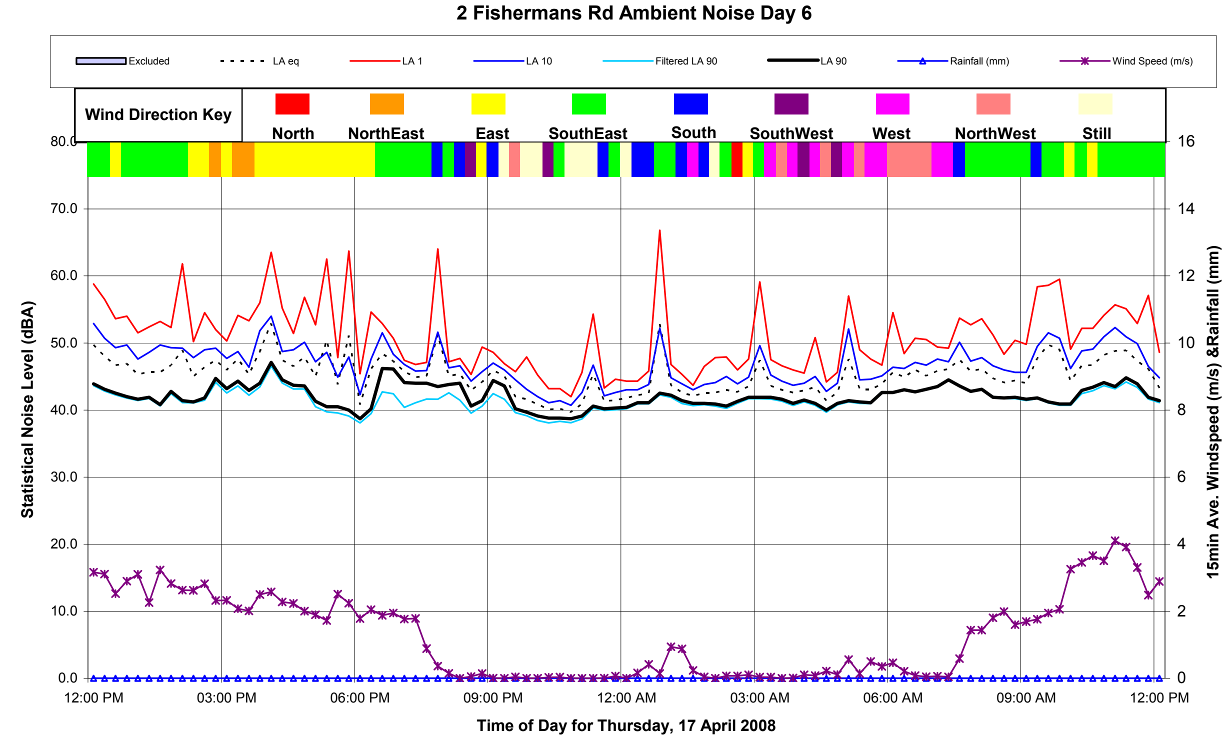

2 Fishermans Rd Ambient Noise Day 4
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
Time of Day for Tuesday, 15 April 2008

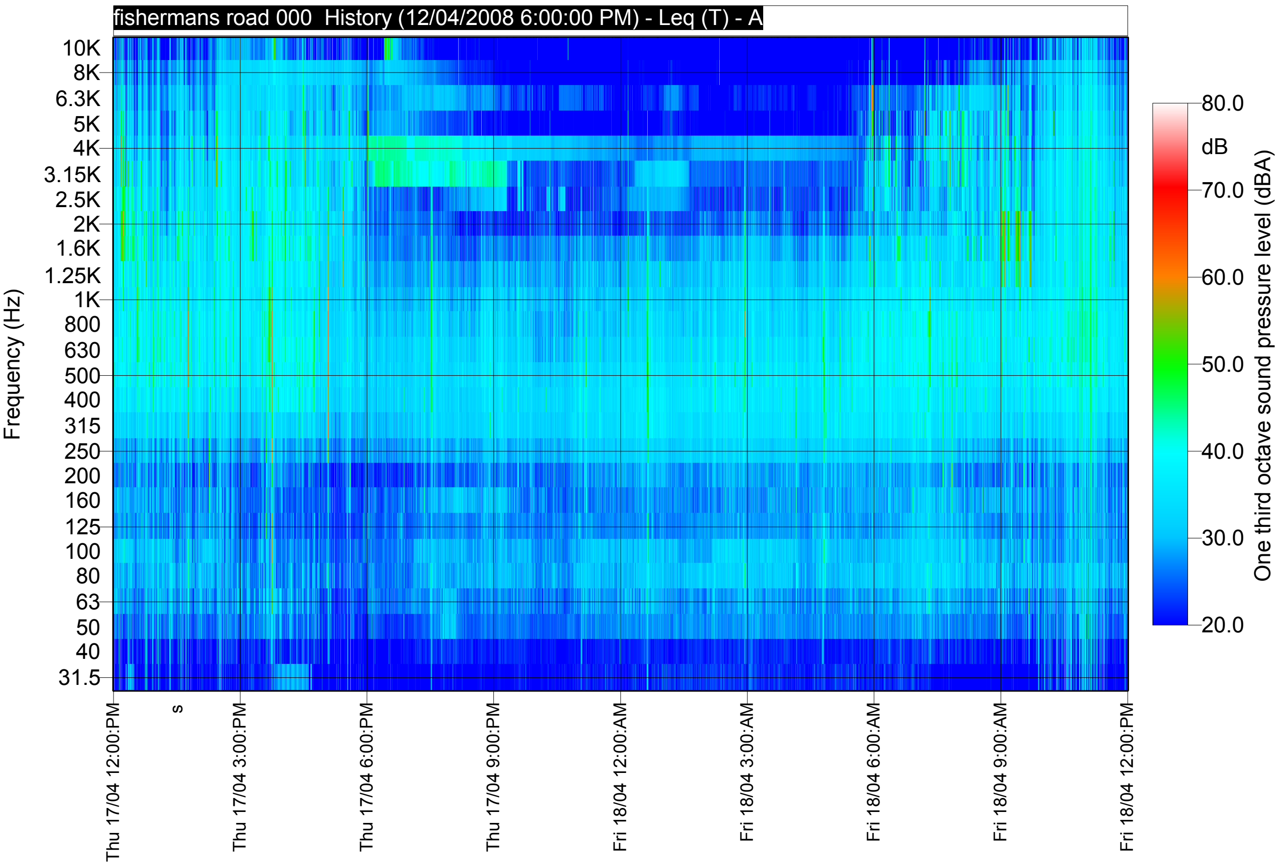

fishermans road 000 History (12/04/2008 6:00:00 PM) - Leq (T) - A
Frequency (Hz)
One third octave sound pressure level (dBA)
dB
Tue 15/04 12:00:PM
Tue 15/04 3:00:PM
Tue 15/04 6:00:PM
Tue 15/04 9:00:PM
Wed 16/04 12:00:AM
Wed 16/04 3:00:AM
Wed 16/04 6:00:AM
Wed 16/04 9:00:AM
Wed 16/04 12:00:PM

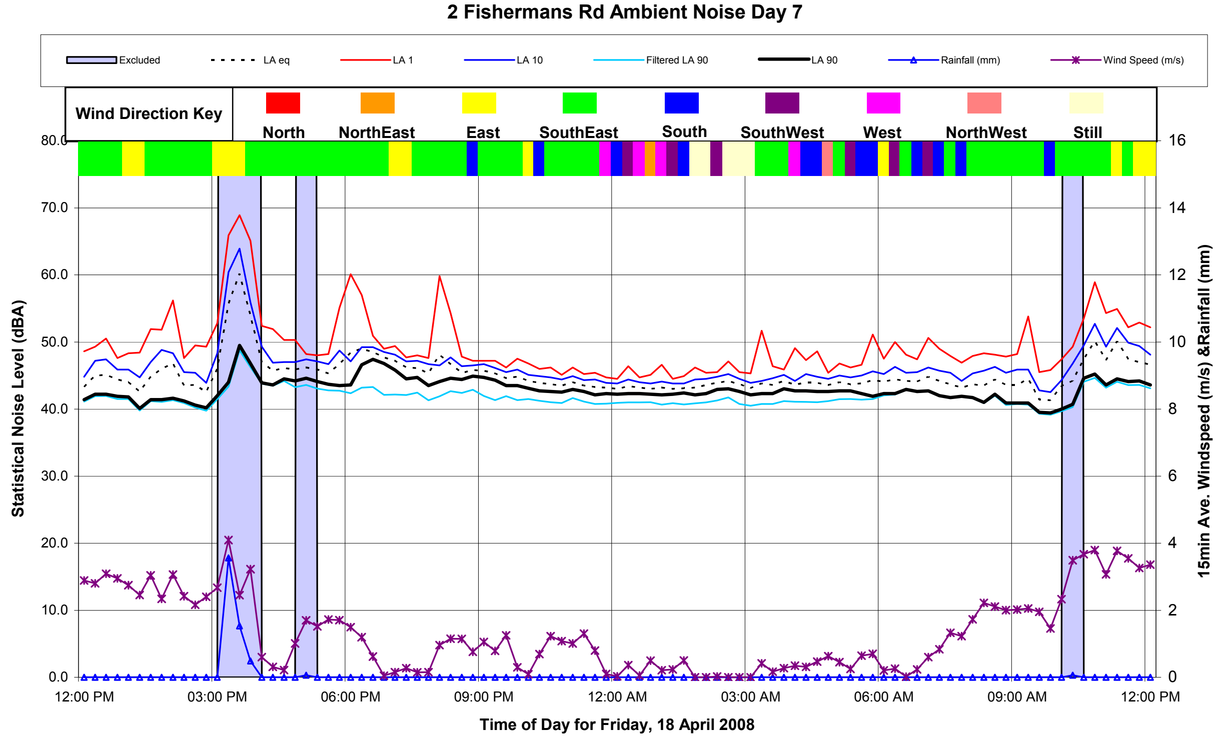
2 Fishermans Rd Ambient Noise Day 5

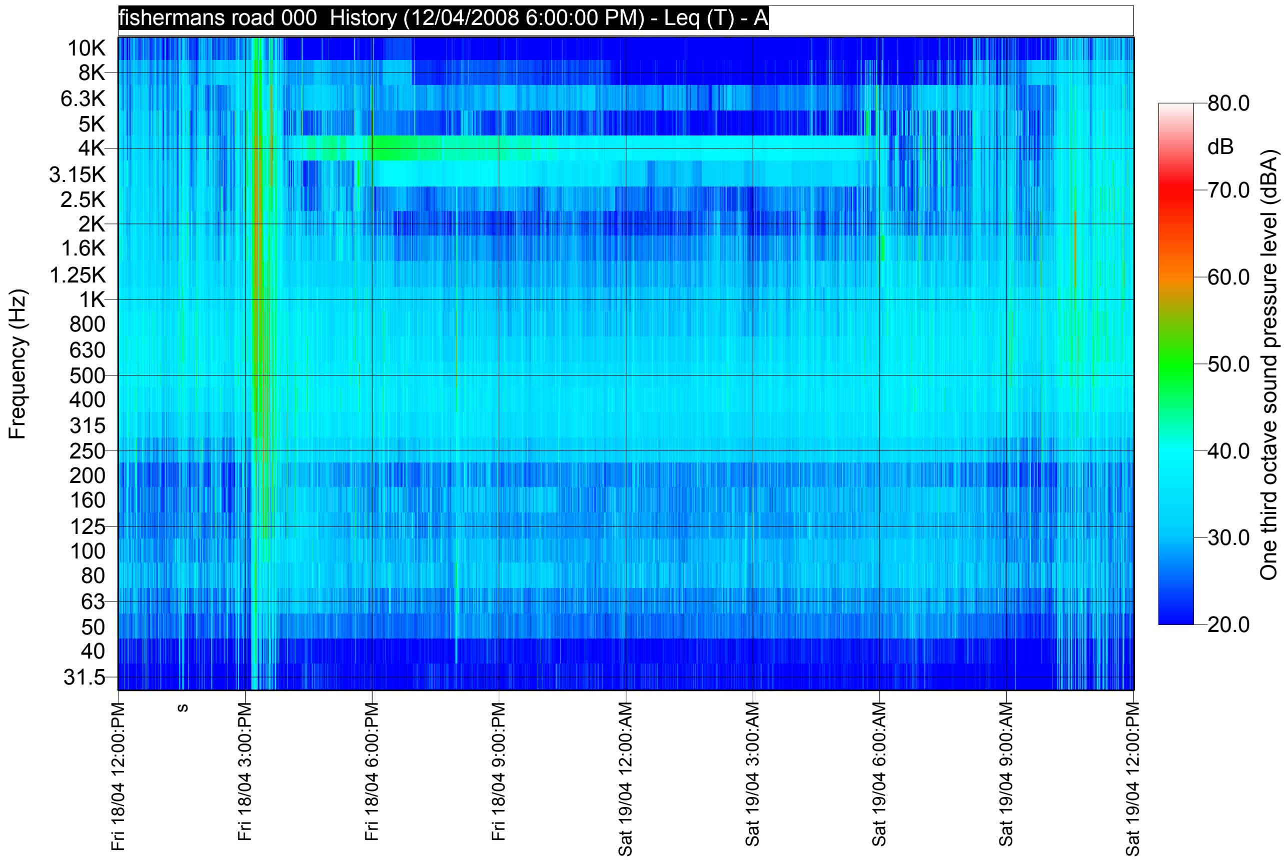


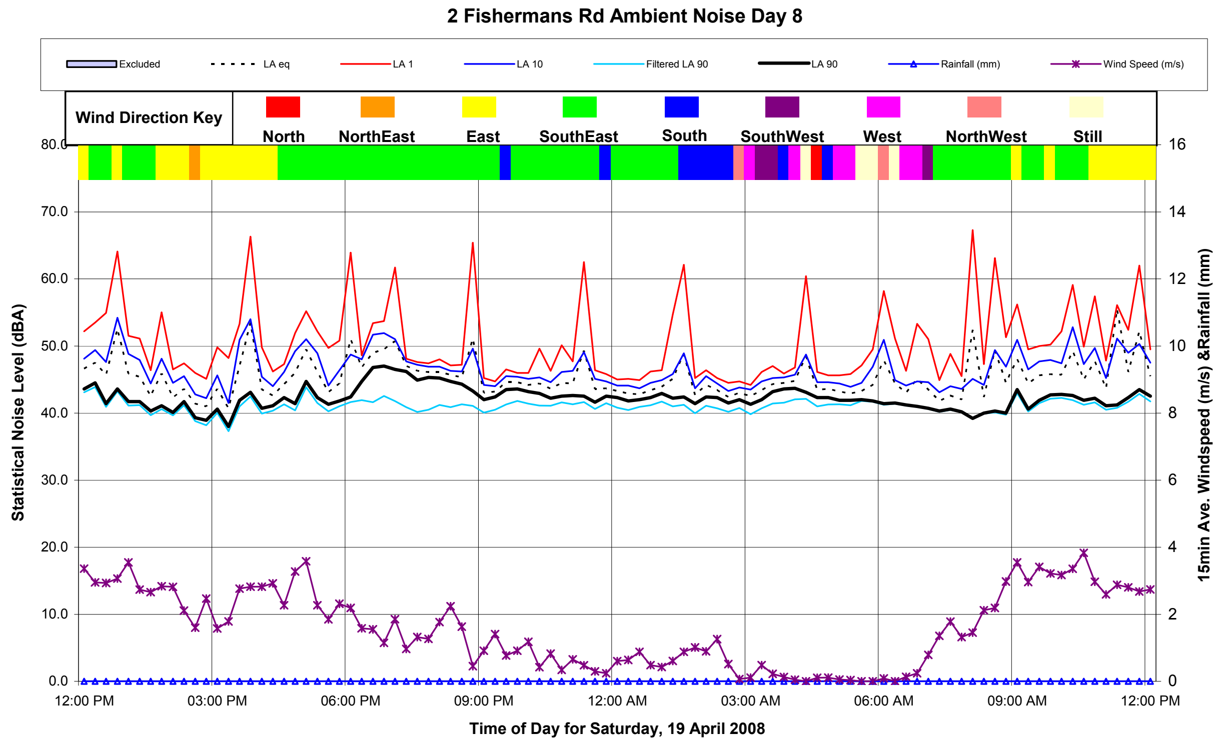


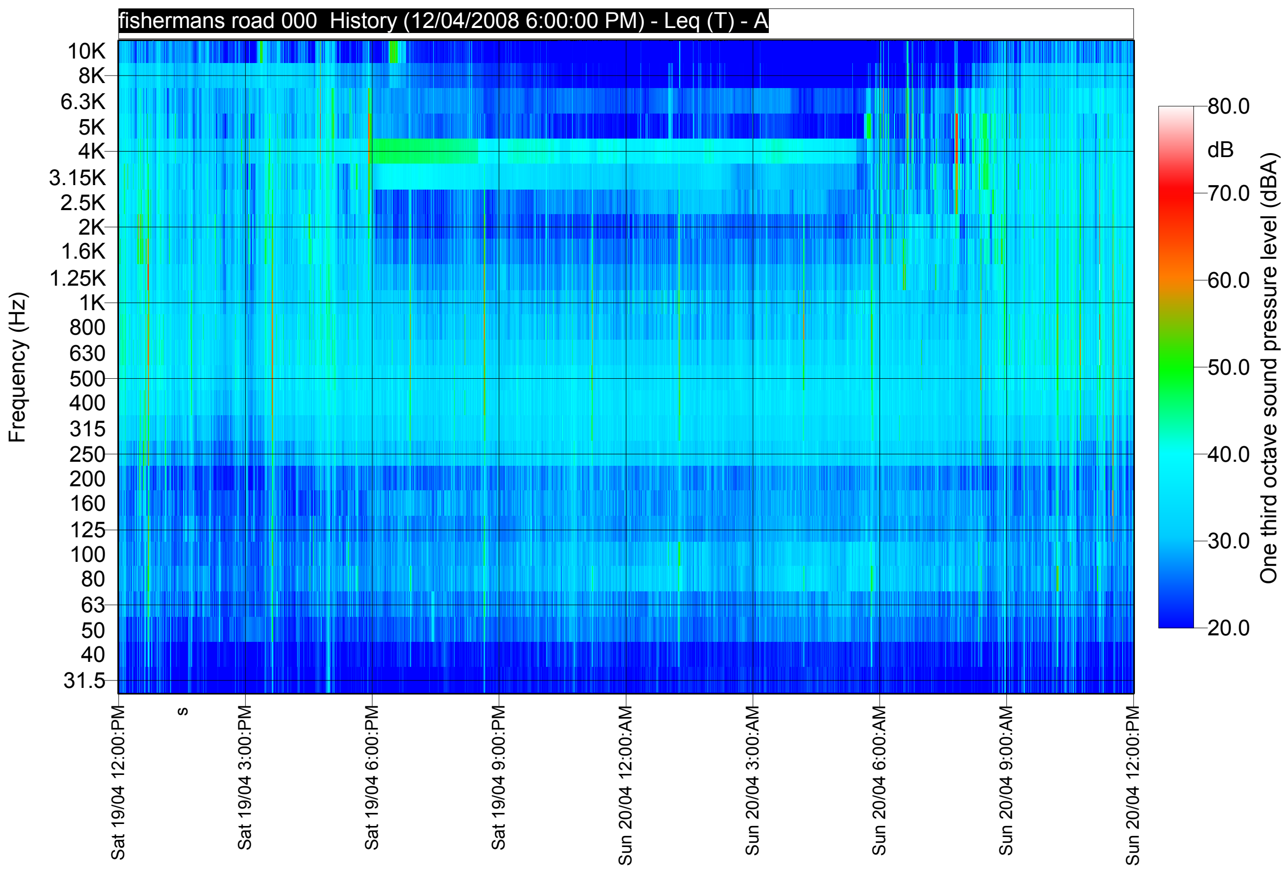

2 Fishermans Rd Ambient Noise Day 6
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16
14
12
10
8
6
4
2
0
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM
Time of Day for Thursday, 17 April 2008

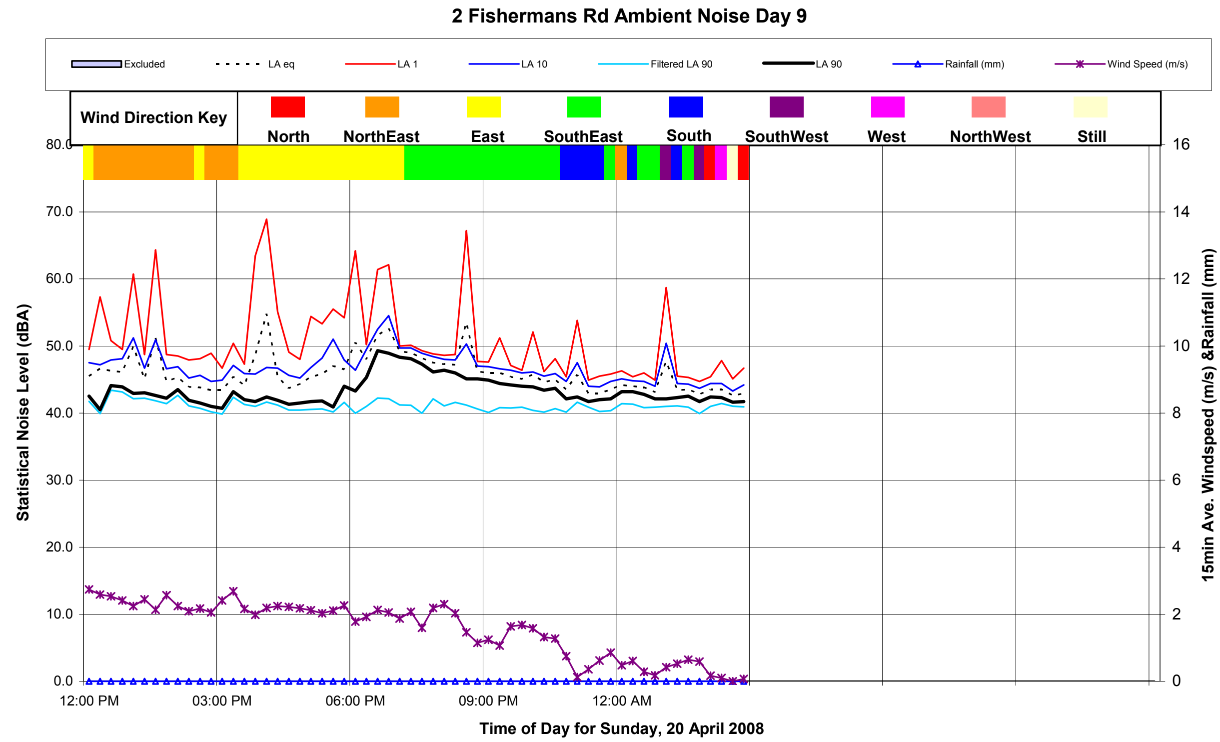

fishermans road 000 History (12/04/2008 6:00:00 PM) - Leq (T) - A
Frequency (Hz)
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
Thu 17/04 12:00:PM
Thu 17/04 3:00:PM
Thu 17/04 6:00:PM
Thu 17/04 9:00:PM
Fri 18/04 12:00:AM
Fri 18/04 3:00:AM
Fri 18/04 6:00:AM
Fri 18/04 9:00:AM
Fri 18/04 12:00:PM
80.0
dB
70.0
60.0
50.0
40.0
30.0
20.0
One third octave sound pressure level (dBA)

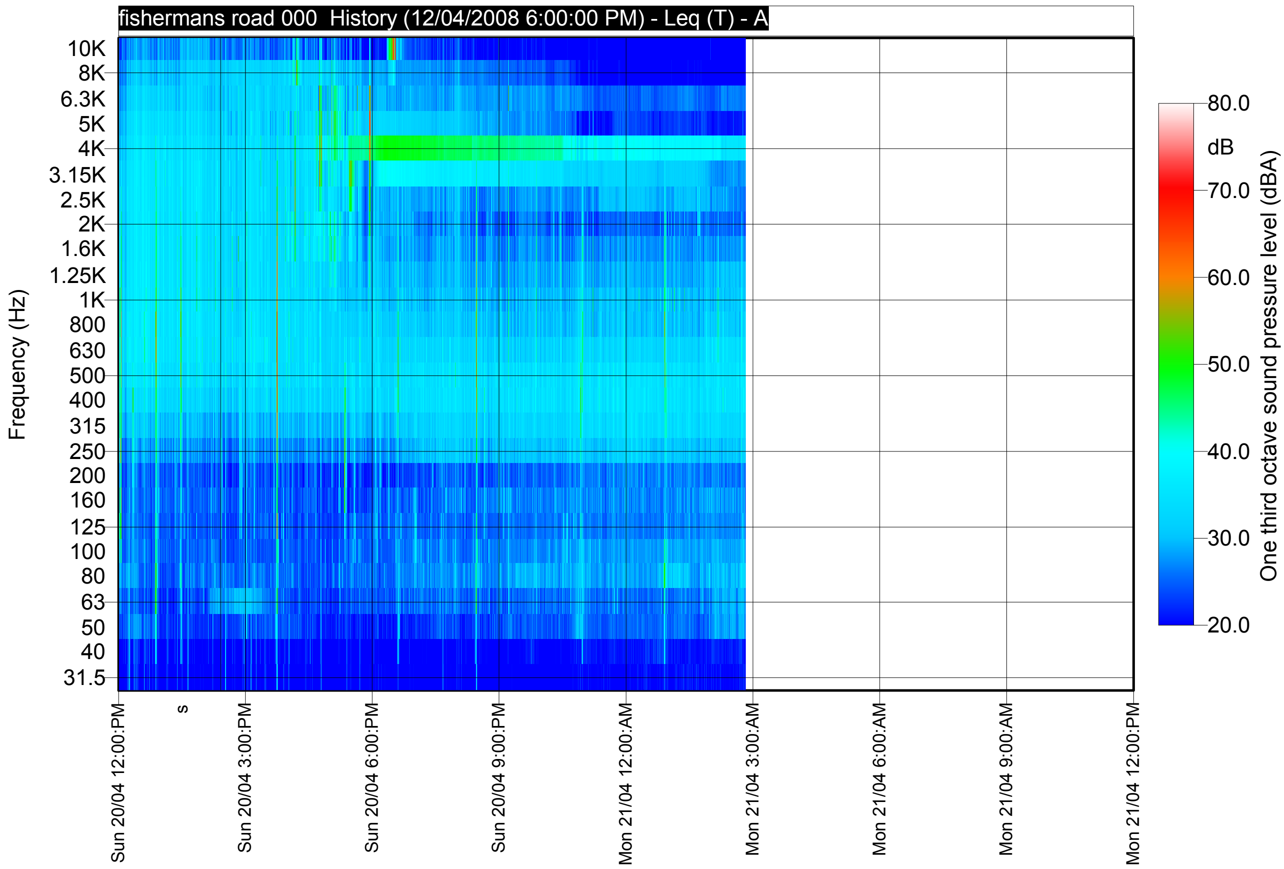

2 Fishermans Rd Ambient Noise Day 7
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM
Time of Day for Friday, 18 April 2008


fishermans road 000 History (12/04/2008 6:00:00 PM) - Leq (T) - A
Frequency (Hz)
One third octave sound pressure level (dBA)
dB
Fri 18/04 12:00:PM
Fri 18/04 3:00:PM
Fri 18/04 6:00:PM
Fri 18/04 9:00:PM
Sat 19/04 12:00:AM
Sat 19/04 3:00:AM
Sat 19/04 6:00:AM
Sat 19/04 9:00:AM
Sat 19/04 12:00:PM


2 Fishermans Rd Ambient Noise Day 8
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM
Time of Day for Saturday, 19 April 2008


fishermans road 000 History (12/04/2008 6:00:00 PM) - Leq (T) - A
Frequency (Hz)
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
dB
One third octave sound pressure level (dBA)
Sat 19/04 12:00:PM
Sat 19/04 3:00:PM
Sat 19/04 6:00:PM
Sat 19/04 9:00:PM
Sun 20/04 12:00:AM
Sun 20/04 3:00:AM
Sun 20/04 6:00:AM
Sun 20/04 9:00:AM
Sun 20/04 12:00:PM


2 Fishermans Rd Ambient Noise Day 9
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
Time of Day for Sunday, 20 April 2008


fishermans road 000 History (12/04/2008 6:00:00 PM) - Leq (T) - A
Frequency (Hz)
One third octave sound pressure level (dBA)
dB
Sun 20/04 12:00:PM
Sun 20/04 3:00:PM
Sun 20/04 6:00:PM
Sun 20/04 9:00:PM
Mon 21/04 12:00:AM
Mon 21/04 3:00:AM
Mon 21/04 6:00:AM
Mon 21/04 9:00:AM
Mon 21/04 12:00:PM

Appendix E – Site 4 ambient noise records

Coordinates: 23.79049ºS,151.11864E — Site description: Forest Road

Instrument: CESVA310 + C130 mic. — Serial No: T225957 (Logger 6)

Calibrator: Bruel & Kjaer Type 4231 — Serial No: 2463922

Reference weather station: Reinhardt MWS 5MV at Site 4

Logging period: Saturday, 12 April 2008 to Sunday, 20 April 2008

Comments:

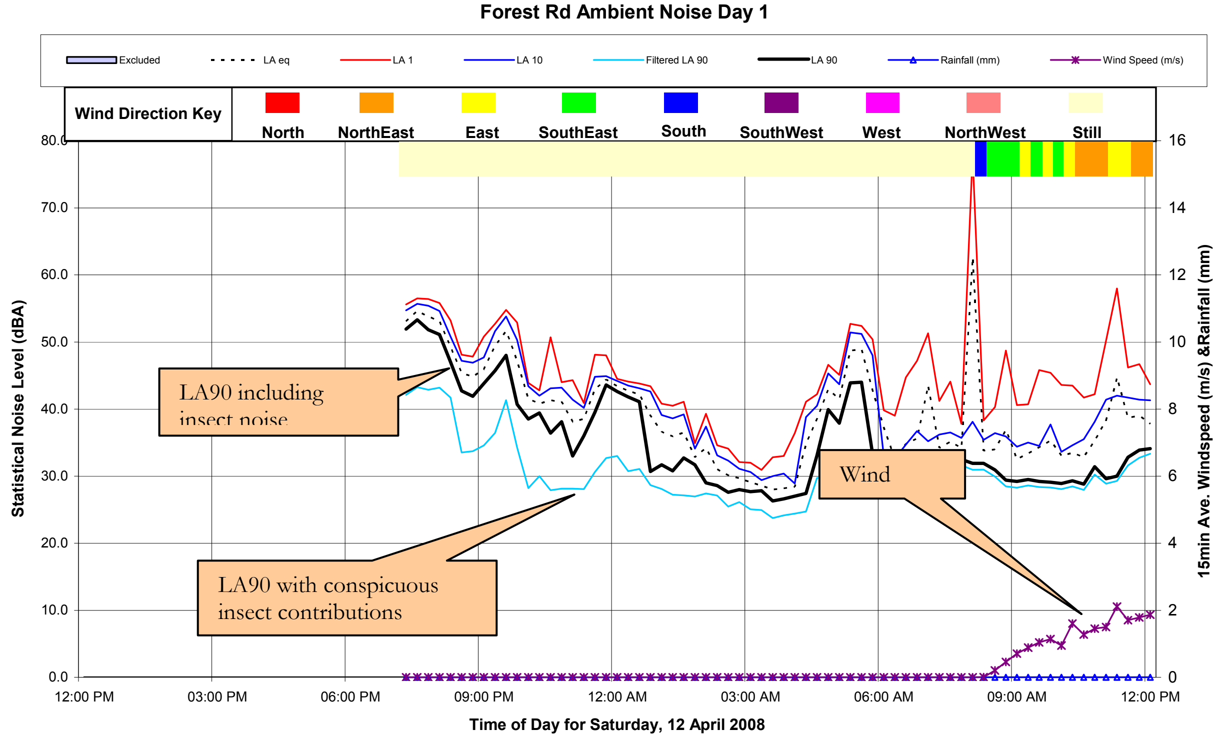
- This location was selected to represent ambient noise residential dwellings at the western side of Targinie State Forest. The noise logger was positioned upon a former residential property (the house had been removed prior to noise logging) approximately 100m south of Forest Road, Targinie. This site is located approximately 3500m west of the Yarwun Cement Australia facility.
- Evening insect noise is evidenced by 2.5kHz, 3.15kHz, 4kHz and 5kHz banding in the spectral records. This is significant to overall levels in the early evening (i.e. typically 6pm to 9pm) and at night.
- The influence of industrial noise is evident at night as banding between 80Hz and 1.6kHz when the wind direction ranges from easterly through to southerly.

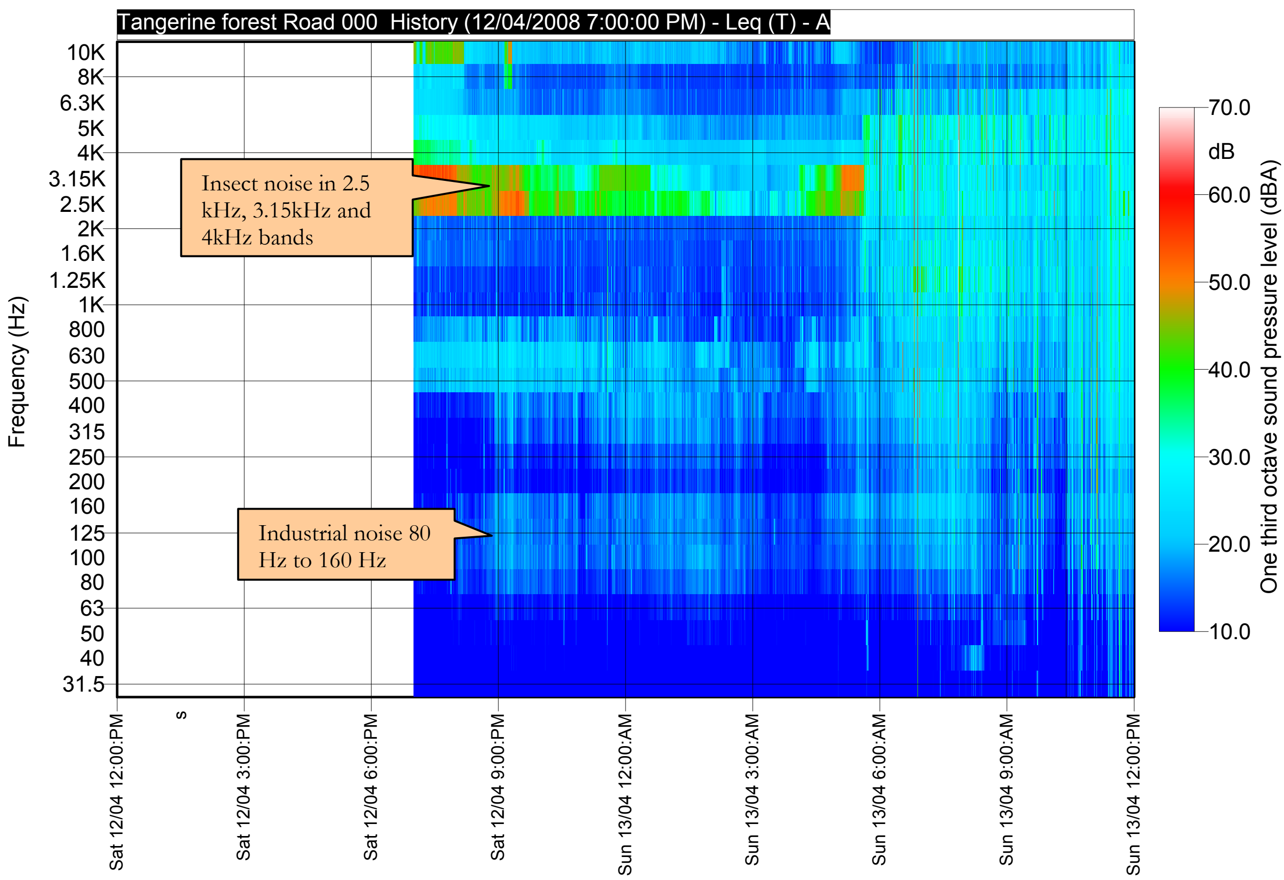
ABL Summary - LA90									
	Raw Data						Filtered Data		
Date	6am to 6pm Day	Fill %	6pm to 10pm Evening	Fill %	10pm to 6am Night	Fill %	6am to 6pm Day	6pm to 10pm Evening	10pm to 6am Night
Sat, 12 Apr 2008	Nil	0%	41.9	69%	27.4	100%	Nil	33.7	24.7
Sun, 13 Apr 2008	28.9	100%	32.0	100%	24.8	100%	27.7	26.0	22.1
Mon, 14 Apr 2008	27.6	100%	33.9	100%	25.9	100%	25.6	26.2	22.3
Tue, 15 Apr 2008	28.9	100%	43.0	100%	33.5	100%	28.0	36.0	30.5
Wed, 16 Apr 2008	32.1	100%	37.1	100%	33.0	100%	31.3	31.1	30.7
Thu, 17 Apr 2008	31.4	100%	32.1	100%	33.8	100%	30.5	30.7	32.0
Fri, 18 Apr 2008	30.8	92%	37.2	100%	36.3	100%	30.1	32.2	33.2
Sat, 19 Apr 2008	31.5	98%	39.0	100%	38.3	81%	30.3	32.6	33.1
RBL (Median)	30.8		37.1		33.2		30.1	31.7	30.6

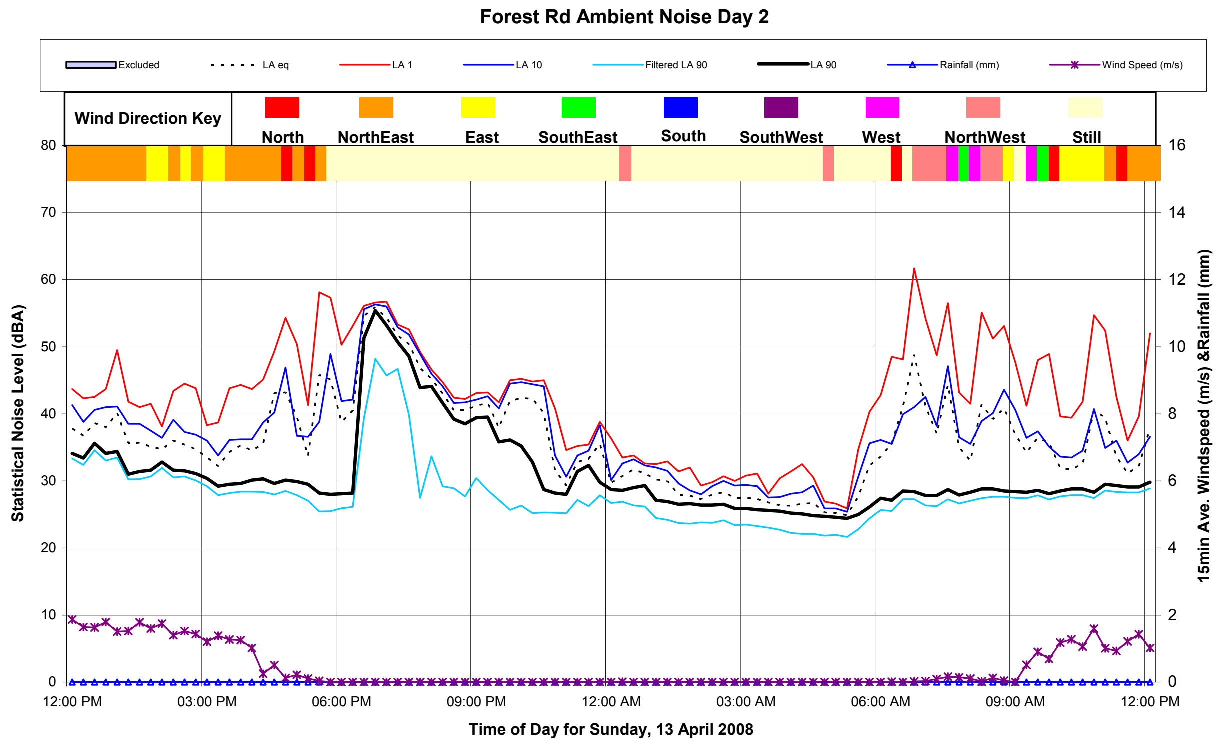
Filters Exclude: 2.5 kHz 3.15 kHz 4 kHz 5 kHz

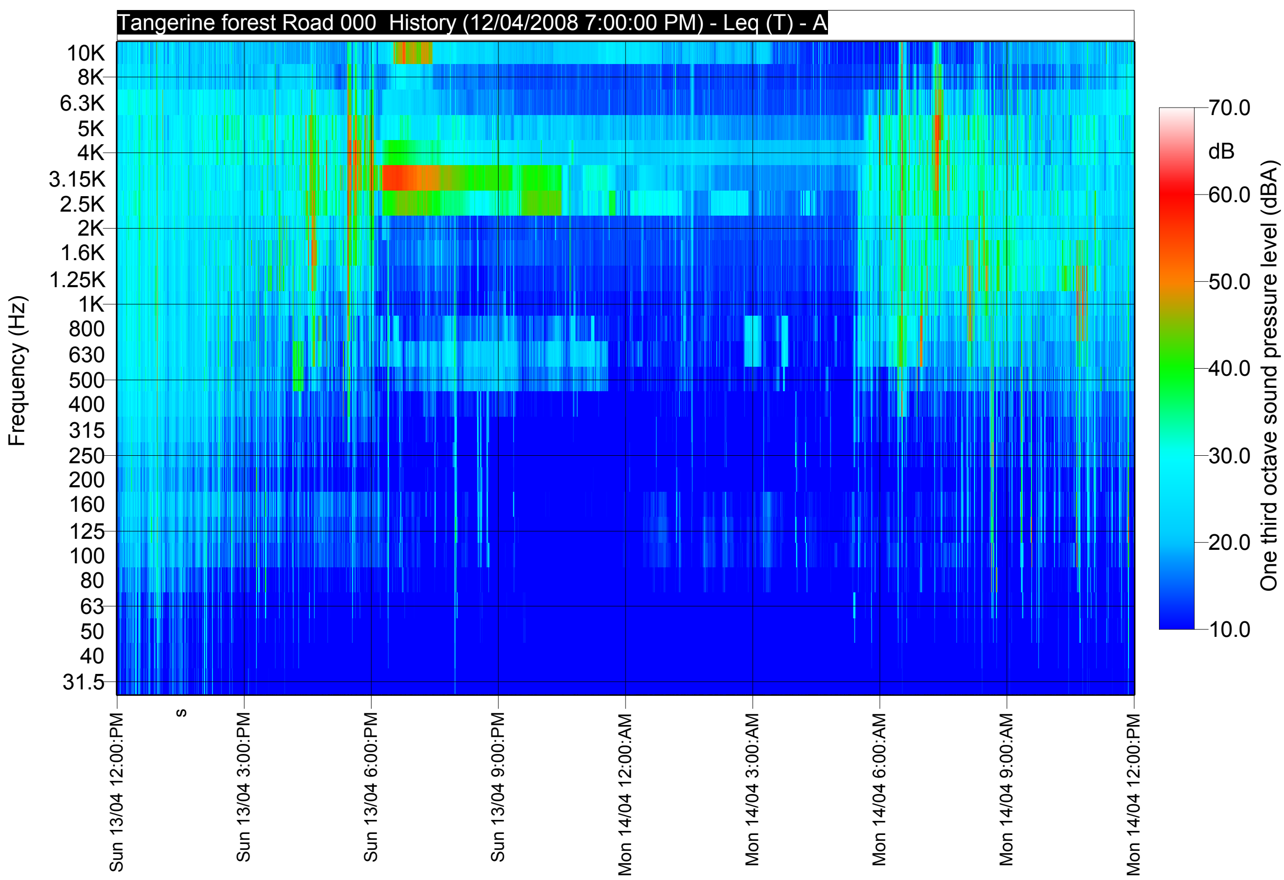
Summary - Minimum one hour LAeq									
	Raw Data						Filtered Data		
Date	6am to 6pm	Fill	6pm to 10pm	Fill	10pm to 6am	Fill	6am to 6pm	6pm to 10pm	10pm to 6am

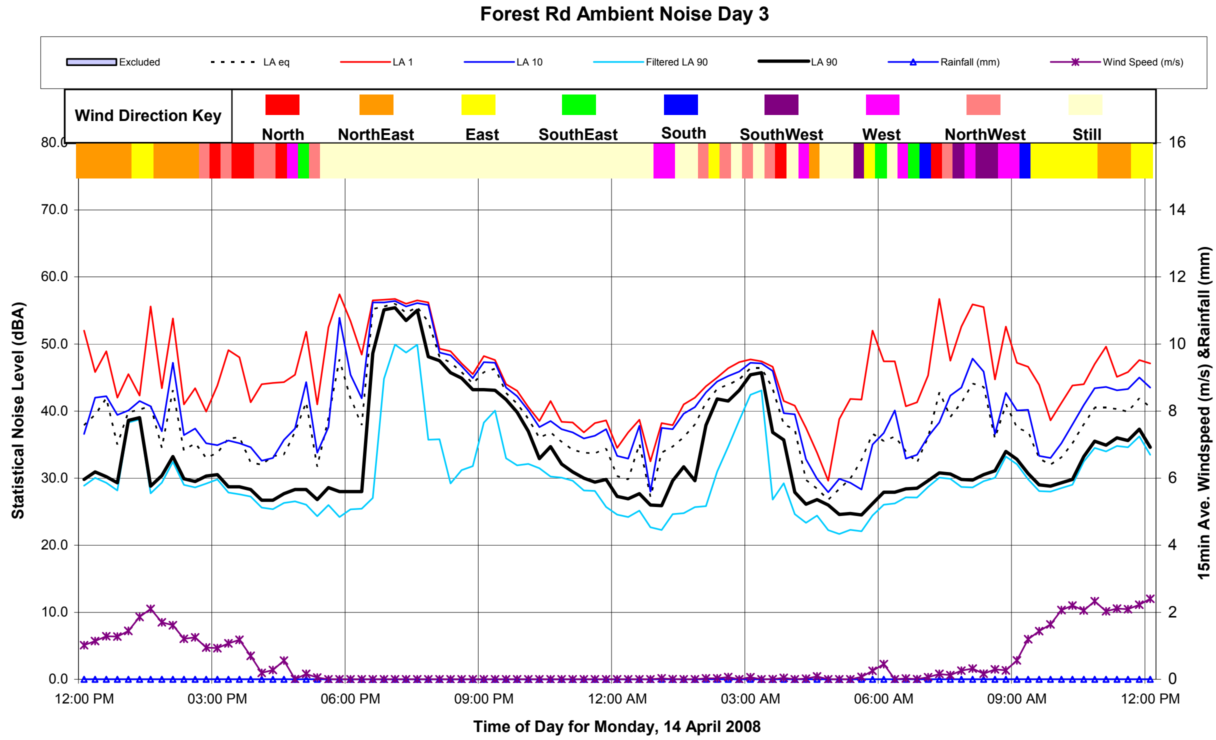
	Day	%	Evening	%	Night	%	Day	Evening	Night
Sat, 12 Apr 2008	53.1	2%	48.3	69%	29.6	100 %			
Sun, 13 Apr 2008	35.1	100%	42.0	100 %	27.0	100 %			
Mon, 14 Apr 2008	34.4	100%	43.4	100 %	30.5	100 %			
Tue, 15 Apr 2008	34.9	100%	57.1	100 %	38.3	100 %			
Wed, 16 Apr 2008	37.7	100%	50.0	100 %	38.5	100 %			
Thu, 17 Apr 2008	37.5	100%	43.0	100 %	39.7	100 %			
Fri, 18 Apr 2008	38.8	92%	48.4	100 %	39.6	100 %			
Sat, 19 Apr 2008	36.0	98%	51.5	100 %	43.6	78 %			
Median Level	36.8		48.3		38.4				

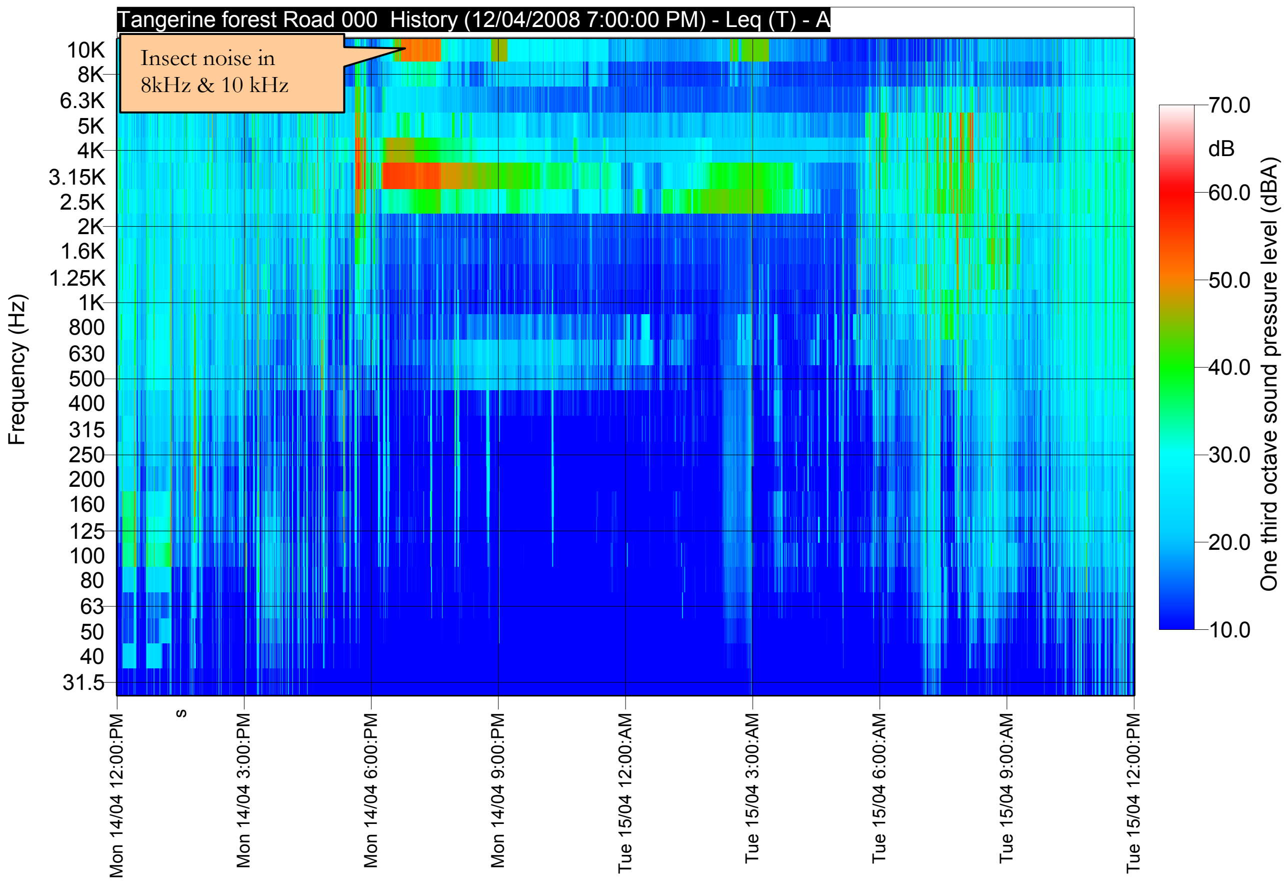

Forest Rd Ambient Noise Day 1
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
LA90 including insect noise
LA90 with conspicuous insect contributions
Wind
Time of Day for Saturday, 12 April 2008
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM

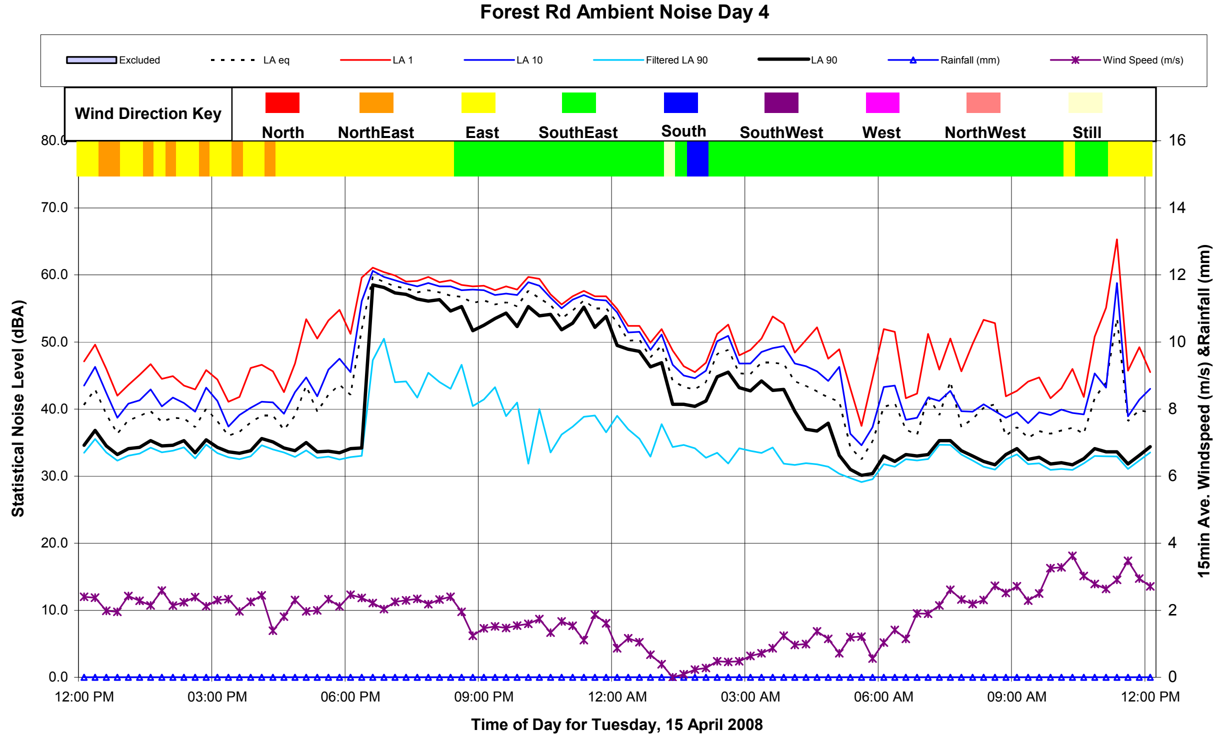

Tangerine forest Road 000 History (12/04/2008 7:00:00 PM) - Leq (T) - A
Frequency (Hz)
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
Insect noise in 2.5 kHz, 3.15kHz and 4kHz bands
Industrial noise 80 Hz to 160 Hz
70.0
dB
60.0
50.0
40.0
30.0
20.0
10.0
One third octave sound pressure level (dBA)
Sat 12/04 12:00:PM
Sat 12/04 3:00:PM
Sat 12/04 6:00:PM
Sat 12/04 9:00:PM
Sun 13/04 12:00:AM
Sun 13/04 3:00:AM
Sun 13/04 6:00:AM
Sun 13/04 9:00:AM
Sun 13/04 12:00:PM

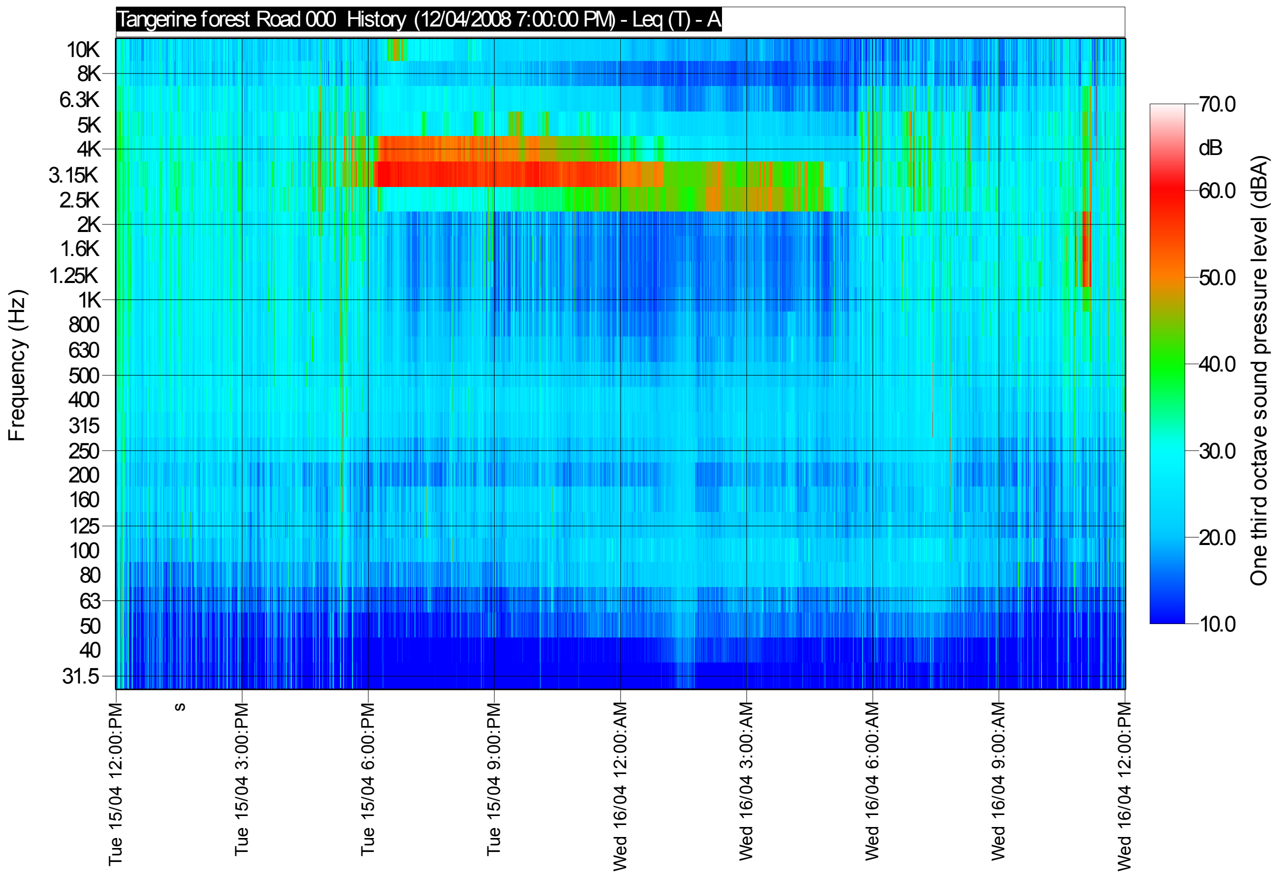

Forest Rd Ambient Noise Day 2
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
Time of Day for Sunday, 13 April 2008

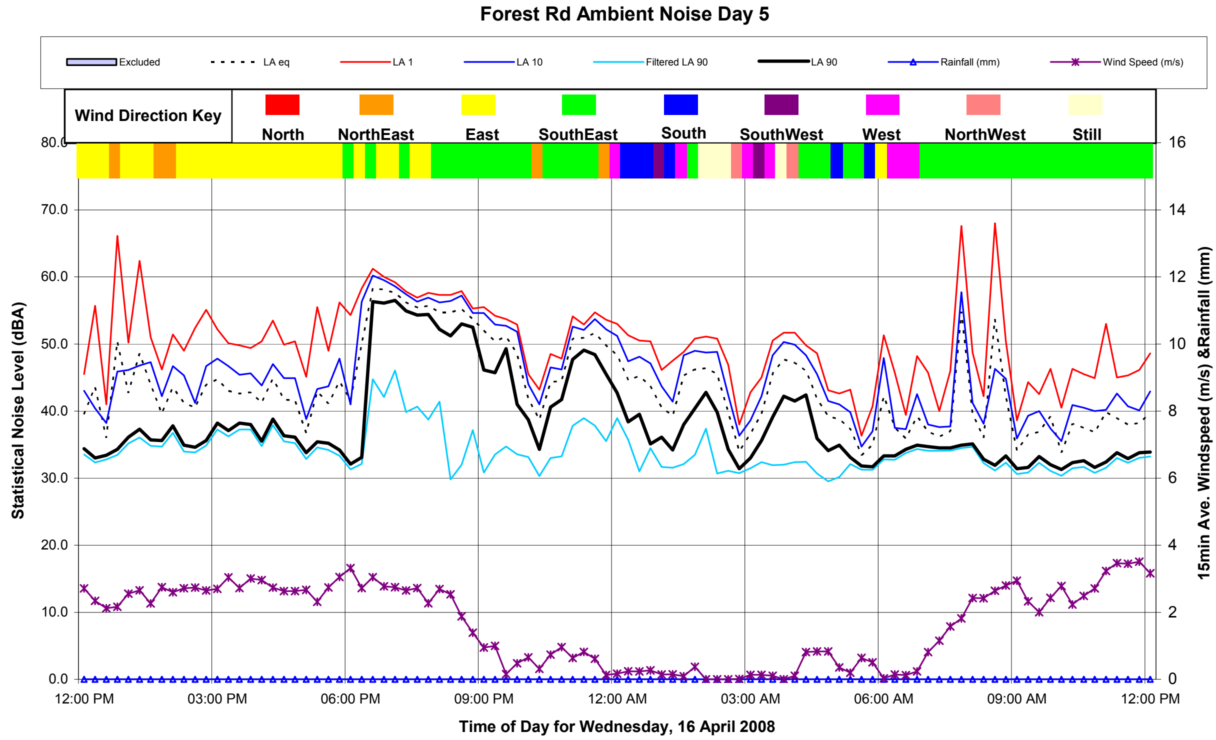

Tangerine forest Road 000 History (12/04/2008 7:00:00 PM) - Leq (T) - A
Frequency (Hz)
One third octave sound pressure level (dBA)
dB

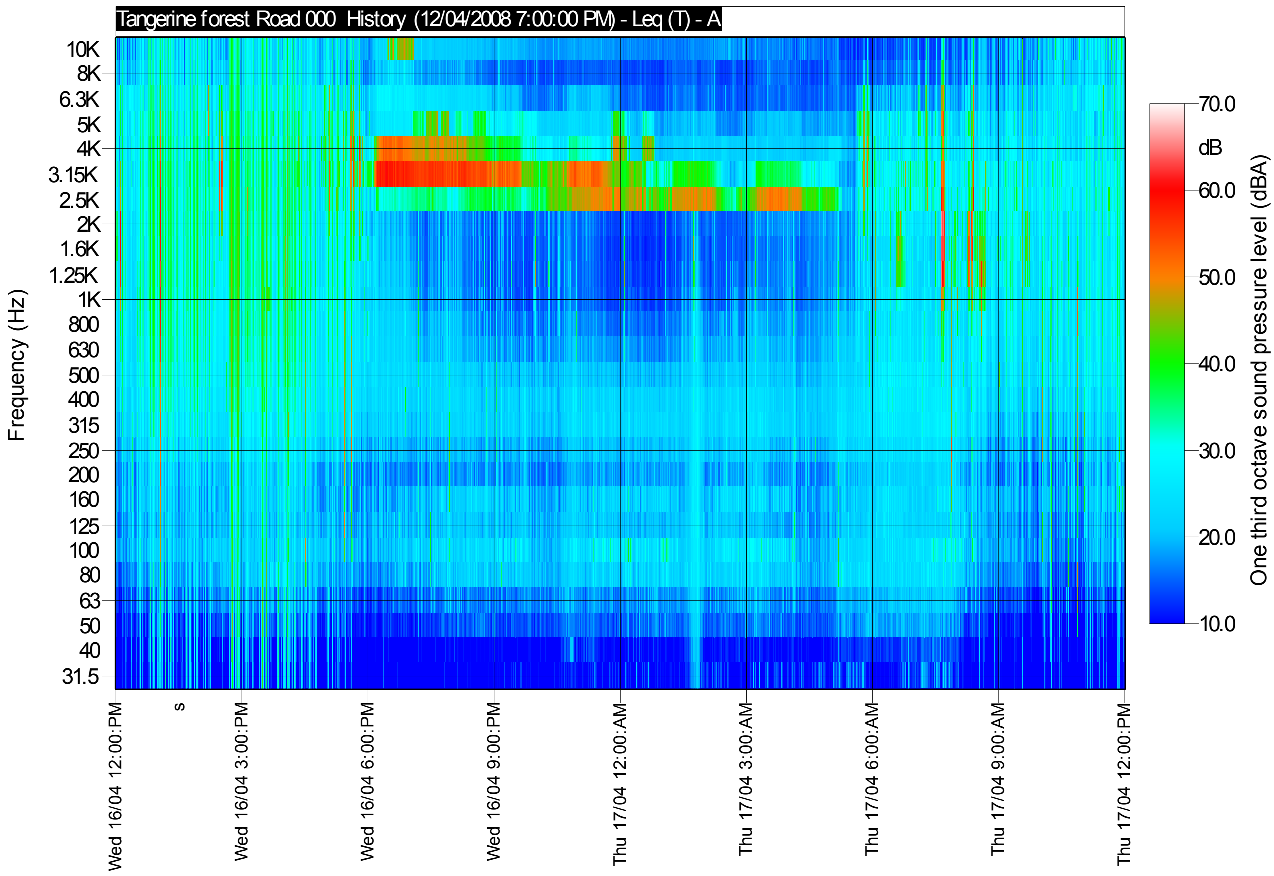

Forest Rd Ambient Noise Day 3
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
Time of Day for Monday, 14 April 2008

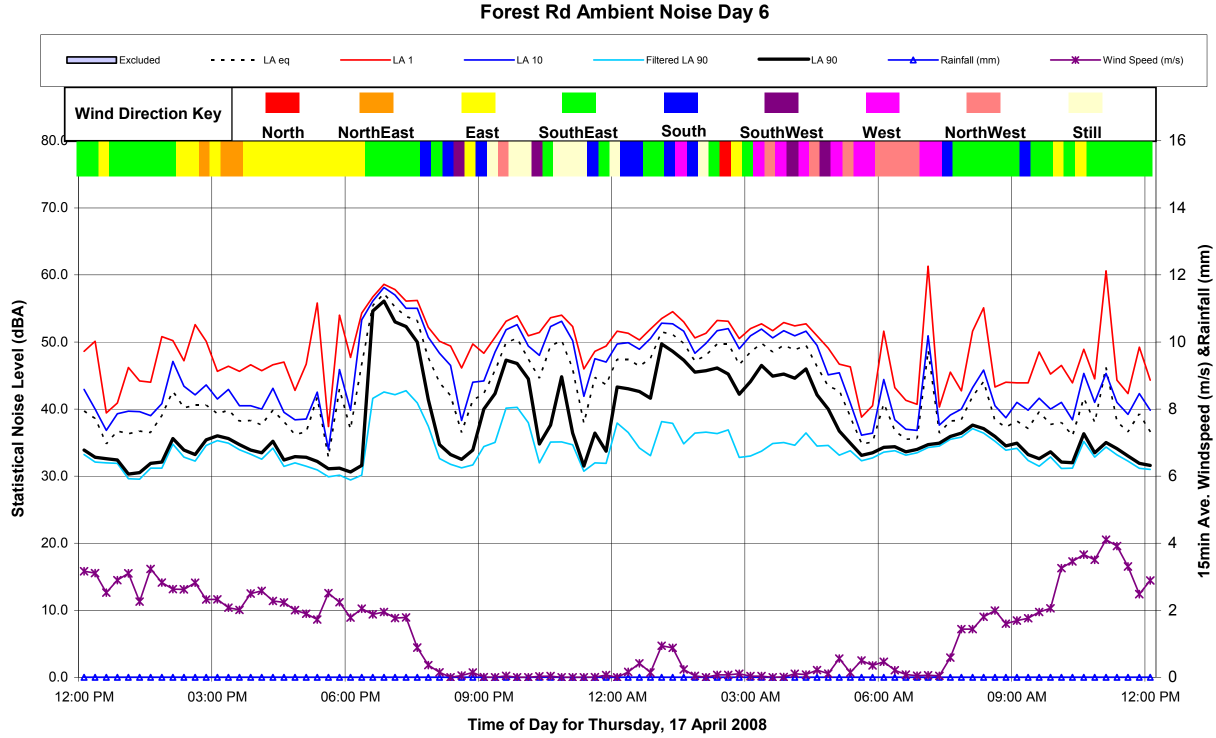

Tangerine forest Road 000 History (12/04/2008 7:00:00 PM) - Leq (T) - A
Insect noise in
8kHz & 10 kHz
Frequency (Hz)
One third octave sound pressure level (dBA)
dB

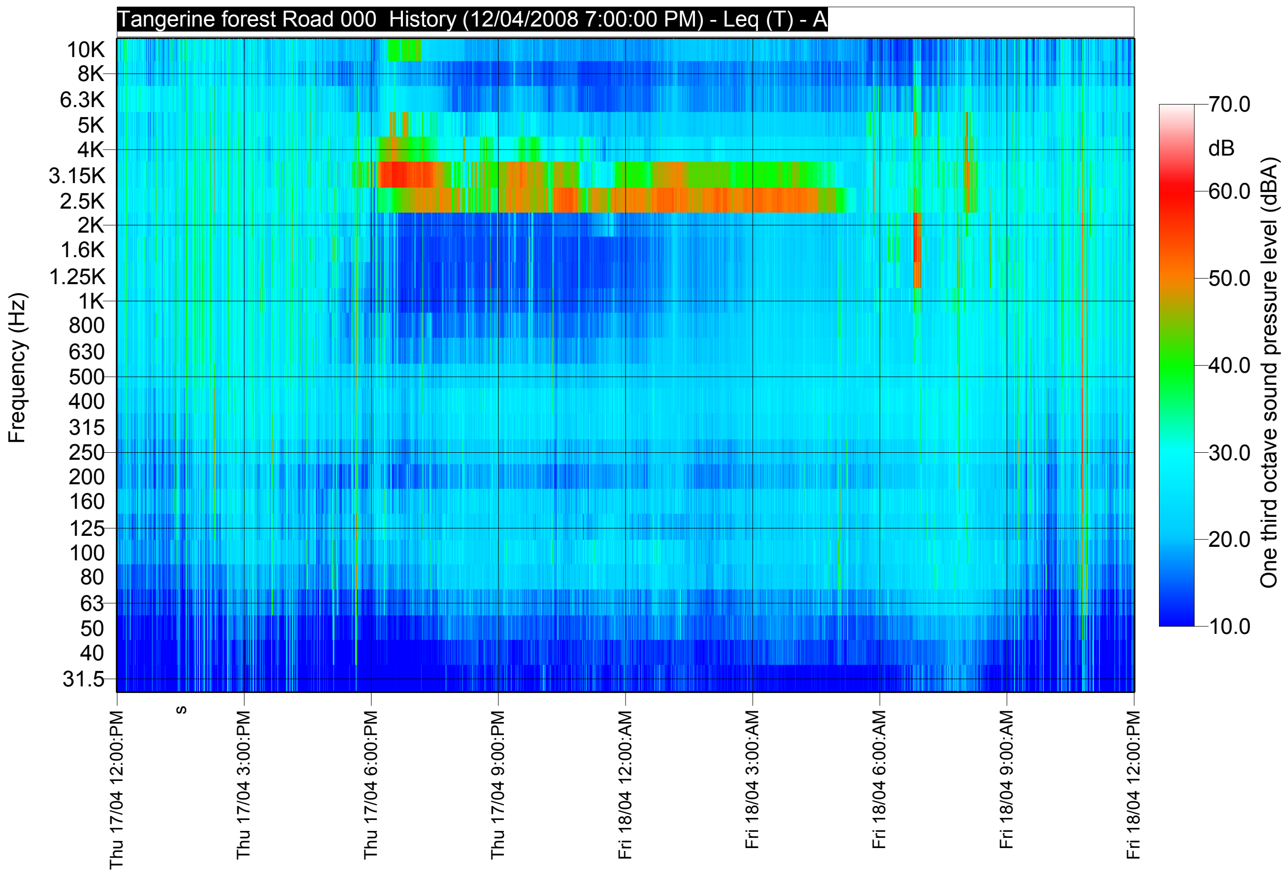

Forest Rd Ambient Noise Day 4
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
Time of Day for Tuesday, 15 April 2008

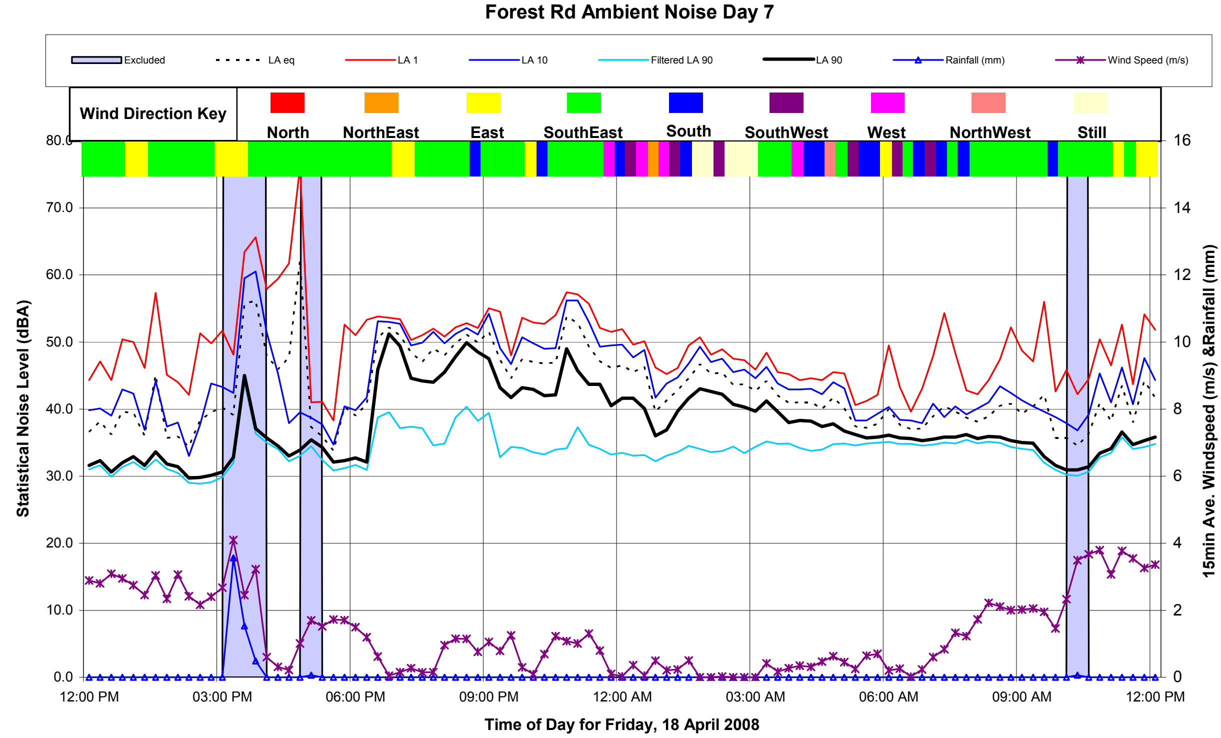

Tangerine forest Road 000 History (12/04/2008 7:00:00 PM) - Leq (T) - A
Frequency (Hz)
One third octave sound pressure level (dBA)
dB
Tue 15/04 12:00:PM
Tue 15/04 3:00:PM
Tue 15/04 6:00:PM
Tue 15/04 9:00:PM
Wed 16/04 12:00:AM
Wed 16/04 3:00:AM
Wed 16/04 6:00:AM
Wed 16/04 9:00:AM
Wed 16/04 12:00:PM

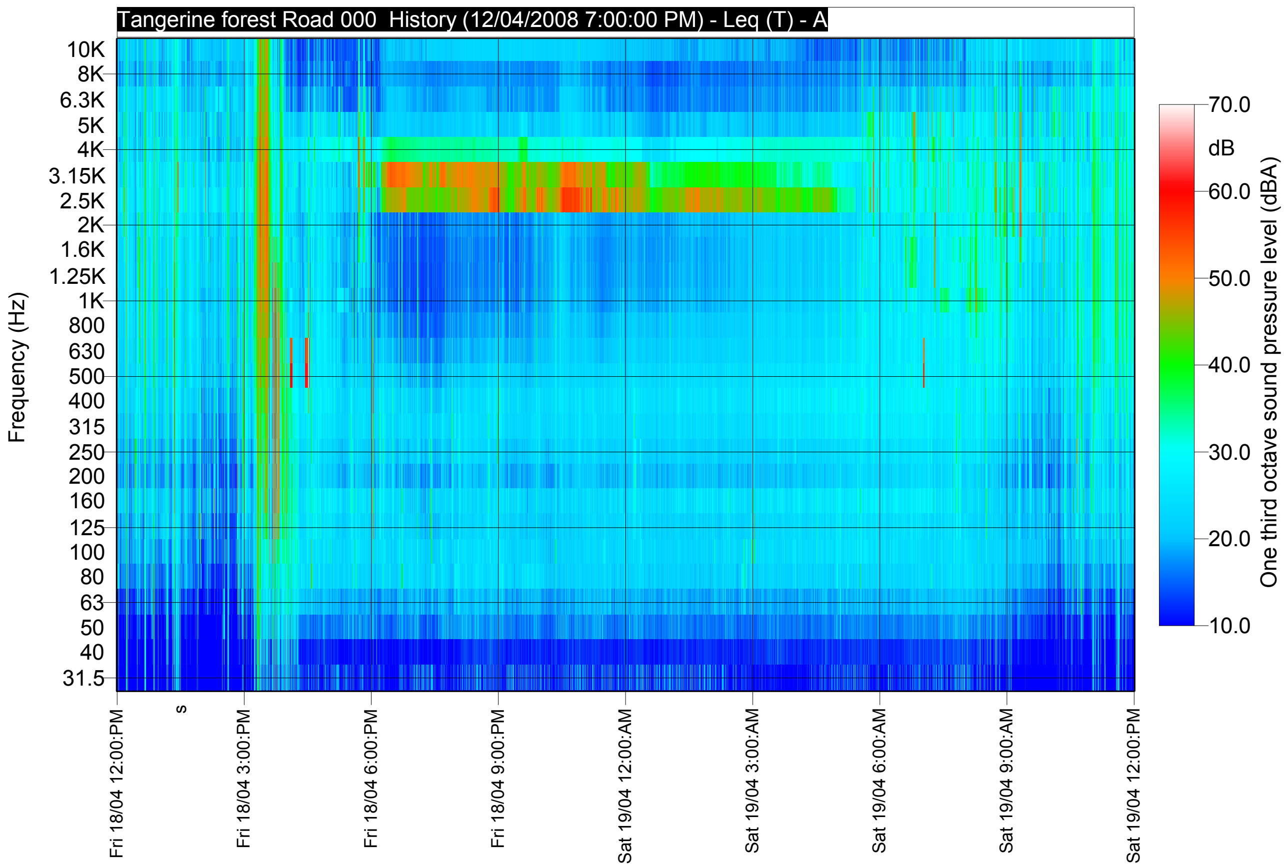

Forest Rd Ambient Noise Day 5
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
Time of Day for Wednesday, 16 April 2008
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM

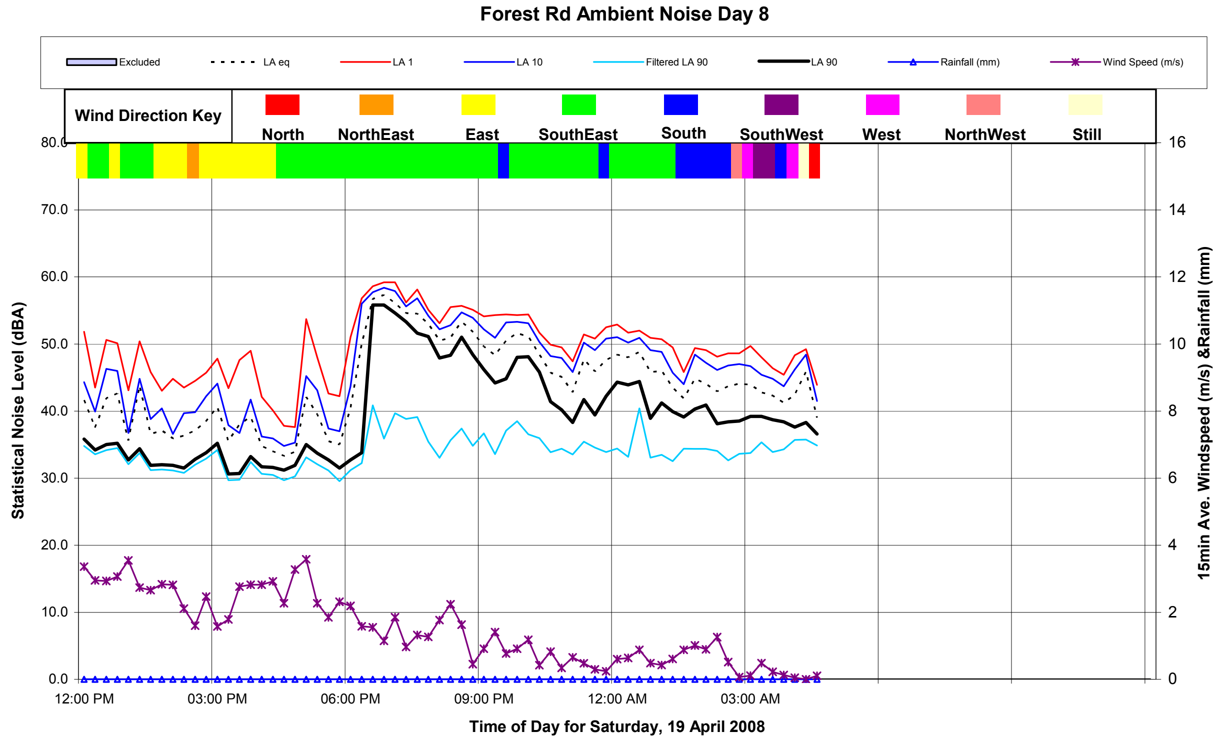

Tangerine forest Road 000 History (12/04/2008 7:00:00 PM) - Leq (T) - A
Frequency (Hz)
One third octave sound pressure level (dBA)
dB
Wed 16/04 12:00:PM
Wed 16/04 3:00:PM
Wed 16/04 6:00:PM
Wed 16/04 9:00:PM
Thu 17/04 12:00:AM
Thu 17/04 3:00:AM
Thu 17/04 6:00:AM
Thu 17/04 9:00:AM
Thu 17/04 12:00:PM

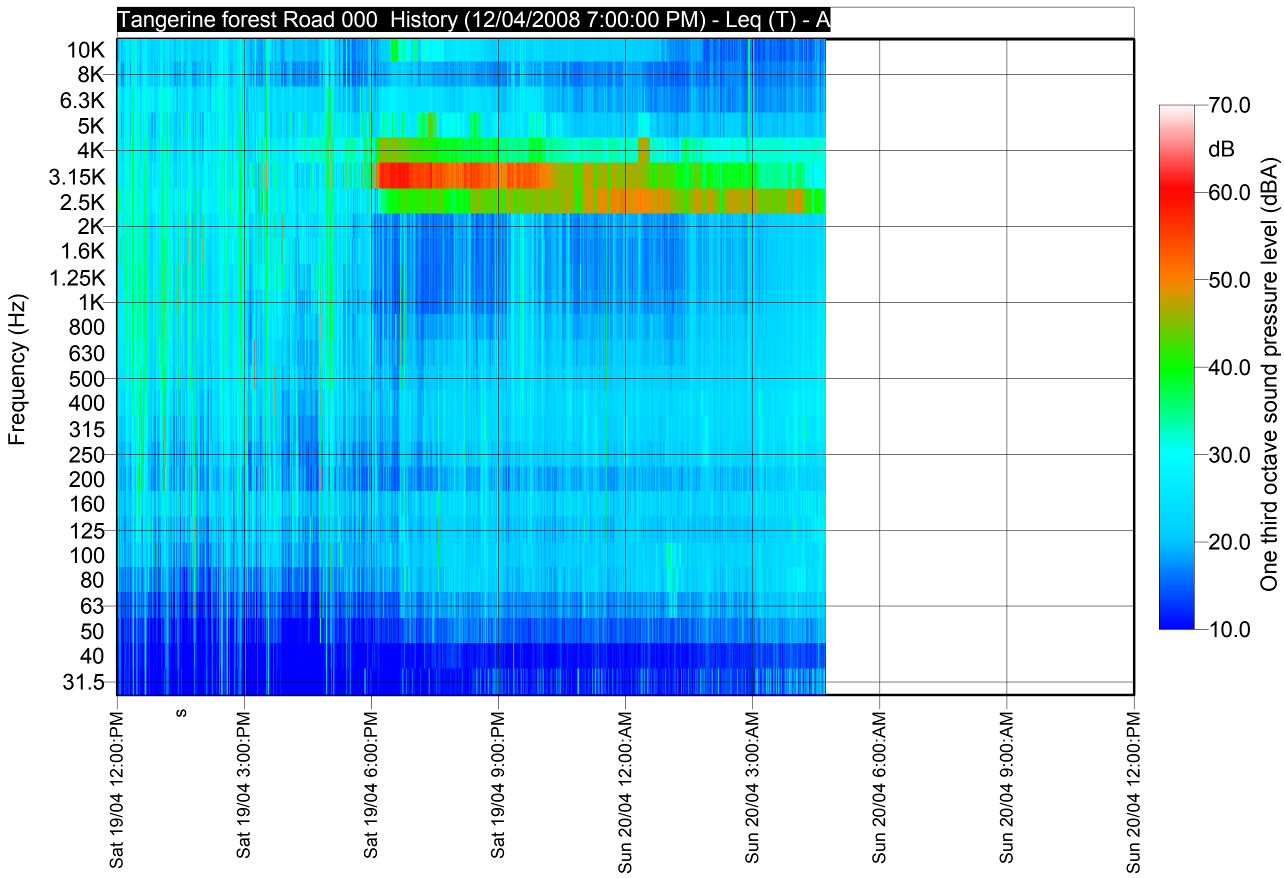

Forest Rd Ambient Noise Day 6
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
Time of Day for Thursday, 17 April 2008


Tangerine forest Road 000 History (12/04/2008 7:00:00 PM) - Leq (T) - A
Frequency (Hz)
One third octave sound pressure level (dBA)
dB
Thu 17/04 12:00:PM
Thu 17/04 3:00:PM
Thu 17/04 6:00:PM
Thu 17/04 9:00:PM
Fri 18/04 12:00:AM
Fri 18/04 3:00:AM
Fri 18/04 6:00:AM
Fri 18/04 9:00:AM
Fri 18/04 12:00:PM

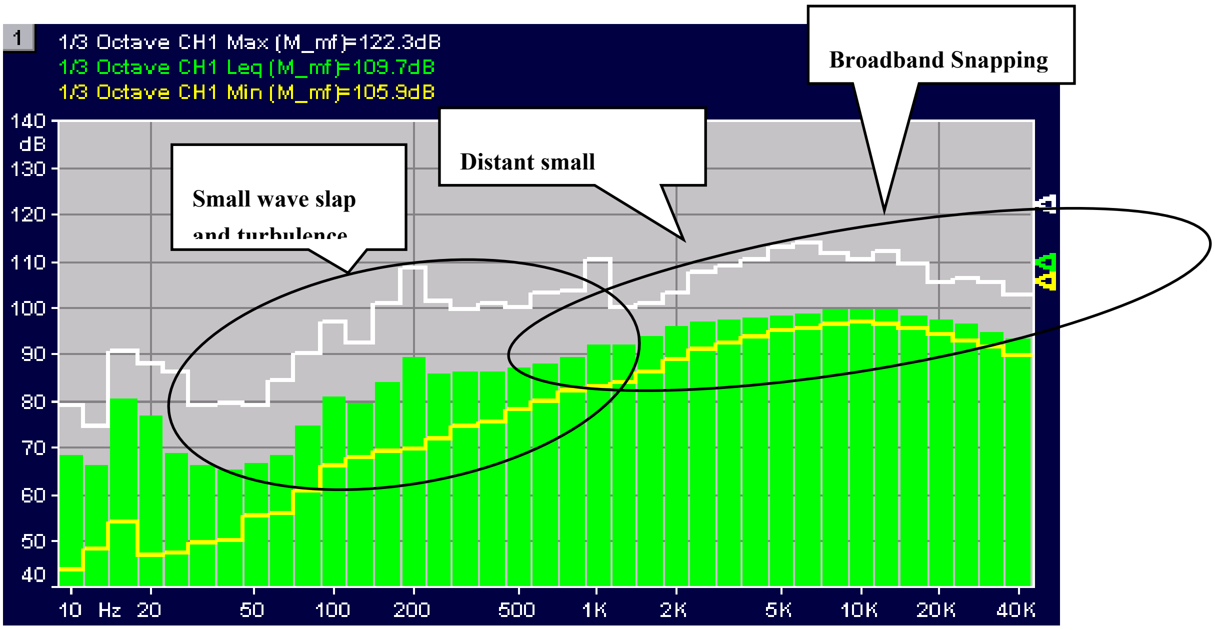

Forest Rd Ambient Noise Day 7
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
Time of Day for Friday, 18 April 2008


Tangerine forest Road 000 History (12/04/2008 7:00:00 PM) - Leq (T) - A
Frequency (Hz)
dB
One third octave sound pressure level (dBA)
Fri 18/04 12:00:PM
Fri 18/04 3:00:PM
Fri 18/04 6:00:PM
Fri 18/04 9:00:PM
Sat 19/04 12:00:AM
Sat 19/04 3:00:AM
Sat 19/04 6:00:AM
Sat 19/04 9:00:AM
Sat 19/04 12:00:PM


Forest Rd Ambient Noise Day 8
Excluded
LA eq
LA 1
LA 10
Filtered LA 90
LA 90
Rainfall (mm)
Wind Speed (m/s)
Wind Direction Key
North
NorthEast
East
SouthEast
South
SouthWest
West
NorthWest
Still
Statistical Noise Level (dBA)
15min Ave. Windspeed (m/s) &Rainfall (mm)
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
03:00 AM
Time of Day for Saturday, 19 April 2008


Tangerine forest Road 000 History (12/04/2008 7:00:00 PM) - Leq (T) - A
Frequency (Hz)
10K
8K
6.3K
5K
4K
3.15K
2.5K
2K
1.6K
1.25K
1K
800
630
500
400
315
250
200
160
125
100
80
63
50
40
31.5
Sat 19/04 12:00:PM
Sat 19/04 3:00:PM
Sat 19/04 6:00:PM
Sat 19/04 9:00:PM
Sun 20/04 12:00:AM
Sun 20/04 3:00:AM
Sun 20/04 6:00:AM
Sun 20/04 9:00:AM
Sun 20/04 12:00:PM
70.0
dB
60.0
50.0
40.0
30.0
20.0
10.0
One third octave sound pressure level (dBA)

Appendix F – Marine baseline noise spectra



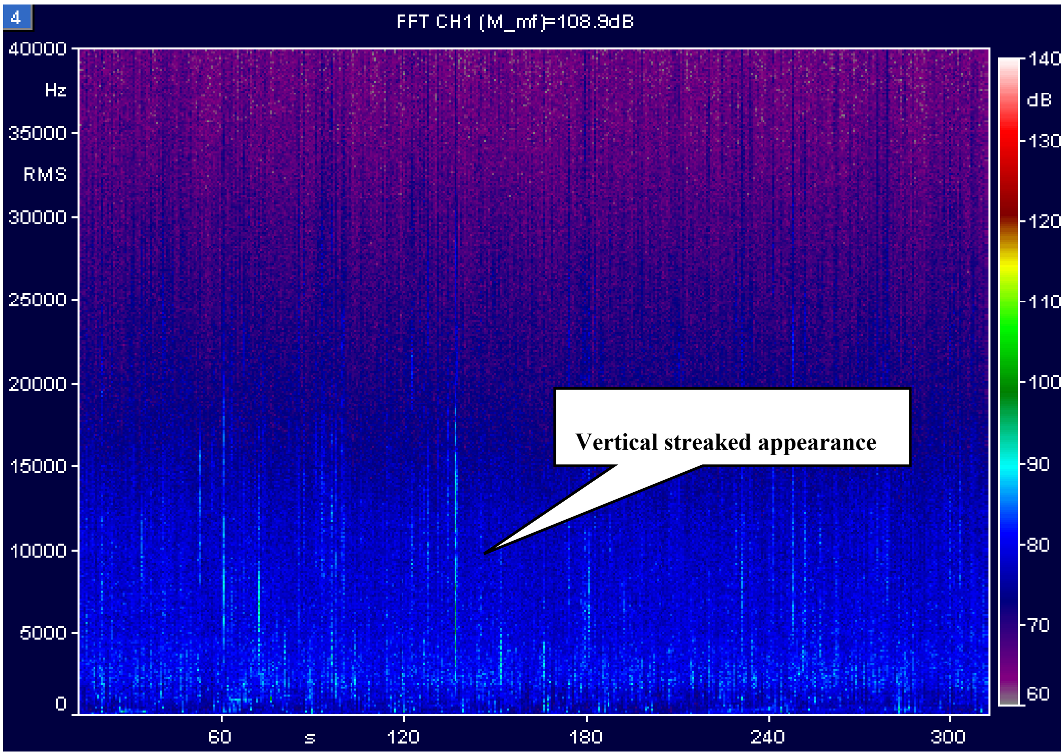
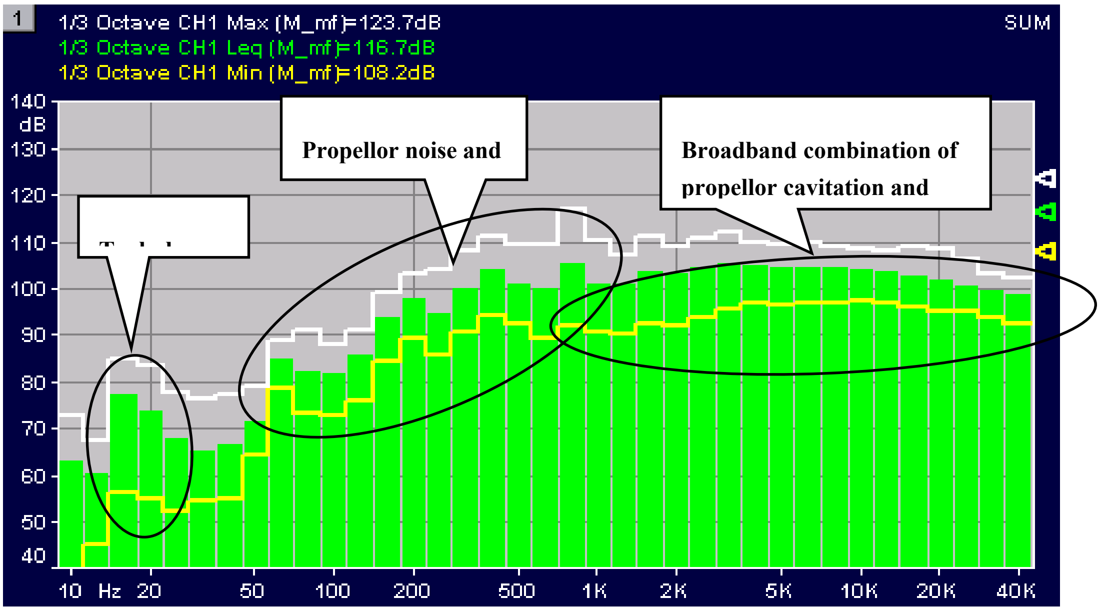


Figure 20: Sample 1: Ambient mid-passage at crossing site –8:35am-8:40am flat water with minimal tidal run – One-third-octave noise spectrum(top graph) and FFT spectral history(bottom graph) – RMS Re: 1µPa



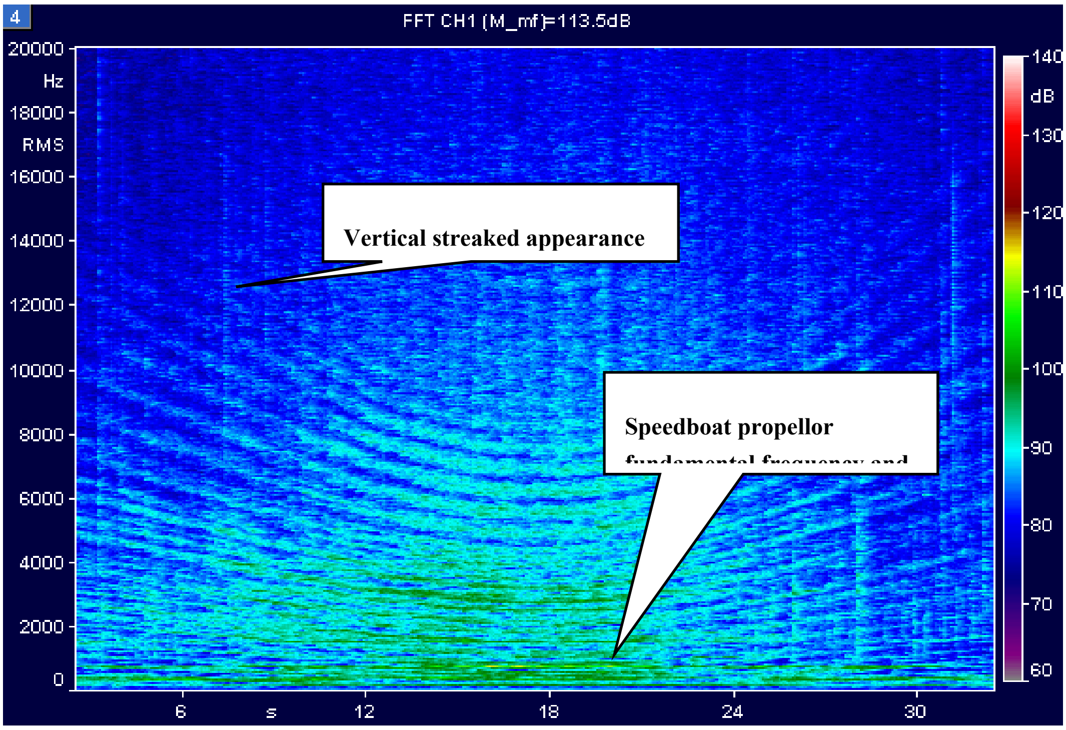
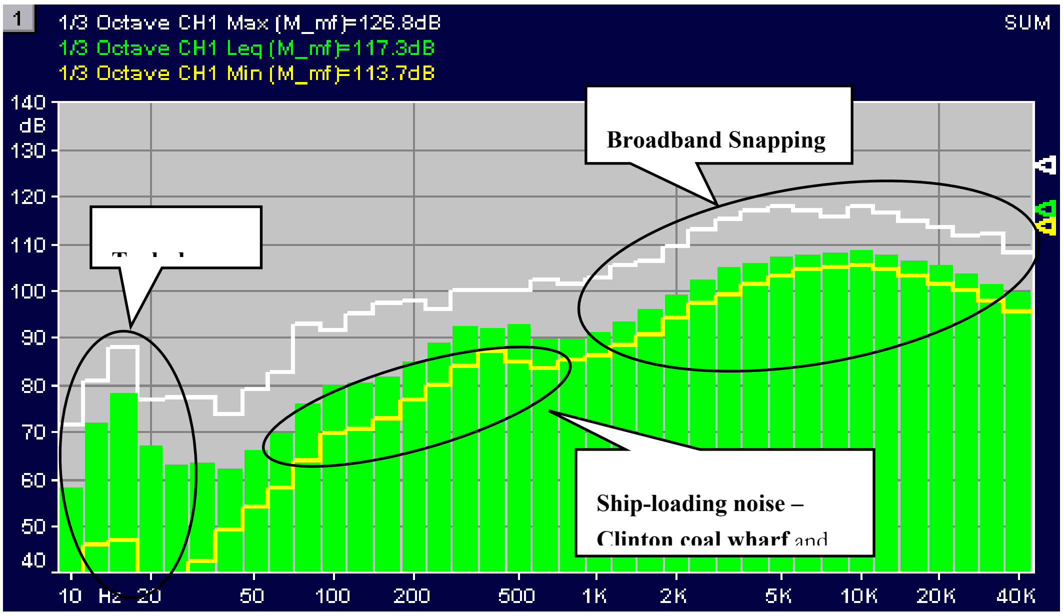


Figure 21: Sample 3: Small speedboat 30 second pass-by along The Narrows at 80m –one-third-cctave noise spectrum(top graph) and spectral history(bottom graph) - RMS Re: 1μPa



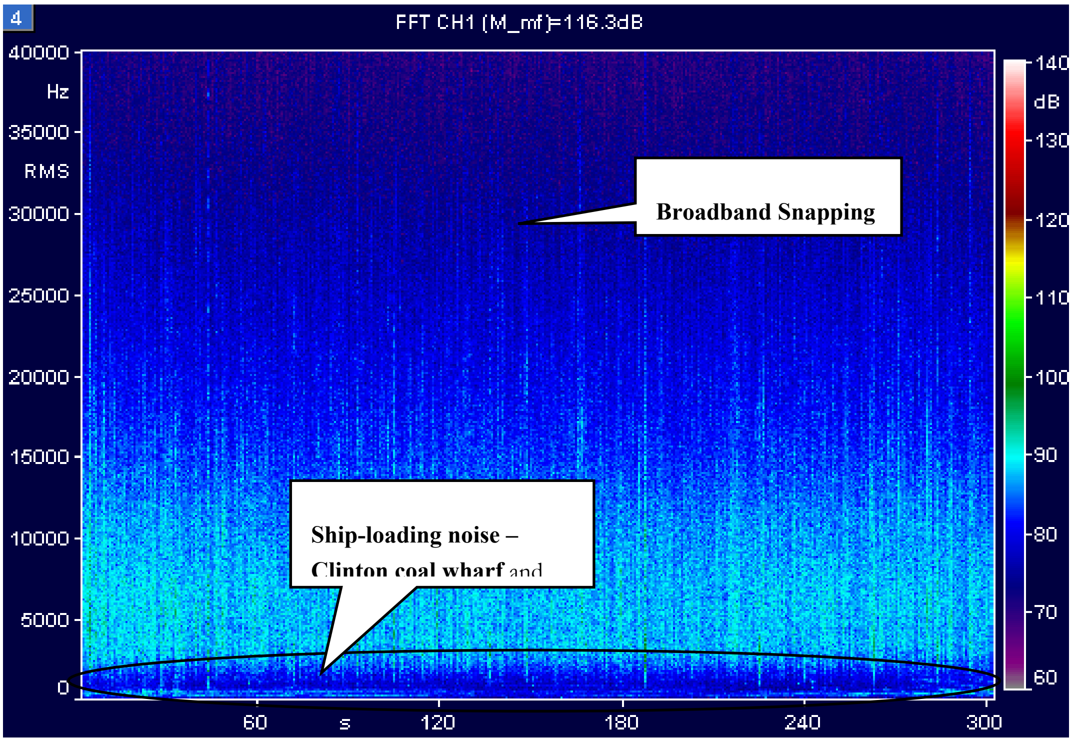
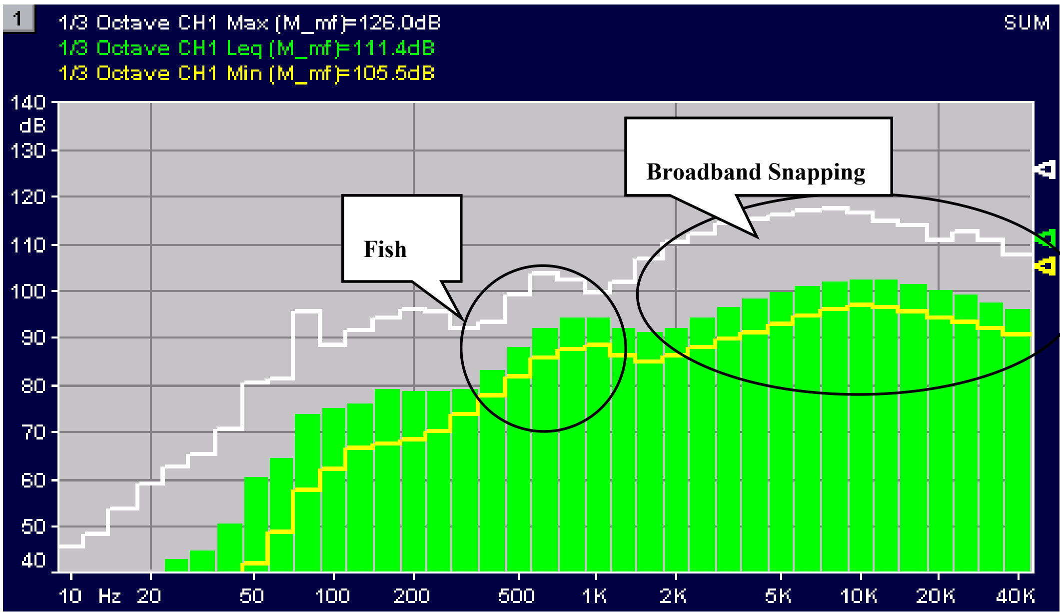


Figure 22: Sample 5: Ambient near Hamilton Point–11:20am flat water with minimal tidal run – one-third-octave noise spectrum(top graph) and FFT spectral history(bottom graph) – RMS Re: 1µPa



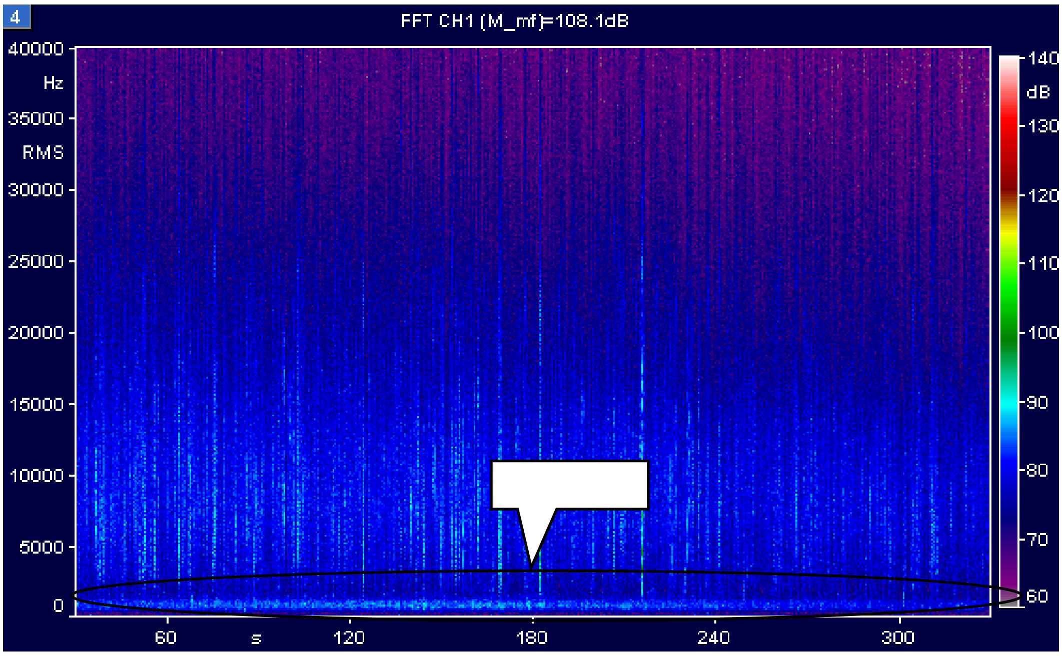
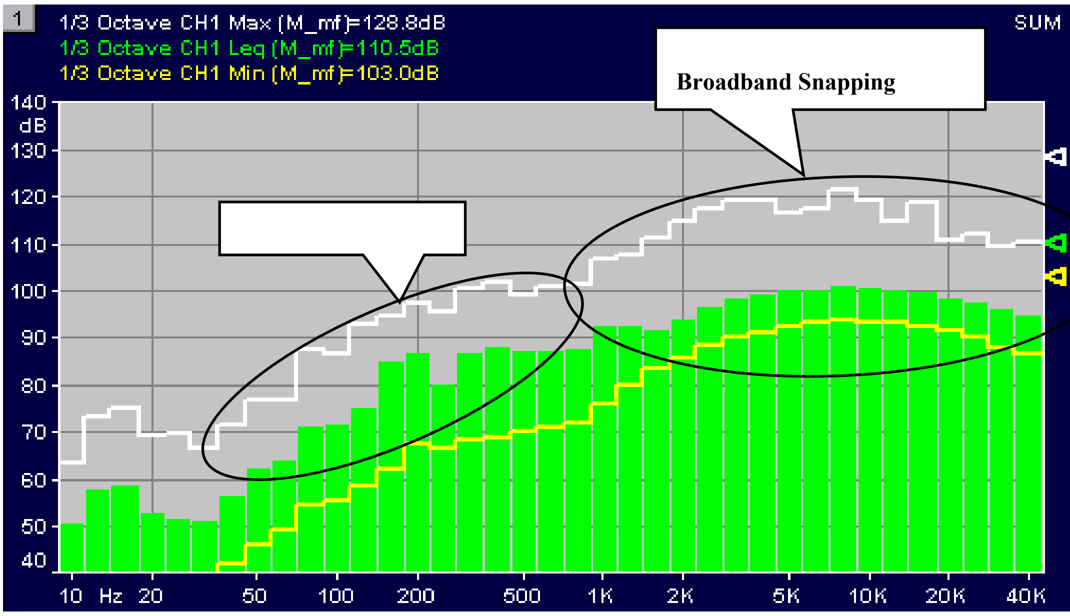


Figure 23: Sample 9: Ambient mid-passage at crossing site –1:35pm flat water with minimal tidal run – one-third-octave noise spectrum(top graph) and 5 minute FFT spectral history(bottom graph) – RMS Re: 1µPa



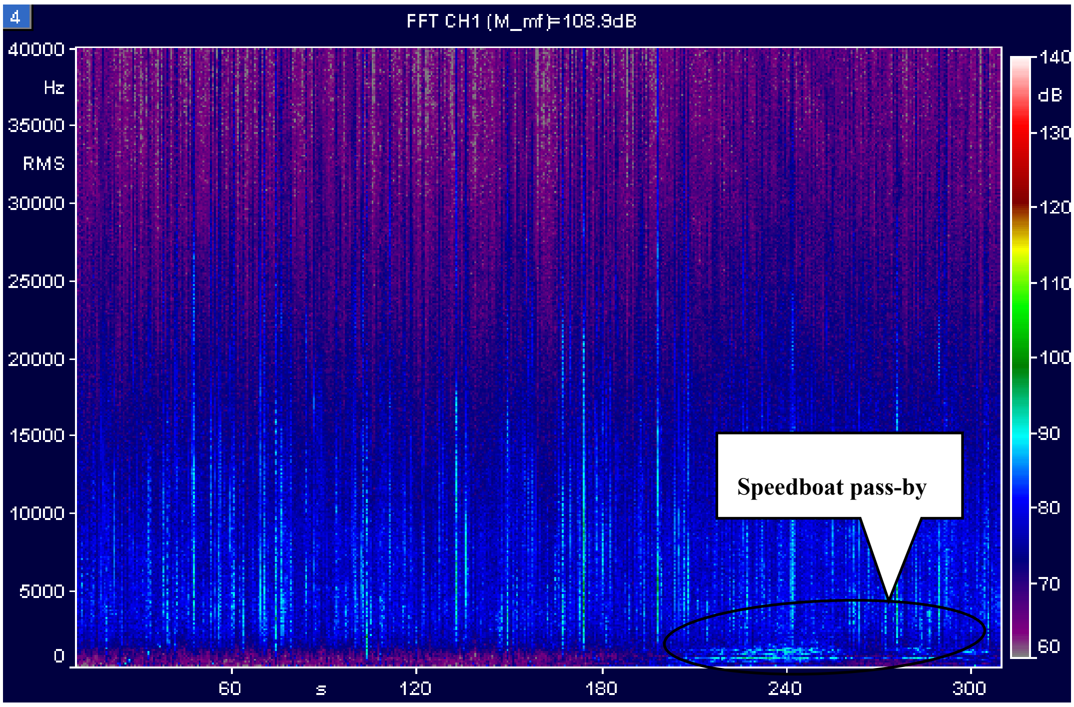
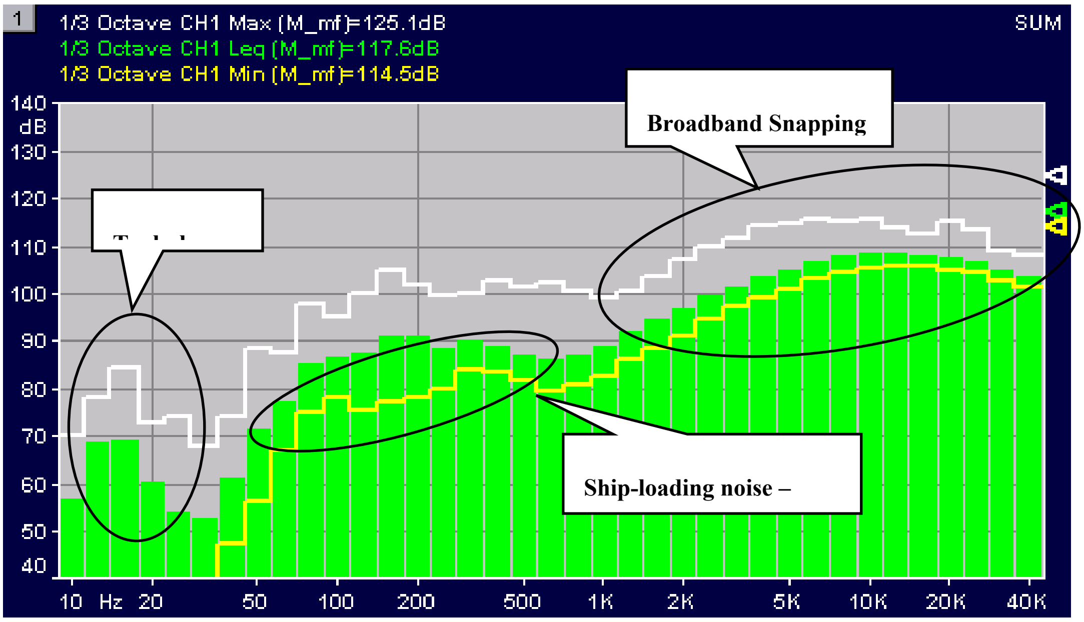


Figure 24: Sample 12: Ambient Grahams Creek entrance –12:30pm flat water with ebb tide – one-third-octave noise spectrum(top graph) and 5 minute FFT spectral history(bottom graph) – RMS Re: 1μPa



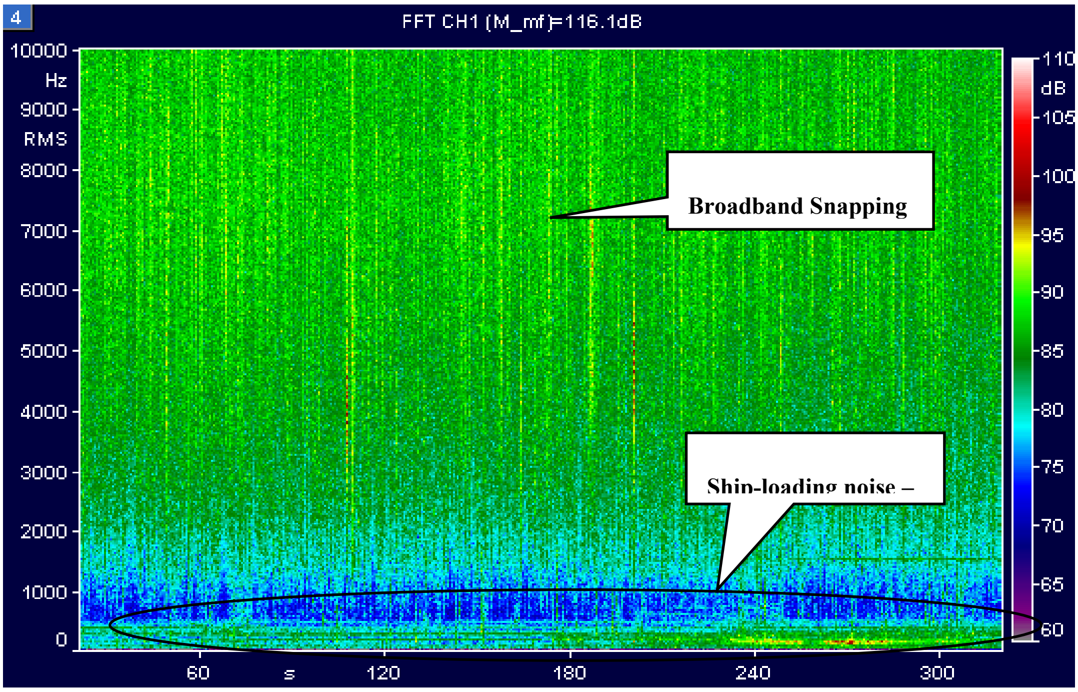


Figure 25: Sample 13: Ambient mid-passage at crossing site –12:45pm flat water with ebb tide – one-third-octave noise spectrum(top graph) and 5 minute FFT spectral history(bottom graph) – RMS Re: 1μPa

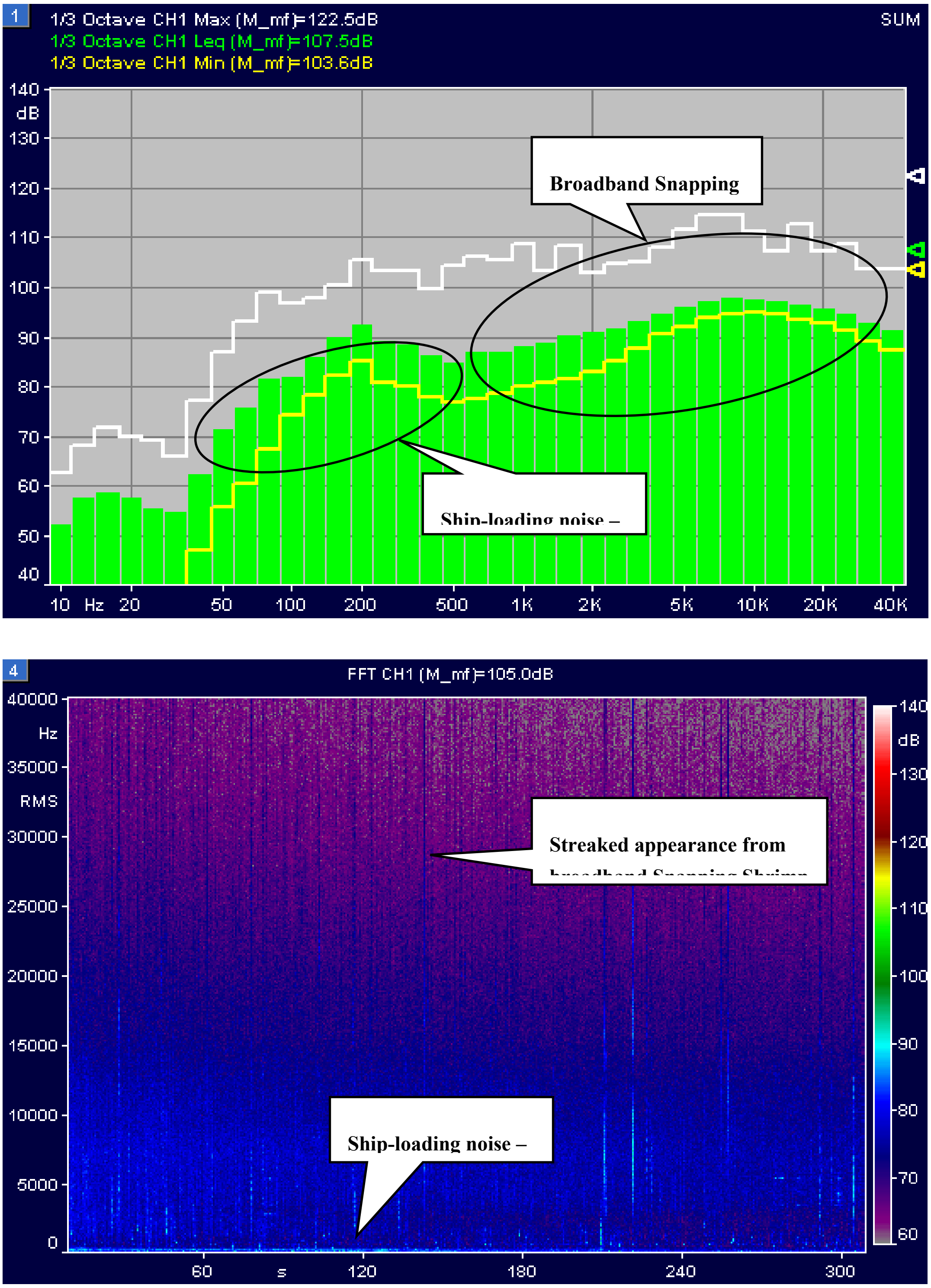
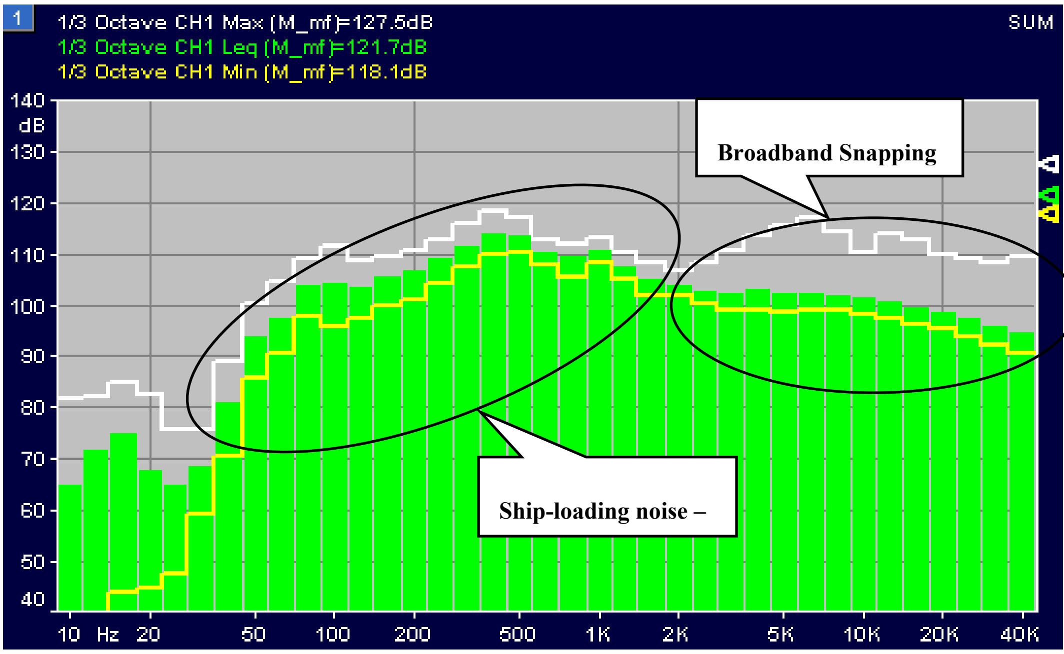


Figure 26: Sample 15: Ambient - passage edge at crossing site –1:03pm flat water with ebb tide – one-third-octave noise spectrum(top graph) and 5 minute FFT spectral history(bottom graph) – RMS Re: 1µPa



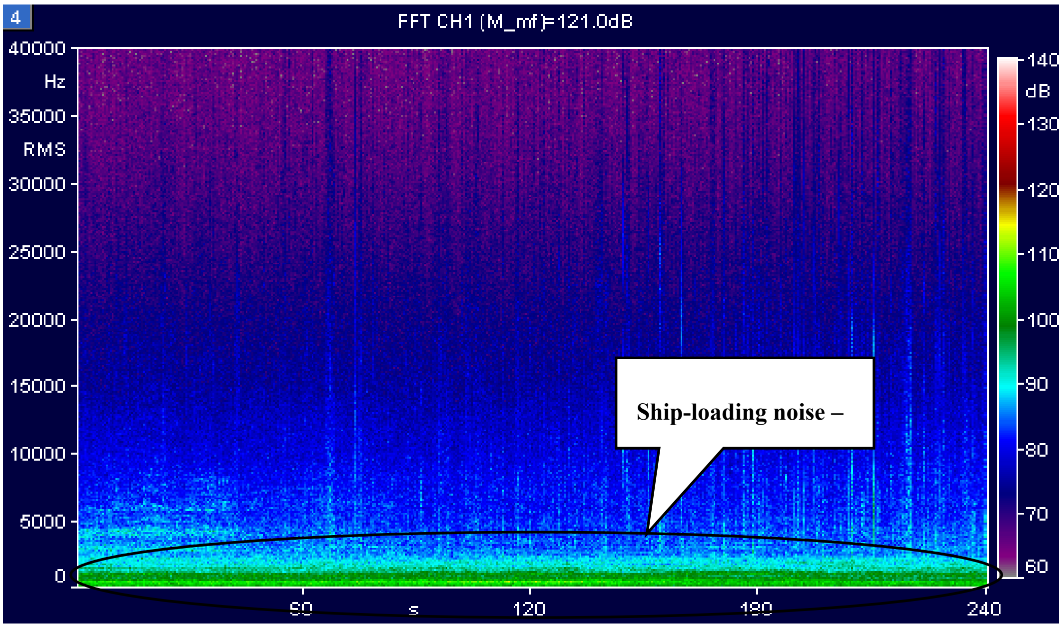
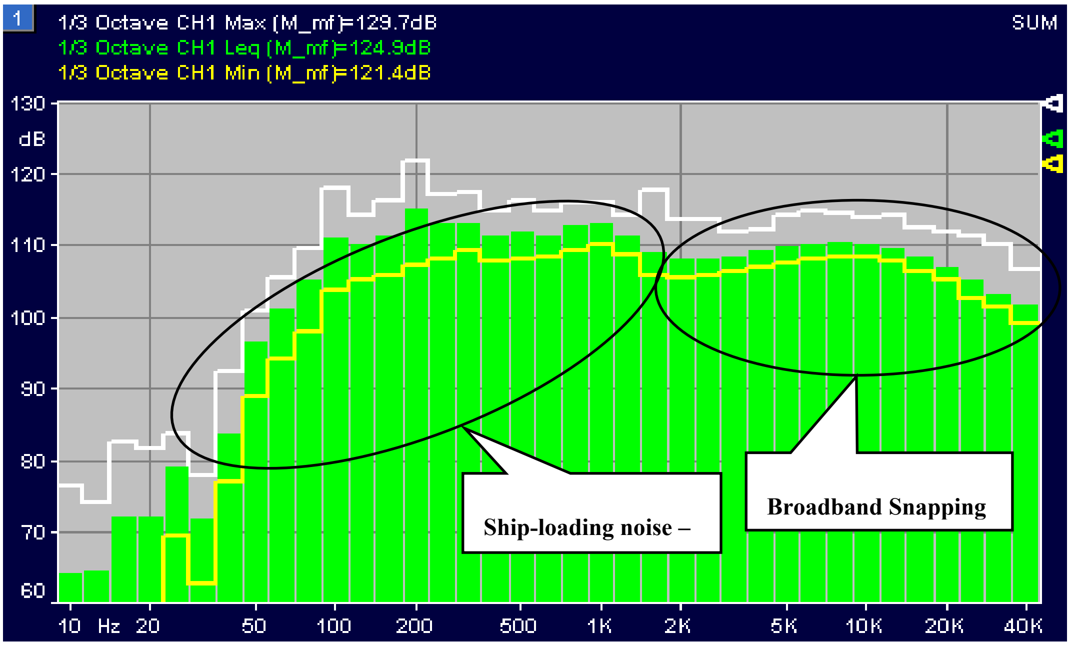


Figure 27: Sample 17: Along-side Fisherman's Landing at 350m –1:24pm flat water with ebb tide – one-third-octave noise spectrum(top graph) and 4 minute FFT spectral history(bottom graph) – RMS Re: 1µPa



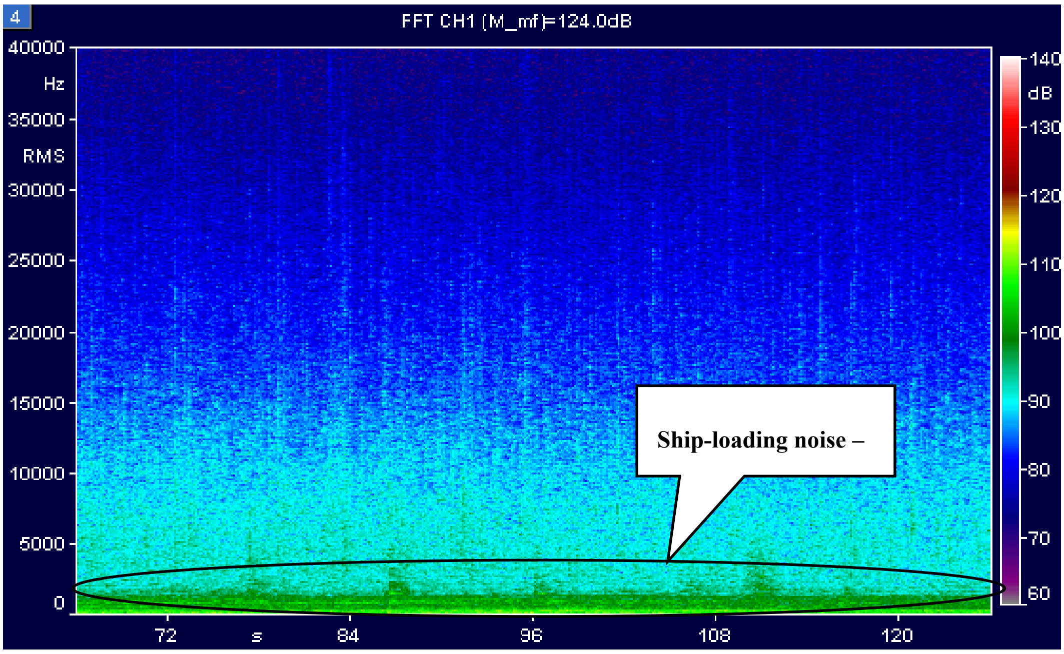


Figure 28: Sample 18: Along-side Clinton coal wharf at 250m –2:06pm flat water with ebb tide – one-third-octave noise spectrum(top graph) and 2 minute FFT spectral history(bottom graph) – RMS Re: 1µPa

Appendix G – Glossary of acoustic terminology

Auditory frequency range

A frequency range in which sounds are potentially perceivable by humans, often reported as 20 Hertz – 20 kiloHertz (1 Hertz = 1 cycle per second).

Airblast overpressure

A measure of the transient air-pressure pulse that is generated by a blast. Units of un-weighted peak pressure, expressed as a decibel level referenced to 20 microPascals (Lpeak).

Ambient noise level

Concept of the all-encompassing noise level environment at a location of interest. A full description of the ambient noise level includes description of level variations in time and variations in the frequency composition in time, including subjective audible characteristics.

Background noise level (L_{Abg})

Concept of the typical minimum ambient noise level, numerically evaluated[50] from the level exceeded for 90 percent of 15-minute sample periods (LA90,15 minute) during a defined time period of interest (e.g. daytime, evening or night-time).

Baseline noise level

Concept of the noise level prior to a development, that can be evaluated by a range of level parameters such as the minimum (LAmin), maximum (LAmax) and percentile descriptors (LA1, LA10, LAeq, LA90)

Broadband noise

A noise with approximately equal acoustic energy distribution over a large range of frequencies, for example 100 Hz – 2 KHz. Natural examples include noise from a waterfall, or the sound of wind in trees.

Construction/blast vibration

Transient oscillating movement of the ground or a building structure from transmission of elastic pressure waves from the vibration source, through the ground to the receptor location.

Far-field

A distance defined to be so far from the noise source that the source can be treated as a point source.

Hydrophone

A microphone designed to be used underwater for recording or listening to underwater sound.

[50] By AS1055 this evaluation is by averaging the $L_{A90,15minute}$ values. By the DERM Planning for noise control guideline this evaluation is more complex, taking the 90th percentile of the $L_{A90,15minute}$ values relevant to the day, evening and night periods on a given day, and then taking the median of the daily results over a minimum seven day period.

RMS (root-mean-square) sound pressure

Mathematical averaging process for the rapid positive and negative acoustic pressure cycles (relative to atmospheric pressure) that constitutes sound, to define a positive equivalent pressure level (relative to atmospheric pressure) with the same energy as the cyclical quantity (because the RMS pressure is a time averaged quantity, it cannot indicate the peak instantaneous pressure such as may be relevant to assessing risk of bursting an ear-drum, as an example).

Sound

Sound consists of small air-pressure fluctuations or pressure waves. The human auditory system responds to both the intensity (pressure-wave amplitude) of a sound and the frequency (number of pressure cycles per second) of a sound. These pressure fluctuations travel along the ear canal and vibrate the ear-drum. The vibrations of the ear-drum are transmitted via the middle-ear to the inner ear where the intensity and frequency are coded into electrical signals for interpretation by the brain. This allows a person to sense the 'pitch' and 'loudness' of a sound.

Statistical acoustic parameters for environmental noise assessment

Common noise sources, such as industrial processes, transportation (cars, trucks, trains), natural noise (wind in trees, birds, insects), vary with time. Therefore, during a measurement period of duration 'T', it is important to define whether the maximum, minimum, average or a percentile statistical level is being specified.

In a quiet rural area, for example, the maximum sound pressure level for a fraction of a second may be 80dBA from a nearby bird call, whereas the minimum sound pressure level between bird calls, and when the trees are still, may be 20dBA. Without statistical definition, the level range of 20dBA to 80dBA would be confusing.

The following sound level parameters are used to describe the 'prevalence' of the acoustic environment at different sound pressure levels (all fast response, A-weighted, RMS sound pressures levels relative to a 20μPa reference pressure):

$L_{Amax,T}$ –the maximum level in time interval 'T'.

$L_{Amin,T}$–the minimum level in time interval 'T'.

$L_{Aeq,T}$ – the theoretical constant level with the same sound energy as the actual fluctuating level in a time interval 'T'.

$L_{A1,T}$ – the level exceeded for 1 percent of time interval 'T'.

$L_{A10,T}$ – the level exceeded for 10 percent of time interval 'T'.

$L_{A90,T}$ – the level exceeded for 90 percent of time interval 'T', often termed the 'background' level.

One-third-octave spectrum

The frequency content of a noise is described by a frequency spectrum. A frequency spectrum can be expressed as a one-third-octave spectrum, which, instead of displaying every frequency individually, is comprised of sub-frequency ranges centred at the following frequencies, measured in Hertz (1 Hertz = 1 cycle per second):

20,25,31.5,40,50,63,80,100,125,160,200,250,315,400,500,630,800,1000,1250, etc.

Planning noise level (PNL)

Nomenclature specific to the DERM Ecoaccess guideline 'Planning for noise control' defining the permissible noise contribution from a proposed facility at a defined receptor

Rating background noise level (RBL)

Nomenclature specific to the DERM Ecoaccess guideline 'Planning for noise control' defining the background noise level from LA90,15miute levels during the day, evening and night over a minimum seven day period.

Response time

The human auditory system has a certain delay in responding to noise. For extremely 'fast' sources of noise, such as a gun-shot at the ear of the firer, the increase in sound is so rapid that the hearing system is unable to respond quickly enough for the protective muscular reflex of the ear-drum to operate.

Sound level meters are designed to emulate the 'response-speed' of the human auditory system. This is conventionally described as the 'fast response' sound level meter response setting.51

Sensitive receptor

A place that may be sensitive to additional noise associated with a proposed development

[51] Objective measures of gun-shot noise or other explosive events, in the context of hearing damage potential, use a peak sound pressure level detection to ensure that the actual maximum sound pressure impacting on the human subject is known.

Sensitivity to sound frequency

At any instant the acoustic environment contains a complex mix of sound components at different frequencies and at different levels. A person speaking, for example, will simultaneously produce vowel sounds typically in the range of 250Hertz to 1kiloHertz, and higher frequency sounds associated with consonants, such as ‘hisses’ and ‘clicks’, in the range of 2kiloHertz to 8kiloHertz.

Human hearing has the greatest ‘sensitivity’ to sound at frequencies in the range of 2kiloHertz to 4kiloHertz, with decreasing sensitivity at higher and lower frequencies. At 1kiloHertz, the sensitivity is only slightly lower (-1dB, or around 90% of optimal pressure sensitivity), whereas at 100Hertz the sensitivity is much lower (-19dB, or around 10% of optimal pressure sensitivity).

Sensitivity to sound level

Laboratory testing of the hearing of a large number of human subjects has been conducted by scientists to determine the ‘threshold’ of human hearing. This threshold is the quietest sound that can be just determined by the human ear under ideal (quiet) laboratory conditions. This nominal hearing threshold has been quantified as a root mean squared (RMS), or ‘average’ pressure fluctuation of 0.00002 Pascals or 20 microPascals (20μPa).

The upper limit of human hearing for sounds of short duration is an RMS pressure fluctuation of around 20Pascals (20Pa). Above this level, the auditory system is rapidly unable to translate information about level and frequency.

To provide a more manageable scale for the wide numerical range of sound pressures that the human ear is able to respond to (i.e. 0.00002Pa to 20Pa), it is conventional to define a ‘sound pressure level’ as the ratio of a given sound pressure (p) relative to the human threshold of hearing (pref = 20μPa RMS) as follows:-

Sound pressure level, Lp = 10*log10(p2/pref2)

With this definition, the nominal threshold of hearing becomes zero decibels (or 0dB), and the maximum, clearly audible level becomes 120dB, referenced to 20μPa.

0dB equates to the quietest level of introduced sound that a person with healthy hearing can detect in a much quieter laboratory. A level of 120dB might be experienced close to speakers at a loud rock concert, or near an industrial nailing gun. Two people standing a metre apart and conversing might speak at levels that are about 50dB to 60dB.

Laboratory studies have found that a 10dB increase in a sound is perceived as approximately doubling in loudness. Conversely, a 10dB decrease in a sound is perceived as halving in loudness.

Sound exposure level (SEL)

The total sound energy produced by a noise event of interest, such as an aircraft flyover, a single pile strike, or the total sound exposure over a defined period such as an 8 hour working day, or 24 hour period.

Sound level meters and A-weighting

The sound level meter was invented to enable systematic investigation and study of sound that is of concern to humans. One of its tasks is to gauge the level of a sound as it may be perceived by the human ear. This is not easy as the human ear not only has different sensitivities depending on the frequency of sound, but the sensitivity also changes as the level of sound changes.

The 'A-weighting' system is an internationally agreed system of sensitivity adjustments to measured sound at frequencies ranging from 10Hz to 20kHz, enabling a sound level meter to approximate the sound level response of the human auditory system. A sound pressure level with an 'A frequency weighting' or A-weighting is an approximate gauge of the significance of a measured sound pressure level to the human ear.

A measured sound pressure level that incorporates A-weighting is denoted LpA, and has units of dB(A), often written as dBA.

Sound power

The total sound radiated from a source per unit of time, expressed in decibels relative to 1 x 10-12 Watts.

Threshold shift (temporary, TTS)

Exposure to noise that causes the auditory system of a human or animal to temporarily lose some degree of sensitivity to sound, where the sensitivity is recovered after cessation of the noise exposure.

Threshold shift (permanent, PTS)

Exposure to noise that causes the auditory system of a human or animal to permanently lose some degree of hearing sensitivity. The sensitivity is not recovered after cessation of the noise exposure.

Tonality and impulsivity adjustments to measured levels

The human brain tends to 'tune-in' to tones, sound patterns and rhythms to an extent that is not sufficiently reflected by the A-weight fast-response indication of a sound level meter. For example, a person is able to differentiate a distant siren sound from background noise before it will be apparent on an A-weight indicating sound level meter. Similarly, hearing is attuned to sounds that change rapidly in level, such as bangs and knocks, which are described as 'impulsive'. To account for these discrepancies between human sensitivity and sound level meter sensitivity, a 'tonal adjustment' or an 'impulse adjustment' to the measured level is defined.52 A measured sound pressure level that has been adjusted to account for the increased audibility by virtue of its impulsive or tonal characteristics is denoted LA,adj.

[52] The methodology for this adjustment is described in AS1055.1-1997 *Acoustics-Description and measurement of environmental noise Part 1: General Procedures*.

Appendix H – Noise contour maps

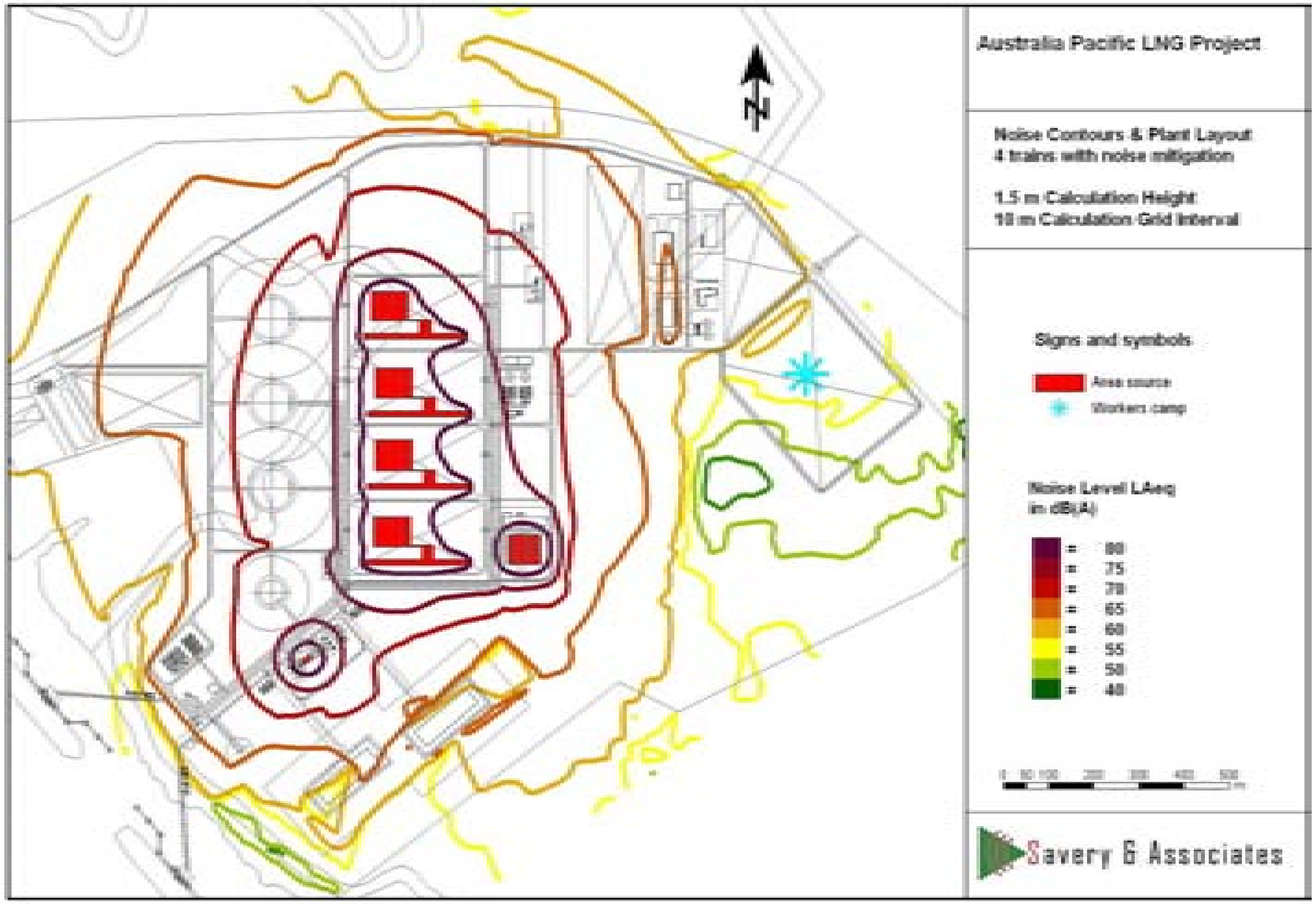


Figure 29: Site area noise contours – four compression train operation –with noise mitigation

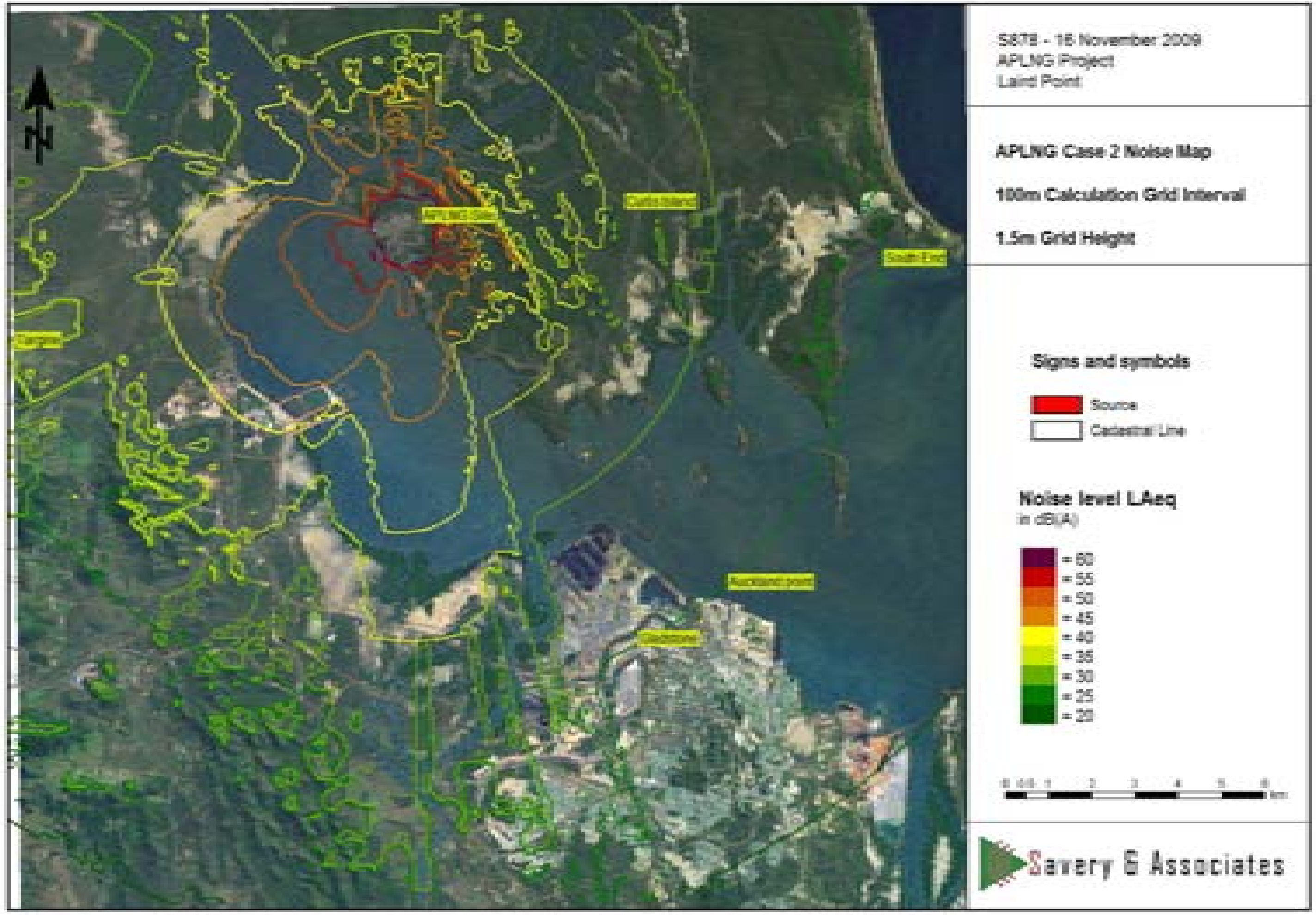


Figure 30: Australia Pacific LNG only – four compression train operation –with noise mitigation

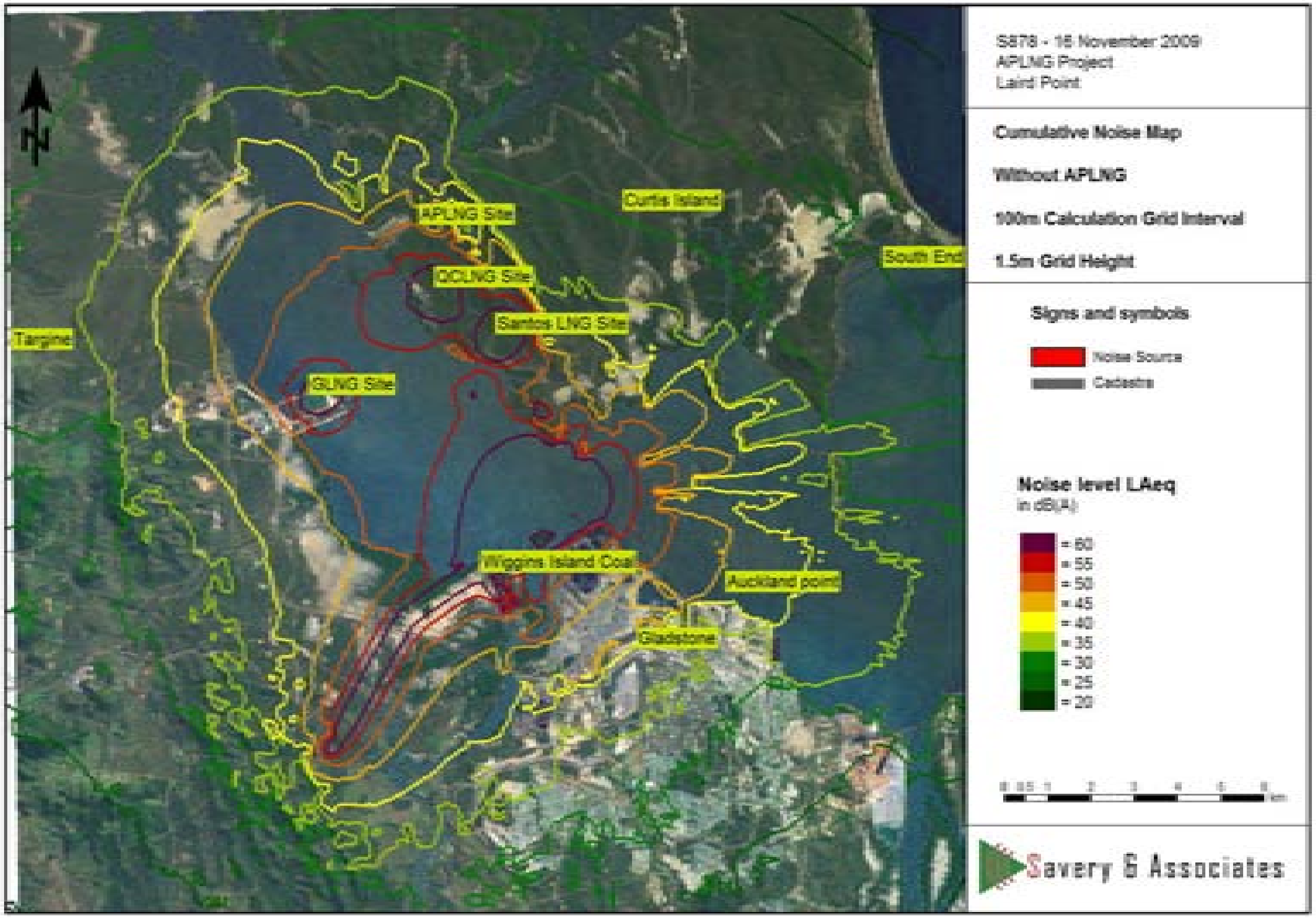


Figure 31: Cumulative noise maps from other existing and proposed industrial facilities (excluding APLNG)

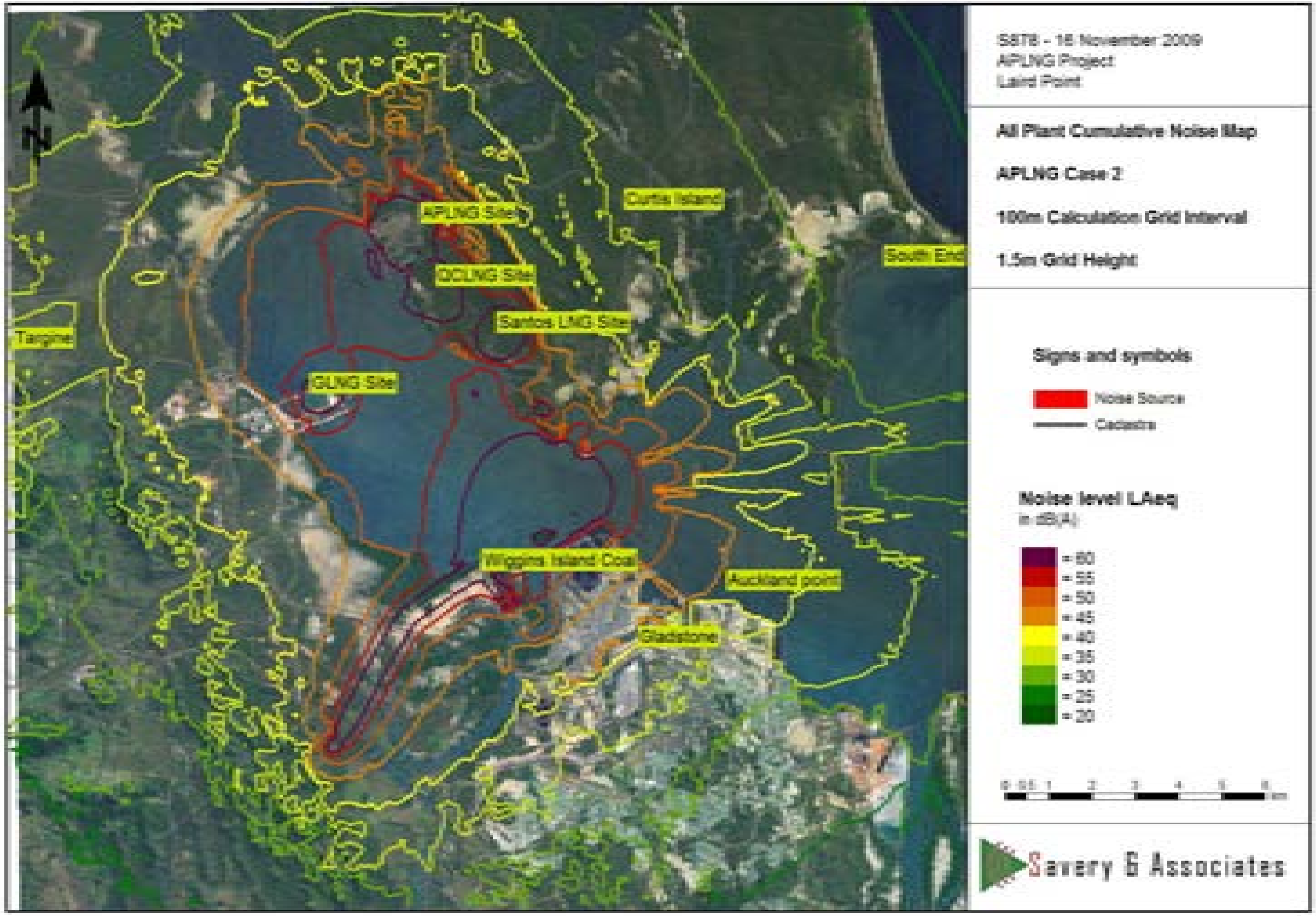


Figure 32: Cumulative noise maps from proposed APLNG Case 2 (mitigated) and other facilities

Appendix I – Noise model source data – plant operation

Table 42: Mitigated sound power levels per Train – L_{Aeq}

Plant group	31.5Hz (dB)	63Hz (dB)	125Hz (dB)	250Hz (dB)	500Hz (dB)	1kHz (dB)	2kHz (dB)	4kHz (dB)	8kHz (dB)	Sum (dBA)
Four boil-off gas compressors 1m above grade.	78	78	93	105	108	112	113	115	101	119
12 gas turbine generators and four compressors 2m above grade.	136	133	130	124	117	115	113	110	105	122
LNG compression train 2m above grade.	121	121	120	113	110	111	111	107	98	117
LNG compression train 10m above grade.	141	140	129	118	114	112	112	110	111	121
LNG compression train 20m above grade.	123	123	123	119	116	113	105	101	97	118
LNG compression train 30m above grade.	102	106	108	108	108	108	103	97	96	112
Ground flare – one burner	125	125	125	118	118	114	114	117	119	123