QCLNG GLADSTONE CHANNEL UNDERWATER NOISE ASSESSMENT

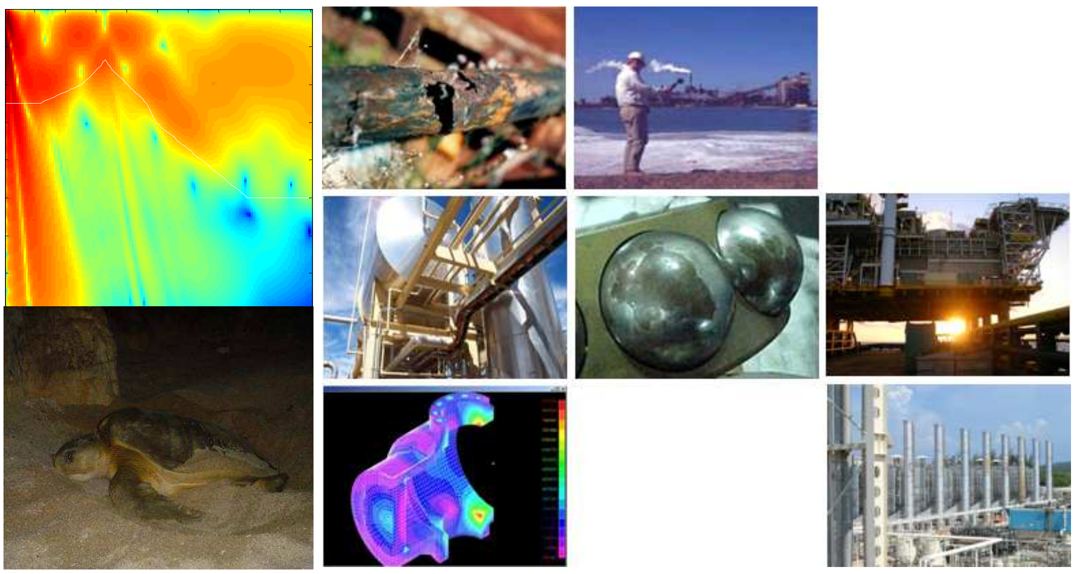

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TABLE OF CONTENTS

1. INTRODUCTION

SVT was commissioned by British Gas (BG) to perform the underwater noise assessment for the underwater noise associated with the proposed Gladstone Channel development. This report documents the outcomes of the underwater noise model and the expected impact on marine fauna from construction activities and LNG tanker operations. The noise modelling was undertaken using noise sources and locations proposed by BG.

1.1 Aim

The aim of this assessment is to assess the impact of underwater noise on turtles, cetaceans, dugongs as a result of QCLNG construction and operational activities in the Gladstone Channel.

1.2 Background

The Queensland Curtis LNG (QCLNG) Project includes the development of existing coal seam gas (CSG) fields in the Surat Basin, western Queensland, the construction of a pipeline network and the construction of a liquefied natural gas (LNG) processing and export facility on Curtis Island near Gladstone in Central Queensland.

1.3 Scope

The scope of this document covers the modelling results for the offshore activities as stipulated by BG and the expected impact of underwater noise on marine fauna. A description of transmission and attenuation of underwater noise and expected received levels is included for the following noise sources:

- Piling at jetty
- Piling at MOF (Materials Offloading Facility)
- Cutter suction dredge (mid to large) at swing basin
- LNG Tanker at swing basin
- Tugboat at swing basin

2. NOISE SOURCES

2.1 Pile Driving

Pile driving operations involve hammering a pile into the seabed. The noise emanating from a pile during a pile driving operation is a function of its material type, its size, the force applied to it and the characteristics of the substrate into which it is being driven.

The action of driving the pile into the sea bed will excite bendy[1] waves in the pile that will propagate along the length of the pile and then into the seabed. The transverse wave component of the wave will create compression waves that will propagate into the ocean while the compression component of the bendy wave will propagate into the seabed. There will also be some transmission of the airborne acoustic wave into the sea.

It can be expected that most of the energy from the hammering action of the pile driver will transfer into the seabed. Once in the seabed, the energy will then propagate outwards as compression and shear waves. Some of the energy may be transferred into Rayleigh waves, which are seismic waves that form on the water/seabed interface, but it is expected that this will be a small portion of the total energy.

Piles can be driven using various methods such as vibration, gravity and hammer. The method that is used is dependent on the size of the pile and the substrate into which the pile is being driven. It is planned that impact hammers will be used for pile driving operations. The noise that is generated by an impact hammer hitting the top of the pile is short in duration lasting approximately 90ms and can therefore be described as an impulsive noise. Table 2-1 is a list of specifications for the pile driving operations at the Jetty and MOF.

Table 2-1 Pile driving specifications

Work Element	Jetty	MOF
Type of pile / TYPICAL	1100 mm dia x 16 mm wall steel pile	Generally 1064 mm dia x 20 or 25 mm wall stell pile & AZ18 Gr270 sheet pile
Depth of piling / TYPICAL	RL -15.00	Circular Pile: RL -12.00 (CD) to RL -17.00 (CD) (wall location dependent) Sheet Pile: RL -11.50 (CD)
Hammer type / TYPICAL	Junttan HH14k Hammer & pwr pack IHC 150 Hammer c/w power pack	Hunttan HH14k Hammer & pwr pack IHC 150 Hammer c/w power pack ICE 416 Hammer & pwr pack ICE 44-50 Hammer c/w power pack

[1] Bendy wave is a wave that comprises of a compression wave and a transverse wave.

Work Element	Jetty	MOF
Location of barges / INDICATIVE	For Jetty construction, barges located adjacent jetty structure used to feed piles, headstocks, ppc deck panels, etc to Jetty mounted crane. For Dolphin construction the piling frame and piling equipment are barge mounted.	Flat deck barges c/w crawler crane, positioning winches and piling hammers will be located immediately over pile driving locations. Various dumb barges will be adjacent to piling barge(s) with ancillary pile driving equipment and as support for barge crane.
Location of piles / INDICATIVE	For Jetty approach, @ 18m Crs	tbc
Approximate durations for piling / INDICATIVE	Say 1 pile/day	Say 1 pile/day
Work-hours – i.e. is it a 24 hour a day / 7 days a week operation or work hours only?	Assume 8 day x 10 hrs, Mon-Fri. When/if welding of piles required, this would be undertaken on evening shift	Assume 9 day x 10 hrs, Mon-Fri. When/if welding of piles required, this would be undertaken on evening shift.

2.2 Cutter Suction Dredging

Dredging is an excavation operation carried out at least partly underwater, in shallow seas or fresh water areas with the purpose of gathering up bottom sediments and disposing of them at a different location.

A cutter suction dredger employs a suction tube with a cutter head at the suction inlet, to loosen the earth and transport it to the suction mouth. The cutter can also be used for hard surface materials like gravel or rock. The dredged soil is usually sucked up by a wear-resistant centrifugal pump and discharged through a pipe line or to a barge.

2.3 Shipping (Tug and LNG Tanker Operations)

Typically shipping of LNG out of the Port of Gladstone will be undertaken by BG Group, with LNG ships being either a combination of vessels owned by BG Group, BG Group associated companies or vessels contracted by BG Group to carry cargo. On occasions throughout the Project life, vessels not contracted by BG Group may also be used.

The planned LNG production rate suggests that approximately 60 LNG vessels will be loaded per year per LNG process train (i.e. approximately 180 LNG vessels per year with three trains operating, with some variation due to variation in ship capacity).

Movement of LNG tankers through the Great Barrier Reef Marine Park (GBRMP) will be within approved shipping zones and conducted under Australian Maritime Safety Authority (AMSA) approved shipping operations.

The operation of the swing basin involves the use of a tug boat to assist in docking the LNG tanker at the wharf. In terms of acoustic emissions, in a worst-case operating scenario a tug boat and LNG tanker will be in operation near the wharf simultaneously. The specific vessel sound sources are propeller cavitation and engines that together generate a continuous sound spectrum.

3. ASSESSMENT CRITERIA

Unlike airborne noise, where impact levels on humans have been regulated, assessment levels for underwater environmental noise impacts have not been defined in regulation except in the case for cetaceans where the EPBC Act policy statement 2.1 applies. As a result assessment levels in this report are determined from peer reviewed and widely accepted literature.

3.1 Zones of Interest

For underwater noise impacts on marine fauna two effects are of interest, namely physical injury and avoidance. These two effects result in the determination of two areas or zones of interest for underwater noise assessments. These areas or zones are as follows:

1. **Area of Possible Physical Injury**. In this area there is a possibility that the animal may suffer physical injury and/or permanent hearing damage.
2. **Area of Possible Avoidance**. In this area there is a possibility that the animal may experience masking and/or behavioural change and/or avoid the area.

3.2 Turtles

3.2.1 Auditory sensitivity

The sea turtle's auditory canal consists of cutaneous plates underlain by fatty material at the side of the head which serves the same function as the tympanic membrane in the human ear. Vibrations are transmitted through the cutaneous plates and underlying fatty tissue to the extracolumella. The extracolumella has a mushroom-shaped head which is loosely attached to the outer middle ear cavity. The extracolumella has a long shaft-like shape which extends through the middle ear and is responsible for transmitting the sound to the stapes in the auditory canal. The footplate of the stapes in turn is responsible for transmitting the acoustic energy through the oval window into the otic cavity which performs a similar function to that of the human cochlea.

Measurements on the cochlea potentials of giant sea turtles have shown their upper auditory limit to be approximately 2 kHz and their maximum sensitivity is between 300 and 400 Hz [2]. Studies using auditory brainstem responses[3] of juvenile Green and Ridley's turtles and sub-adult Green turtles showed that juvenile turtles have a 100 to 800 Hz (Figure 3-1) bandwidth, with best sensitivity between 600 and 700 Hz, while

[2] Ridgway *et al*, 'Hearing in the Giant Sea Turtle, Chelonia mydas', Proc N.A.S, Vol 64, 1969

[3] Some uncertainties regarding Auditory Brainstem Response (ABR) and behavioural audiograms are as follows. The temporal summation influences sensitivity to sound (i.e. sounds shorter than some critical value are generally less detectable than longer signals). For mammals, this may vary between 30 and 800ms.These long pulse lengths cannot be created in a tank that is limited in size without reverberation. If a reference hydrophone is not placed in close proximity to the subjects head then the received levels will be unknown as reverberation has not been considered. SVT is unable to confirm if the sound field is measured at the head of the subject. Some other issues concerning ABR are that the subjects are often drugged. From the reviewed papers it appears that some of the drugs may affect hearing. Another issue is that the number of subjects tested is small and therefore the statistics of the sample size are not stable. Considering all the above, and knowing that there are inaccuracies in the ABR technique, SVT determined the optimum approach was to take the widest bandwidth of the known audiogram with no weighting added to it (i.e. it was assumed that the audiogram frequency response was flat and that there was no attenuation). This is equivalent to taking a linear weighting and not an A-weighting for the human case. This is considered a conservative approach and it is felt that it is reasonable under the circumstances.

adults have a bandwidth of 100 to 500 Hz (Figure 3-2), with the greatest sensitivity between 200 and 400 Hz [4,5]. This indicates that a turtle's frequency and sensitivity bandwidth decreases with age.

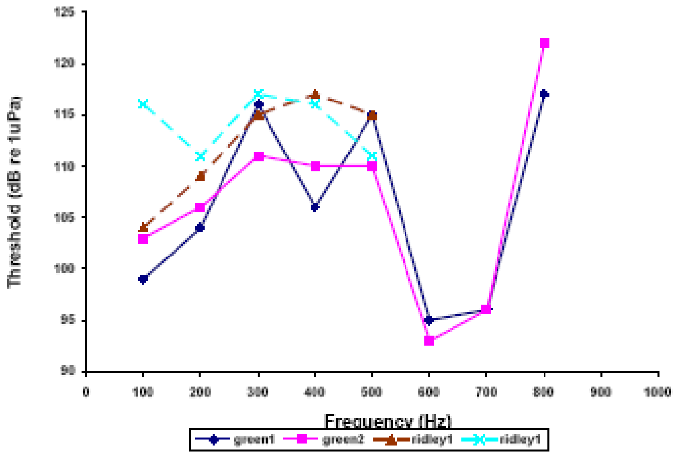

Figure 3-1 Audiograms of two juvenile green turtles and two juvenile Ridley's turtles[6]

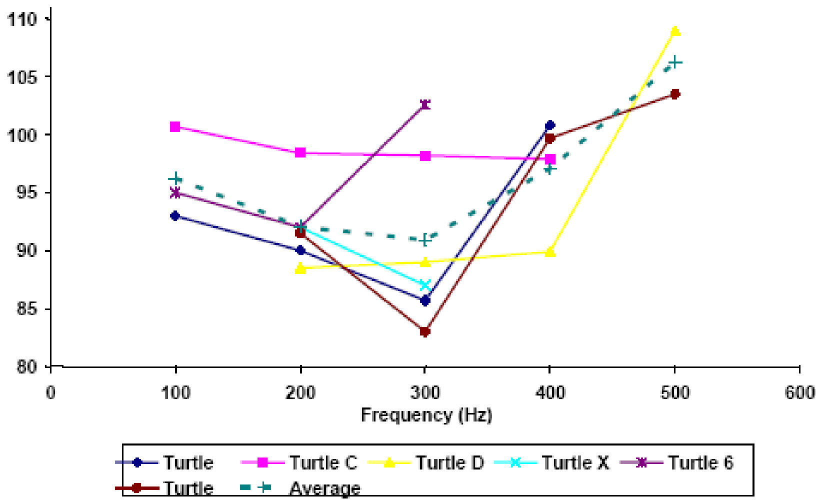

Figure 3-2 Audiograms of six sub-adult Green turtles[7]

3.2.2 Physical injury

Little is known about the source levels and associated frequencies that cause physical injury to a turtle. Some studies on the effects of explosions on turtles recommend that an empirically-based safety range be used for guidance[8]. Using the safety range formula as noted[9] and converting back to peak SPL using Ross[10]

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[4] Ketten and Bartol,' Functional Measures of Sea Turtle Hearing', doc no. 20060509038, Sept 2005.

[5] S Bartol. *"Turtle and Tuna Hearing",* Woods Hole Oceanographic Institute, MA, USA, as part of NOAA Technical Memorandum NMFS-PIFSC-7, December 2007

[6] S Bartol. *"Turtle and Tuna Hearing",* Woods Hole Oceanographic Institute, MA, USA, as part of NOAA Technical Memorandum NMFS-PIFSC-7, December 2007

[7] S Bartol. *"Turtle and Tuna Hearing",* Woods Hole Oceanographic Institute, MA, USA, as part of NOAA Technical Memorandum NMFS-PIFSC-7, December 2007

[8] Young, G.A. 1991. Concise methods for predicting the effects of underwater explosions on marine life. NAVSWC No. 91-22. Naval Surface Warfare Centre, Silverspring, Maryland, USA.

formula, a value of 222 dB re 1μPa is obtained. Based on this SPL, a value of 222 dB re 1μPa should not be exceeded for adult turtles to avoid physical injury.

Hatchlings will be evaluated using the SEL values for fish. As Flatback hatchling weights can vary between 30 and 51g, the SEL value for hatchlings will be taken as 198 dB re 1μPa^{2}s, assuming that hatchlings will suffer the same effects as fish exposed to a similar impulsive pressure wave. This is based on the no injury regression line in Figure 3-3[11].

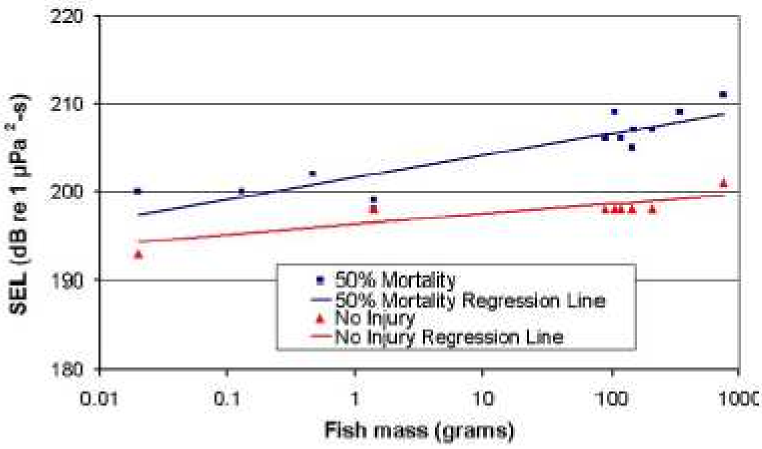

Figure 3-3 Fish mortality regression line plotted against SEL and fish mass

3.2.3 Threshold Hearing Loss

No supporting literature could be found to determine acceptable levels of continuous noise to prevent threshold shift in turtles.

3.2.4 Masking and behavioural change

Only limited literature could be found that shows what SPL will affect the turtles' behavioural patterns or mask their communications. Tests done on two Green and two Loggerhead turtles showed that at levels of between 166 and 175 dB (rms) re 1 μPa there was a noticeable increase in swimming behaviour which was presumed to be avoidance response[12].

3.2.5 Correlating noise levels to biological sound effects

Based on information in the preceding sections, the peak pressure and SEL values are of interest with regard to their effects of noise on turtles are given in Table 3-1.

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[9] Keevan and Hempen,' THE ENVIRONMENTAL EFFECTS OF UNDERWATER EXPLOSIONS WITH METHODS TO MITIGATE IMPACTS, U.S. Army Corps of Engineers, Aug 1997.

10 D. Ross. Mechanics of underwater noise. Penisula Publishing. Los Altos. California, USA

[11] Popper *et al* (Interim Criteria for Injury of Fish to Pile Driving Operations: A White Paper) suggest a 187 dB re 1μPa2s criterion for fish. This is based on the 50% mortality line and testing done on 0.01 g fish. Considering the rationale behind the criteria it was decided to use the no mortality regression line and the weight of the turtle hatchlings.

[12] McCauley RD, *et al*,2000,'Marine Seismic Surveys: analysis and propagation of air-gun signals; and effects of exposure on humpback whales , sea turtles, fishes and squid'. R99-15, Perth Western Australia.

Table 3-1 Estimated received levels at which there is a possibility of physical injury or behavioural effect for Turtles.

	Possible Physical Injury	Possible Avoidance
Peak Pressure	222 dB re 1µPa[13]	175 dB re 1µPa[14]
SEL	198 dB re 1µPa[15]	No Data Available

3.3 Cetaceans and Dugongs

3.3.1 Auditory sensitivity

Whales and Dugongs have typical mammalian ears that consist of a middle ear and cochlea. Ears are the organs most sensitive to pressure and, therefore, to injury. Severe damage to the ears can include damage of the tympanic, fracture of the ossicles, cochlear damage, haemorrhage, and cerebrospinal fluid leakage into the middle ear.

The effects of anthropogenic noise on Baleen[16] whales is a topic of intense interest not only to marine mammalogists but also to a variety of commercial interests, the military, oceanographers, and researchers that use sound in the ocean. One issue in setting standards for noise exposure levels is the absence of knowledge of the auditory properties of Baleen whales.

Humpback whales produce a complex set of vocalised song patterns. The spectrum of the patterns has been measured to be between 20 and 24000 Hz with maximum peak to peak source level of 184dB re 1µPa @ 1m [17]. It can be assumed that this bandwidth and source level is indicative of the whales auditory bandwidth and auditory sensitivities.

3.3.2 Assessment of Noise Impacts

The criteria that will be used for the assessment of cetaceans and dugongs are given in Table 3-2. They are based on the criteria recommended by Southall *et al*[18] and the EPBC Act policy statement 2.1. The following technical notes should be considered regarding the assessment criteria.

The Southall *et al* physical injury criteria are based on experiments conducted on mid frequency mammals (i.e. beluga whales and bottlenose dolphins). Due to the lack of data for low frequency mammals (i.e.

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[13] This value is derived from estimated physical injury levels that have resulted in physical injury to turtles from explosions.

[14] McCauley et al, 'Marine Seismic Surveys- A study of Envornmental Implications' APPEA Journal 200, pg 692-708

[15] This value is applicable to turtle hatchlings only.

[16] The baleen whales, also called whalebone whales or great whales, form the Mysticeti, one of two suborders of the Cetacea (whales, dolphins, and porpoises).Baleen whales are characterized by having baleen plates for filtering food from water, rather than having teeth. This distinguishes them from the other suborder of cetaceans, the toothed whales or Odontoceti. The scientific name derives from the Greek word mystidos, which means "unknowable". The Humpback whale is a Baleen whale.

[17] Whitlow *et al*, 'Acoustic properties of humpback whale songs', JASA, 120(2), Aug 2006.

[18] Aquatic Mammals, Volume 33, Number 4, 2007, ISSN 0167-5427

humpback whales) the data for mid frequency mammals is recommended by Southall *et al* to be used for low frequency mammals.

The avoidance criteria recommended by both Southall *et al*[19] and the EPBC Act policy Statement 2.1 are based on observational data predominately from seismic surveys. It must be noted that observational data is by no means conclusive. Additionally seismic pulses on which the criteria are based are different both in spectrum and time to that of a pile driving pulse. However, as there is no data available that can be used to determine the criteria for pile driving, the criteria for seismic surveys will be used.

Note that the 160 dB re1µPa^2.s SEL value for possible avoidance obtained from the EPBC Act Policy Statement 2.1 is based on a seismic pulse made once every ten seconds.

Table 3-2 Estimated received levels at which there is a possibility of physical injury or behavioural effect for Cetaceans and Dugongs.

Effect	Possible Physical Injury	Possible Avoidance
Peak Pressure	230 dB re 1µPa [20]	224 dB re 1µPa [21]
SEL	198 dB re 1µPa^2.s [22]	160 dB re 1µPa^2.s [23]

[19] Southall et al also considers observational data from other transient sources such as explosions.

[20] Aquatic Mammals, Volume 33, Number 4, 2007, ISSN 0167-5427

[21] Aquatic Mammals, Volume 33, Number 4, 2007, ISSN 0167-5427

[22] Aquatic Mammals, Volume 33, Number 4, 2007, ISSN 0167-5427

[23] EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales

4. METHODOLOGY

4.1 Marine noise

Underwater propagation models use bathymetric data, geoacoustic information and oceanographic parameters as inputs to produce estimates of the acoustic field at any depth and distance from the source. The quality of the model estimate is directly related to the quality of the environmental information used in the model. For example, the geoacoustic parameters of the seabed, such as compressional sound speed, sound attenuation, and sediment density, can significantly affect the acoustic propagation and can therefore affect model predictions. The seabed parameters entered into the model were based on estimates obtained from core samples and seismic surveys.

4.1.1 Model selection

Four categories of acoustic propagation models are used in underwater acoustics: ray, normal mode, parabolic equation (PE) and finite element models. When determining which to use, it is necessary to define the application for which it is to be used and the type of underwater environment it is going to be modelling. For this model, the underwater environment has:

- strong range dependence
- shallow water
- differing bottom types.

PE models[1] are by nature capable of making predictions in environments that are range dependent, shallow water and have changing bottom types. As a result a PE model called the Monterey Miami Parabolic Equation (MMPE) model was selected. This model was selected because it has been rigorously tested for shallow water environments[2].

4.1.2 Model Environmental Inputs

In all cases, the worst case scenario was chosen i.e. the conditions which would produce the greatest propagation of noise. As a result, all depths used in the model for the Gladstone Channel assume spring tide conditions (i.e. Lowest Astronomical Tide (LAT) + 5 m).

4.1.3 Model Contour Depth

The model produces horizontal contours for any depth as well as vertical plots showing depth versus range for any bearing. It is not worthwhile providing plots for each depth (up to 250 depending on the scenario) and for each bearing (i.e. 360 for each scenario). As a result only a selected number of graphs are provided in this report.

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[1] It must be noted that PE models are limited in vertical launch angles. The launch angles of the source are limited to ±40º from the horizontal. For any angles outside of this limit, the model erroneously predicts evanescent (i.e. strongly decaying) waves. This phenomenon is due to the fact that the model predicts an imaginary propagation vector.

[2] Shallow Water Acoustic Modelling (SWAM 99) Workshop

4.1.4 Source Levels

The model has been run for multiple frequencies from 250 Hz to 8 kHz. The source levels used are expected source levels for that noise source at those frequencies. The source levels for each noise source are provided in Appendix A.

The pile driving results have been adjusted by 10 dB to account for the fact that the EPBC Act Policy Statement 2.1 is based on a seismic pulse which is once every ten seconds while a pile driving pulse is once every second. This implies that there are 10 pile pulses for every seismic pulse.

4.1.5 Data and Model Limitations

The following limitations need to be noted:

1. **Reflection**. Specular reflection due to rough seabed surface and waves is not accounted for in the model.
2. **Salinity and Sound Speed Profiles**. The water depth in the modelling area is relatively shallow. It can therefore be assumed that the water column is isothermal. Additionally, salinity will have negligible effect on the sound speed profile. Variation in the model's sound speed profile has been limited to the effects of water column pressure.
3. **Turbidity**. Water turbidity due to silt in the water column was not included in the near shore model.
4. **Bathymetry and Topography**. For the near shore model both bathymetry and topography were used in the model. The 0 m mark of the bathymetry is based on the Lowest Astronomical Tide (LAT) level while the topography 0 m mark is based on a level that is approximately 3.5 m above LAT. As a 5 m tide was used in the model, the model interpolated between these two different levels. This resulted in some portions of the landmass that is usually above water being below water.

4.2 Seabed Types

Seabed types were estimated using geotech data supplied by BG. Figure 4-1 shows the interpretation of the geotech data and the spatial layout of occurrence.

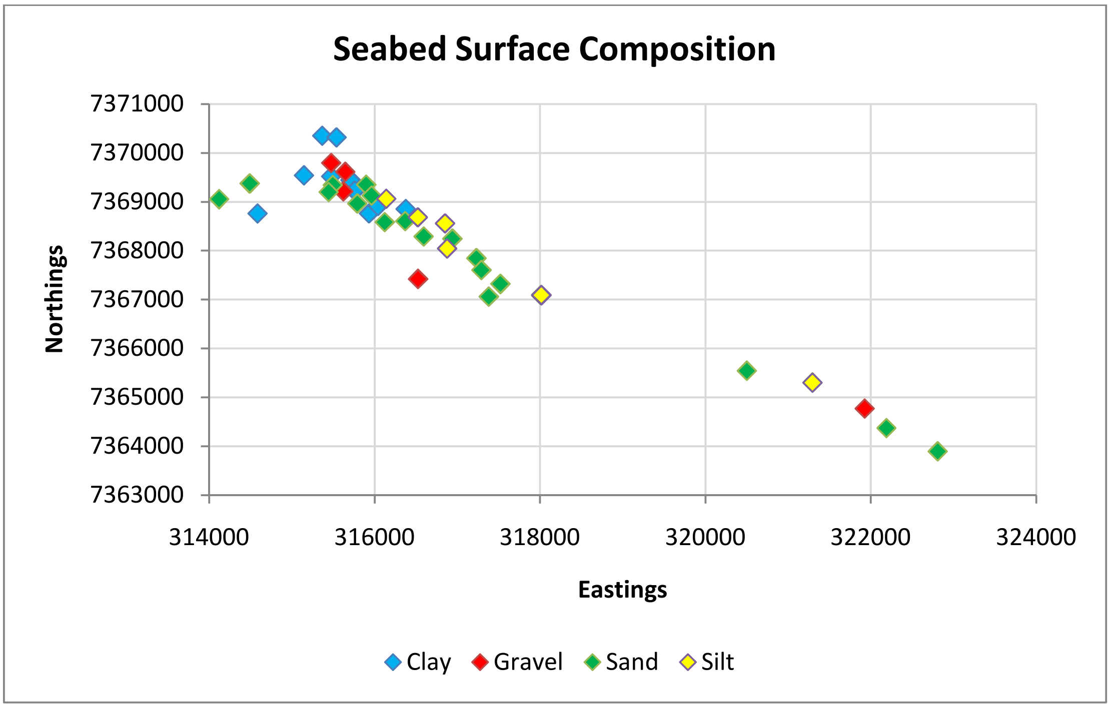

Figure 4-1 Spatial representation of seabed surface composition

The seabed types in Figure 4-1 were interpreted to have the geoacoustic properties as described in Table 4-1.

Table 4-1 Geoacoustic properties used in the model for each seabed type

Type	Sound speed	Density	Attenuation
Fine to medium sand	1774.0 $m\ s^{-1}$	2.050 $g\ cm^{-3}$	0.374 $dB\ m^{-1}\ kHz^{-1}$
Clay silt sand	1610.0 $m\ s^{-1}$	1.699 $g\ cm^{-3}$	0.527 $dB\ m^{-1}\ kHz^{-1}$

4.3 Sound speed profile

The sound speed profile in the Gladstone Channel is assumed to be isothermal, with a constant temperature of 27 ºC and a constant salinity of 35 ppt.

5. MODEL INPUT

5.1 Noise Source Locations

In the Gladstone Channel, five different sources (LNG Tanker, Cutter suction dredge, two Pile driving operations and a Tug) have been placed at locations as shown in Table 5-1 and Figure 5-1:

Table 5-1: Noise sources and their location

Source	Easting (m)	Northing (m)
LNG Tanker	316113	7369023
Cutter Suction Dredge	316113	7369023
Pile Driving at MOF	315440	7370012
Pile Driving at Jetty	316197	7369161
Tug	316016	7369064

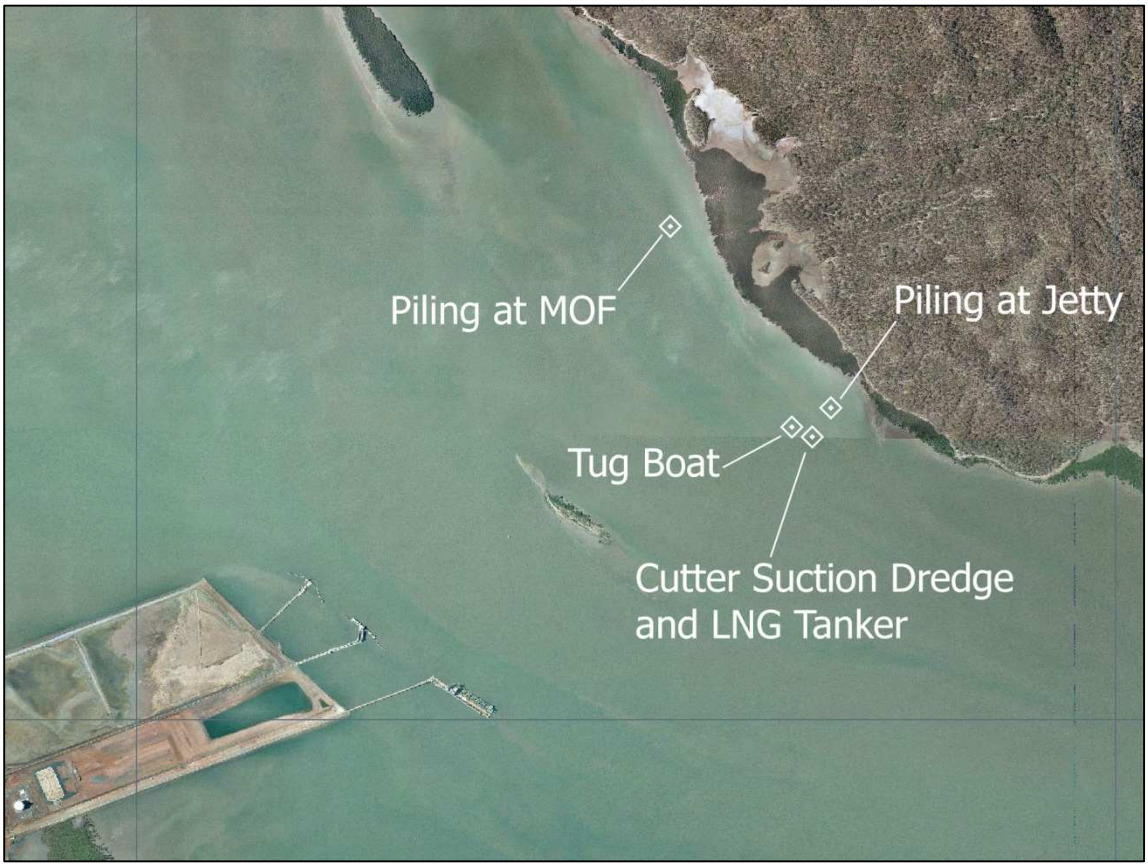

Figure 5-1: Modelled noise sources

5.2 Modelling Sources and Frequencies

Table 5-2 shows the modelling depths and source levels used in the model.

Table 5-2 Noise source frequencies and modelling depth.

Source	Source Depth	Source Characteristics
Piling at MOF	2.5 m below surface	See Figure 6-11 in Appendix A
Piling at Jetty	3 m below surface	See Figure 6-11 in Appendix A
Cutter Suction Dredge	3 m below surface	See Figure 6-12 in Appendix A
LNG Tanker	3 m below surface	See Figure 6-13 in Appendix A
Tug Boat	1 m below surface	See Figure 6-14 in Appendix A

6. MODELLING RESULTS

The figures and tables in the section summarise the results of the underwater assessment. Results in this report were generated with octave band transmission loss characteristics between 250Hz and 8 kHz. The modelled received depth is 2 m below the surface.

6.1 Contour Plots

Table 6-1 summarises the results of the underwater modelling for QCLNG operations in the Gladstone Channel. Contour plots extend 10 km from the modelled noise source(s) and are graduated in 10 dB steps.

Table 6-1 Summary of underwater modelling contour plots

Source(s)	Metric	Figure
Piling at Jetty	SEL	Figure 6-1
	Peak Pressure	Figure 6-2
Piling at MOF	SEL	Figure 6-3
	Peak Pressure	Figure 6-4
Cutter suction dredge	SEL	Figure 6-5
	Peak Pressure	Figure 6-6
Tug boat	SEL	Figure 6-7
	Peak Pressure	Figure 6-8
LNG tanker and Tug boat	SEL	Figure 6-9
	Peak Pressure	Figure 6-10

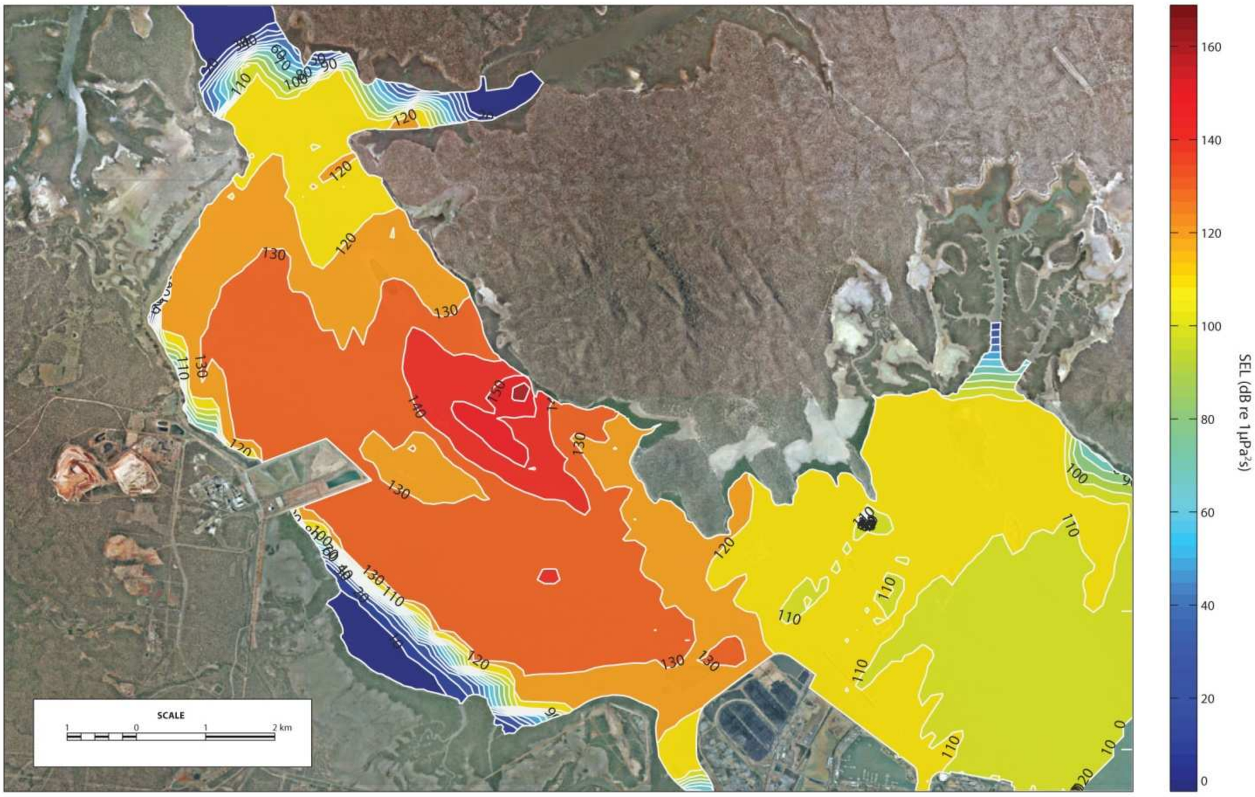

Figure 6-1 Jetty piling operation SEL noise contours 2m below surface

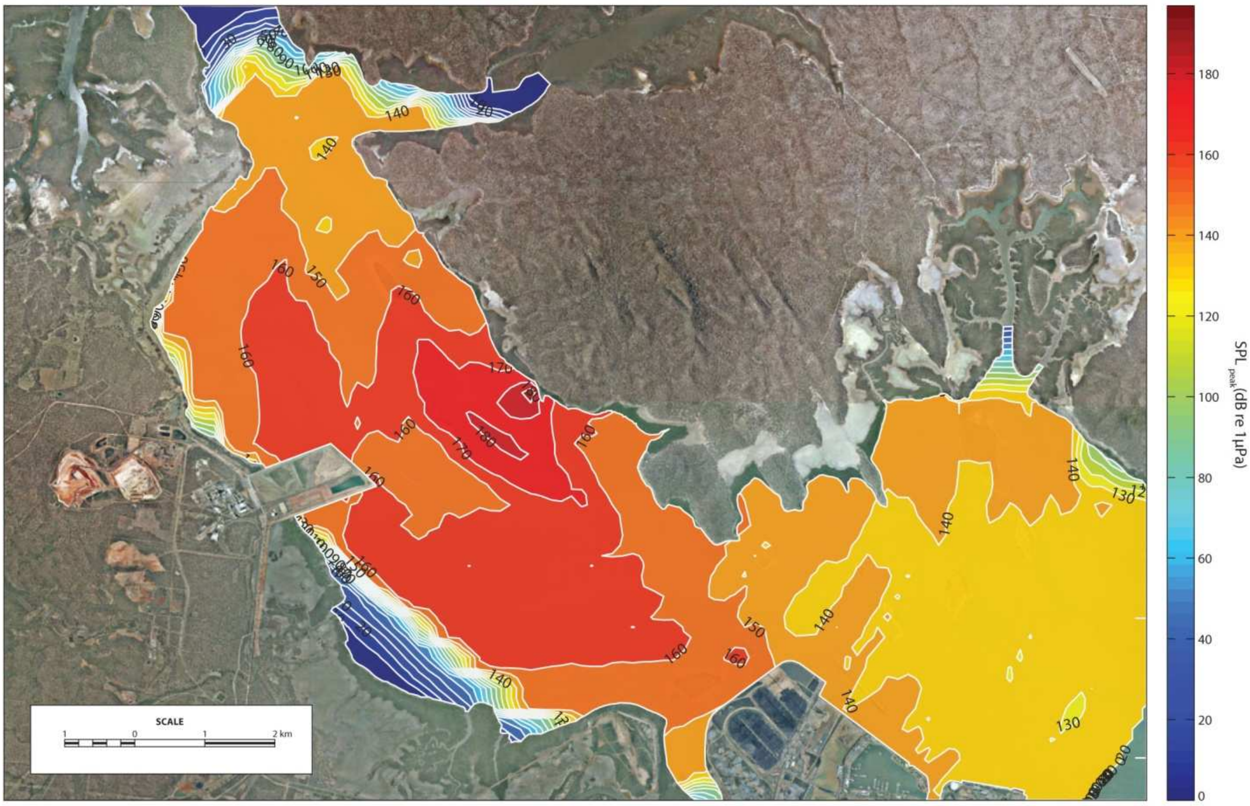

Figure 6-2 Jetty piling operation peak pressure noise contours 2m below surface

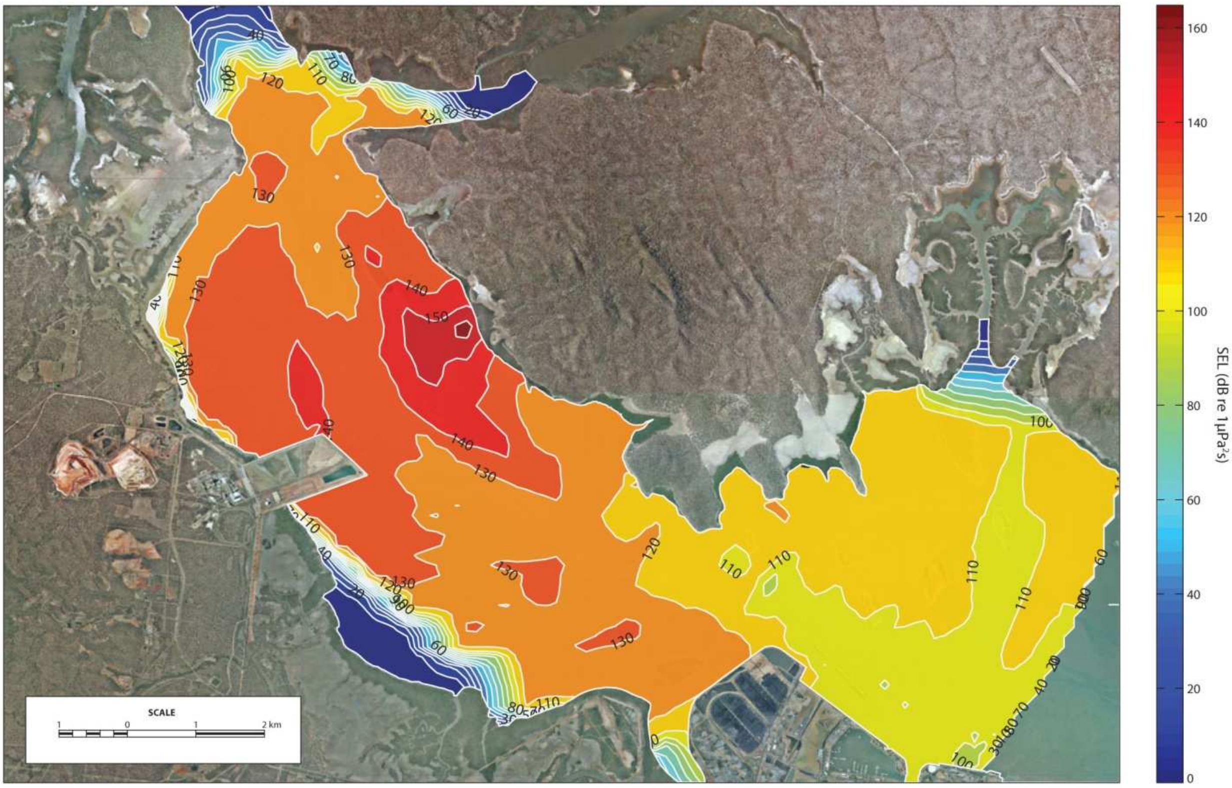

Figure 6-3 MOF piling operation SEL noise contours 2m below surface

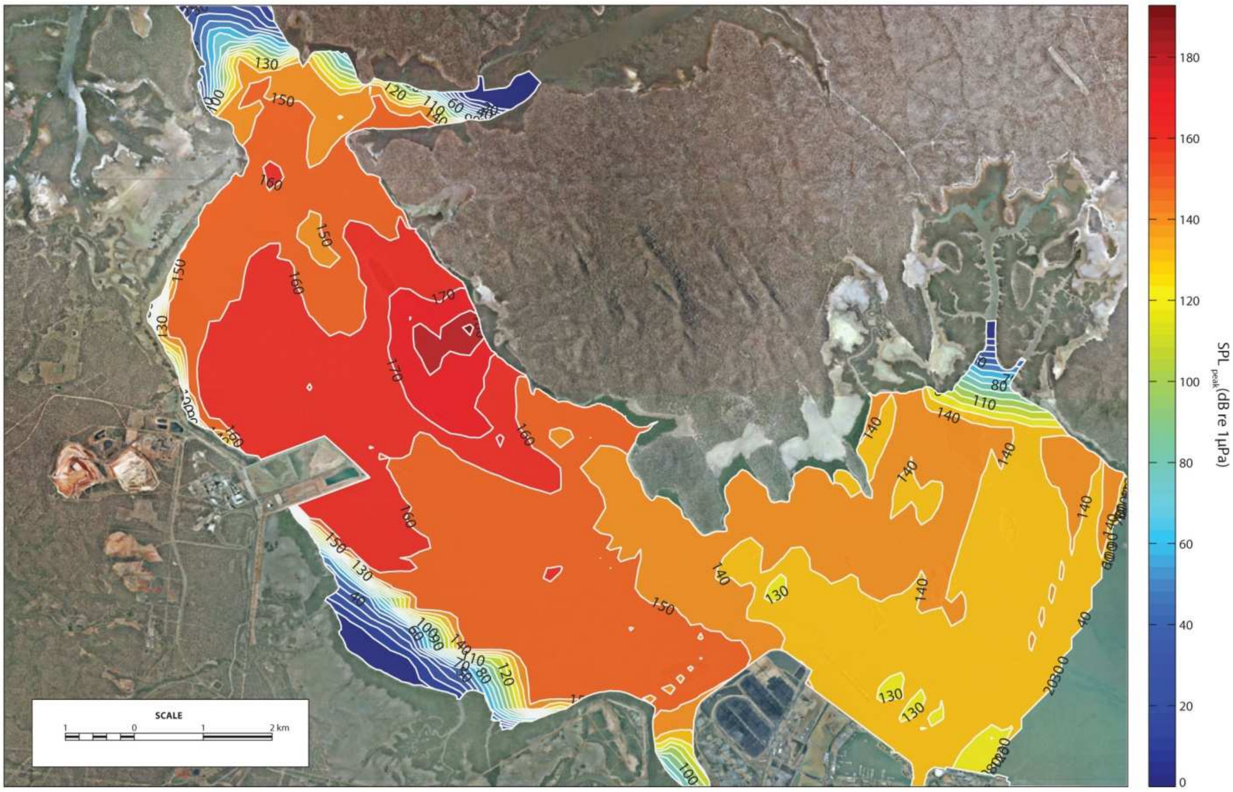

Figure 6-4 MOF piling operation peak pressure noise contours 2m below surface

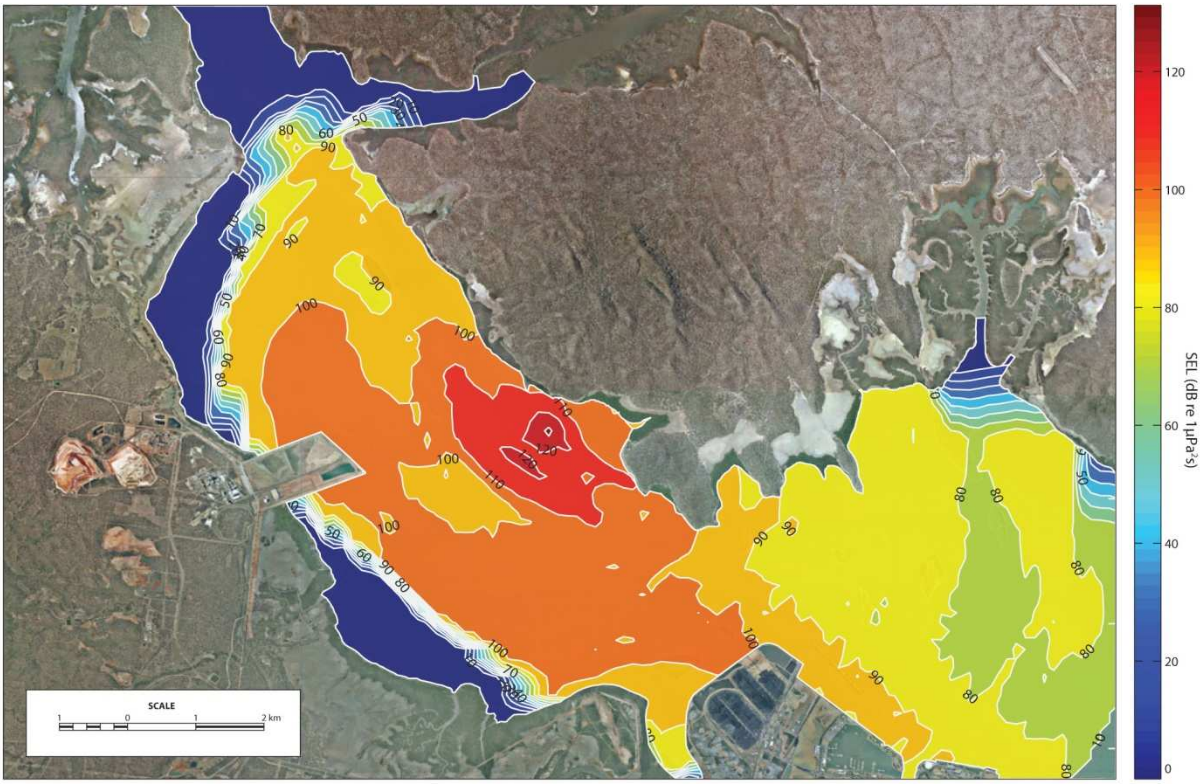

Figure 6-5 Cutter suction dredge operation SEL noise contours 2m below surface

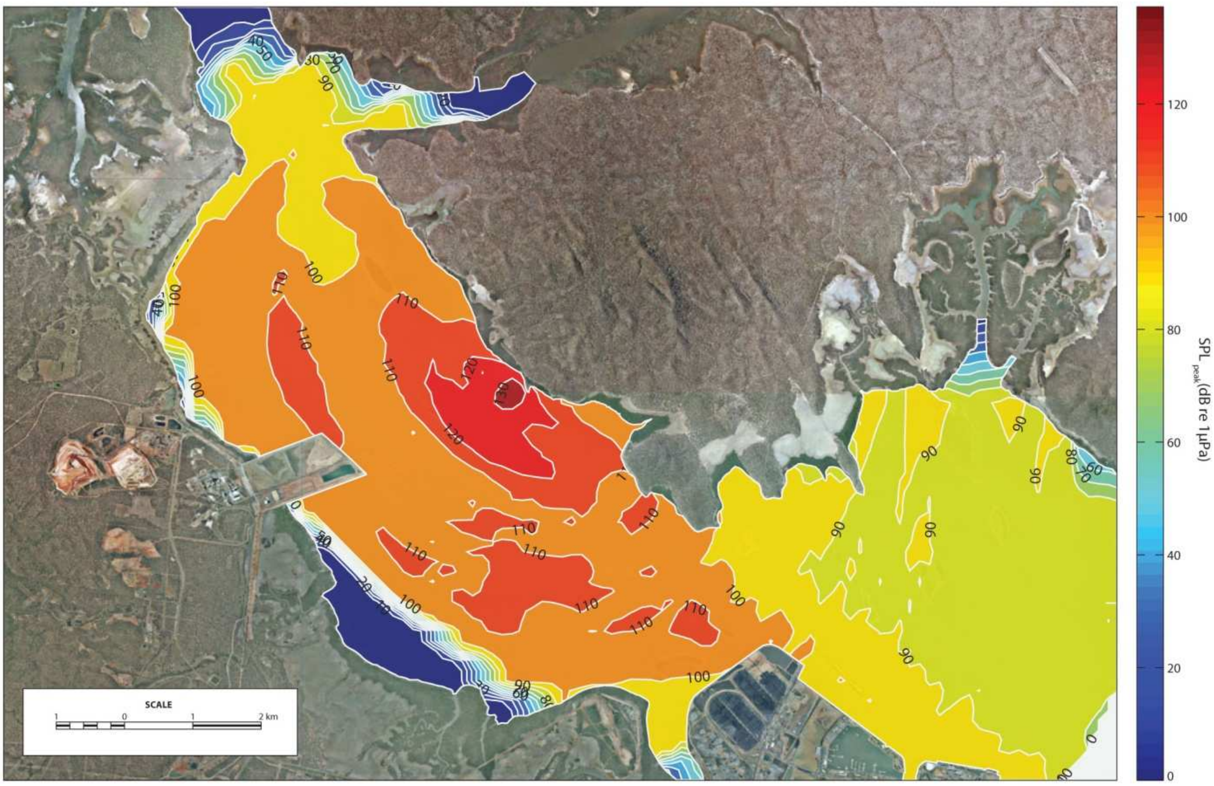

Figure 6-6 Cutter suction dredge operation peak pressure noise contours 2m below surface

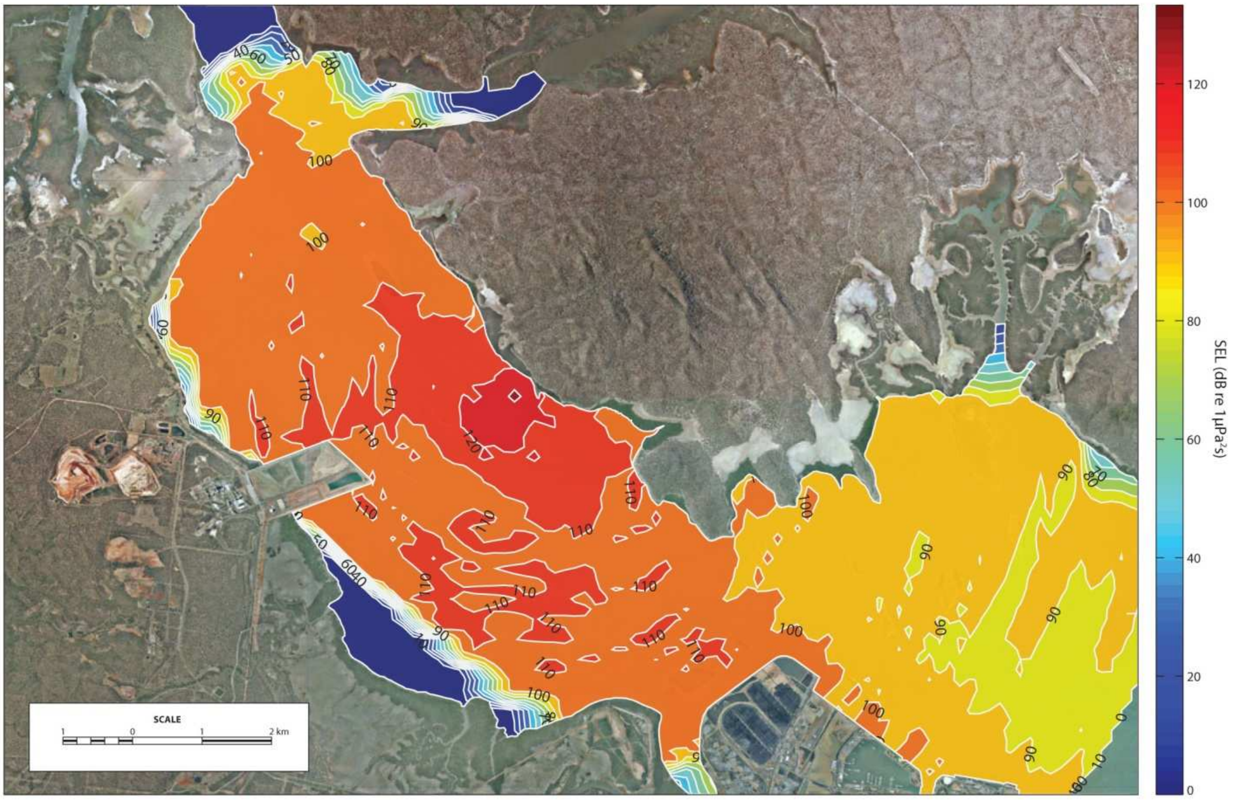

Figure 6-7 Tug Boat operation noise SEL contours 2m below surface

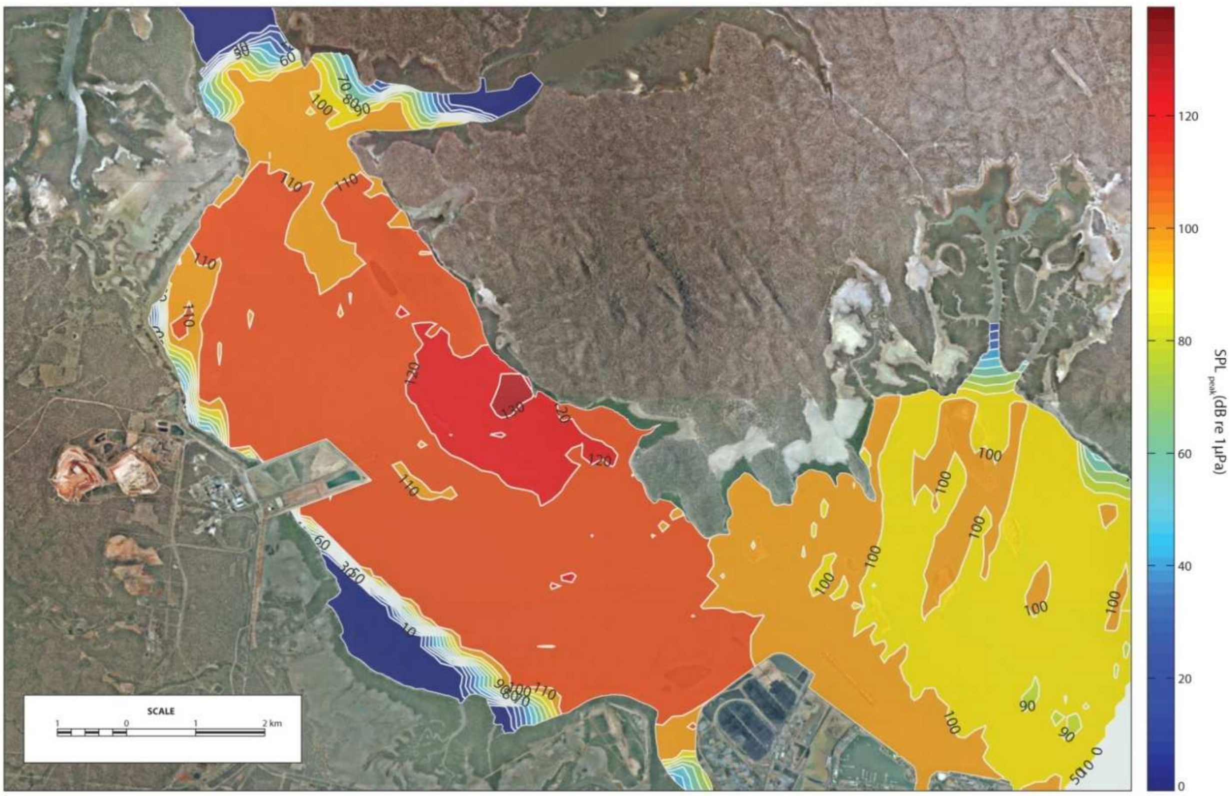

Figure 6-8 Tug Boat operation noise peak pressure contours 2m below surface

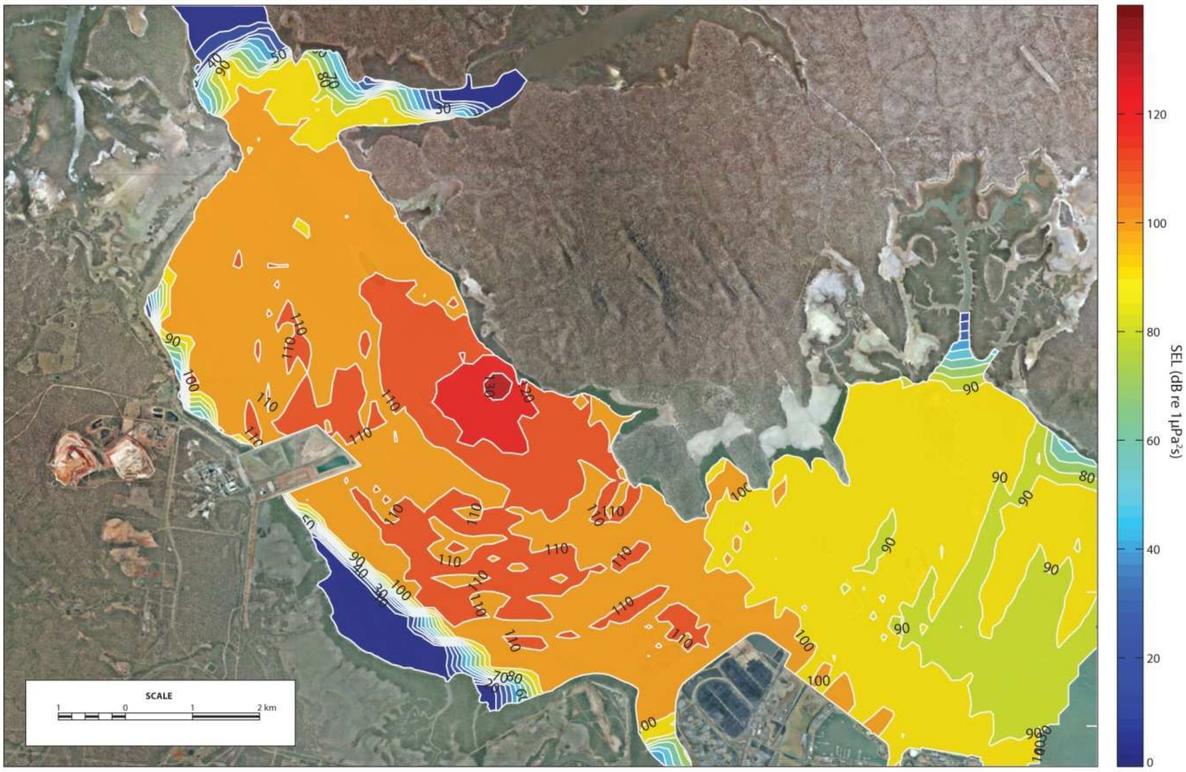

Figure 6-9 Combined LNG tanker and tug boat operation SEL noise contours 2m below surface

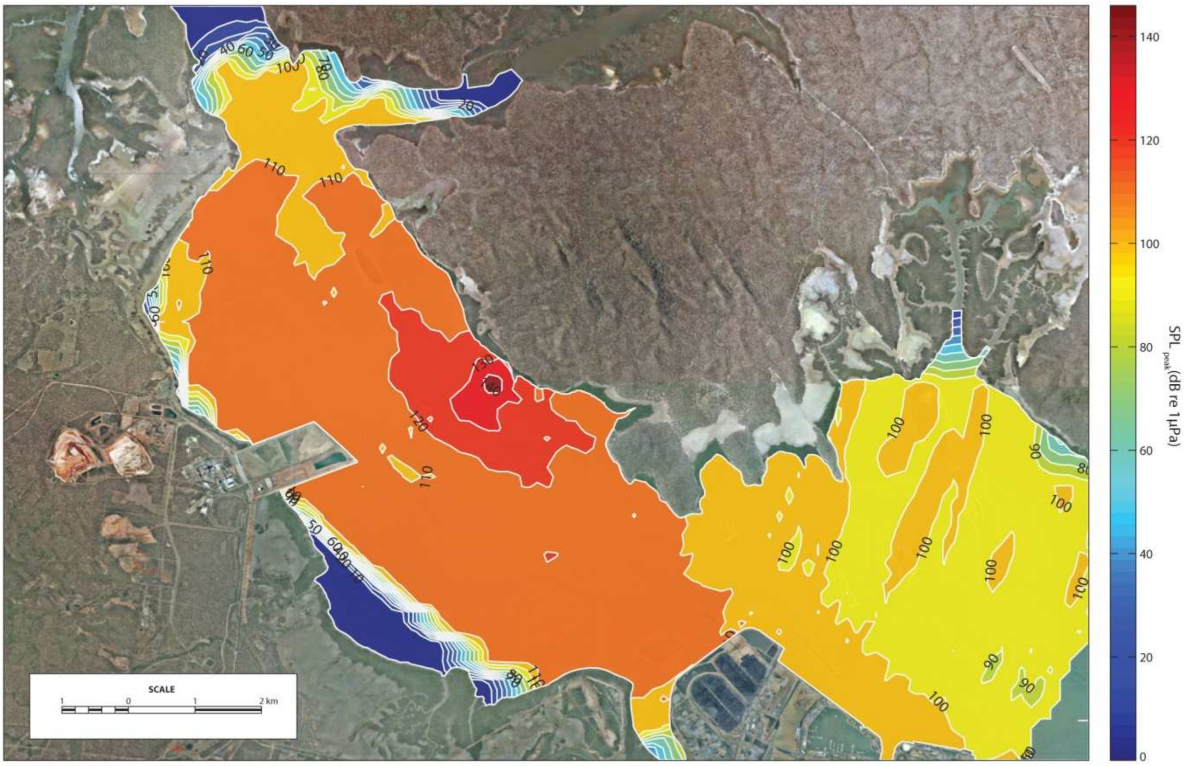

Figure 6-10 Combined LNG tanker and tug boat operation peak pressure noise contours 2m below surface

6.2 Zones of Avoidance and Possible Physical Injury

Table 6-2 summarises the maximum distances between noise sources and the zones of avoidance and possible physical injury for turtles, cetaceans and dugongs.

As can be seen from the table the 160 dB re 1μPa^2.s for cetaceans is approximately 205 m for jetty pile driving and 160 m for piling at the MOF. These relatively short ranges can be attributed to the fact that the jetty and MOF pile driving activities take place in very shallow water (approximately 5m), which implies that only a small portion of the pile is in the water during the pile driving and that most of the acoustic energy is transferred into the seabed. If it is also considered that most of the lower frequencies are below the modal cut off frequency for a 5m water column then it can be expected that most of the acoustic energy from the pile will not be radiated into the water. This should be verified in the field by field measurements.

Table 6-2 Furthest distance to zones of avoidance and possible physical injury

Animal Class	Source(s)	Furthest distance from source to Zone of Avoidance	Furthest distance from source to Zone of Possible Physical Injury	Furthest distance from source to EPBC Act Policy level (160 dB re 1μPa^2.s)
Turtles	Piling at Jetty	1500 m	55 m	N/A
	Piling at MOF	1200 m	55 m	N/A
	Cutter suction dredge	55 m	-	N/A
	Tug boat	-	-	N/A
	LNG tanker and Tug boat	160 m	-	N/A
Cetaceans and Dugongs	Piling at Jetty	205 m	22 m	205 m
	Piling at MOF	160 m	22 m	160 m
	Cutter suction dredge	5 m	-	5 m
	Tug boat	-	-	-
	LNG tanker and Tug boat	-	-	-

6.3 Recommendations

It is recommended that exclusion zones of 55 m for turtles and 22 m for ceataceans and dugings be considered for pilse driving operations. It is recommended that marine monitors be used to ensure that there are no sensitive fauna within the zones before pile driving operations commence.

Exclusions zones based on the 160 dB re 1μPa^2.s (i.e. 160 m and 205 m) should also be considered and monitored by qualified marine monitors.

APPENDIX A : NOISE SOURCE DATA

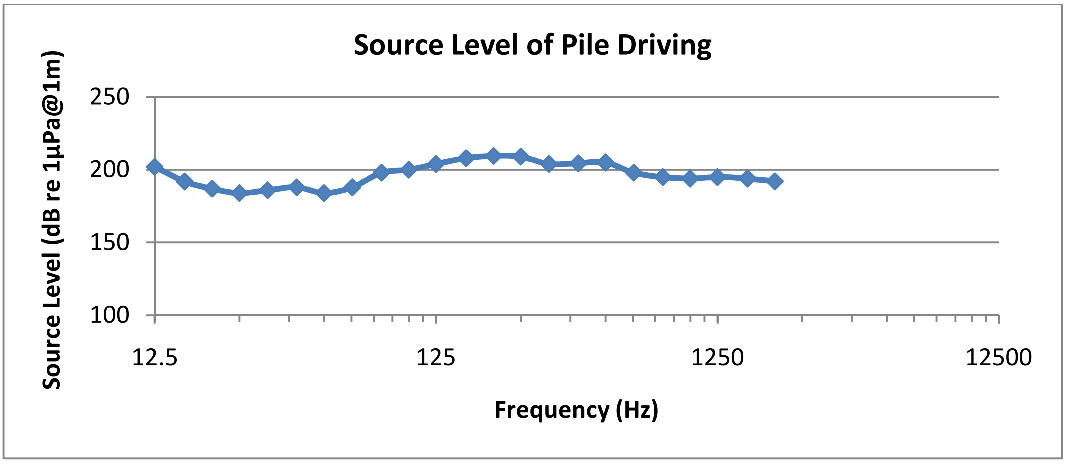

Figure 6-11 Source characteristics of Pile Driving

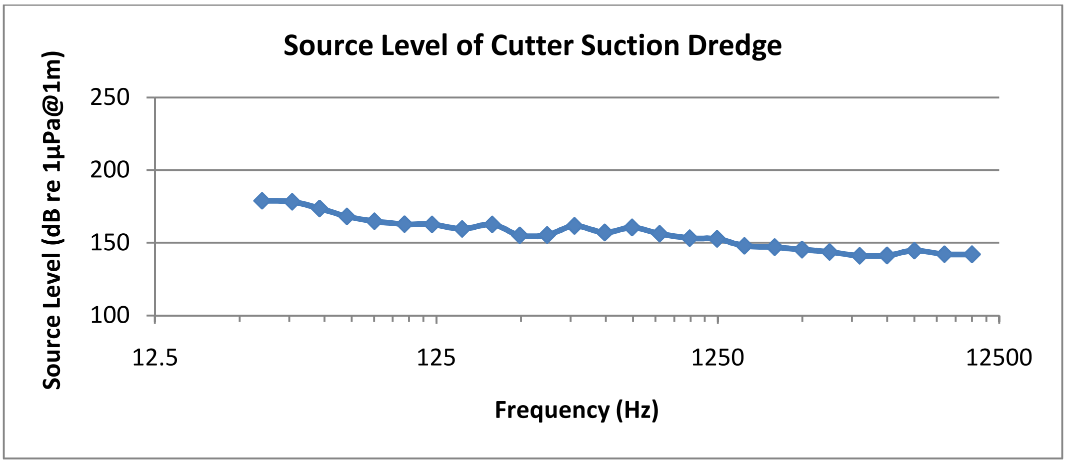

Figure 6-12 Source characteristics of Cutter Suction Dredge

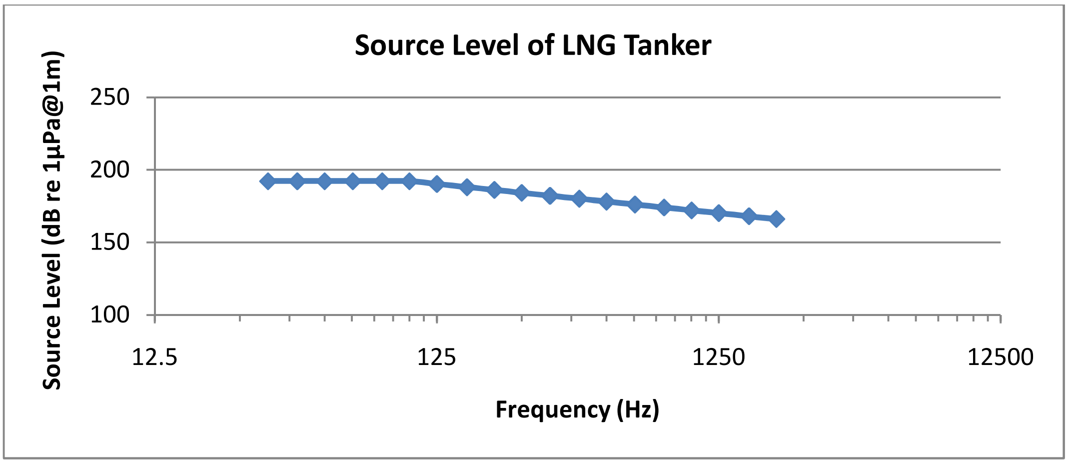

Figure 6-13 Source characteristics of LNG Tanker

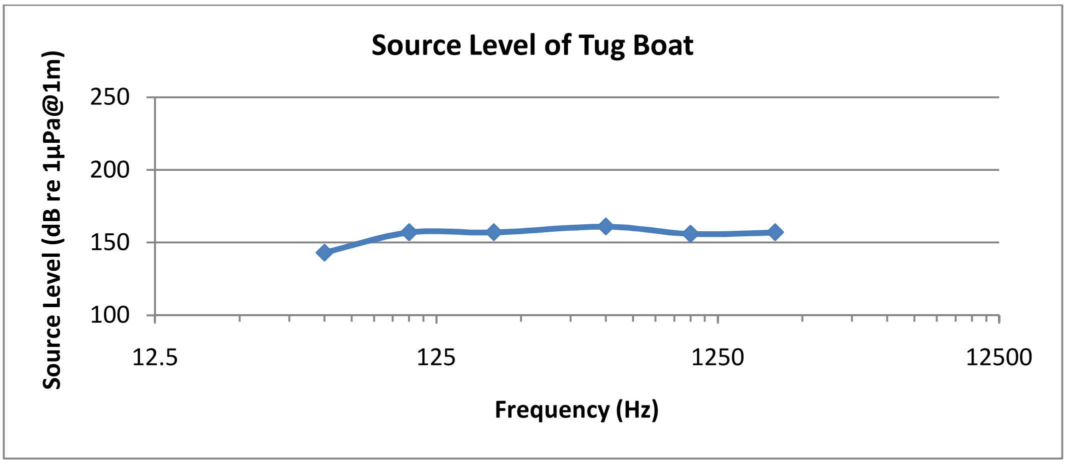

Figure 6-14 Source characteristics of Tug Boat