Appendix G

Underwater Noise Technical Report

SLAMI Underwater Noise Modelling Assessment

Darwin Ship Lift and Marine Industry Project

Prepared for AECOM

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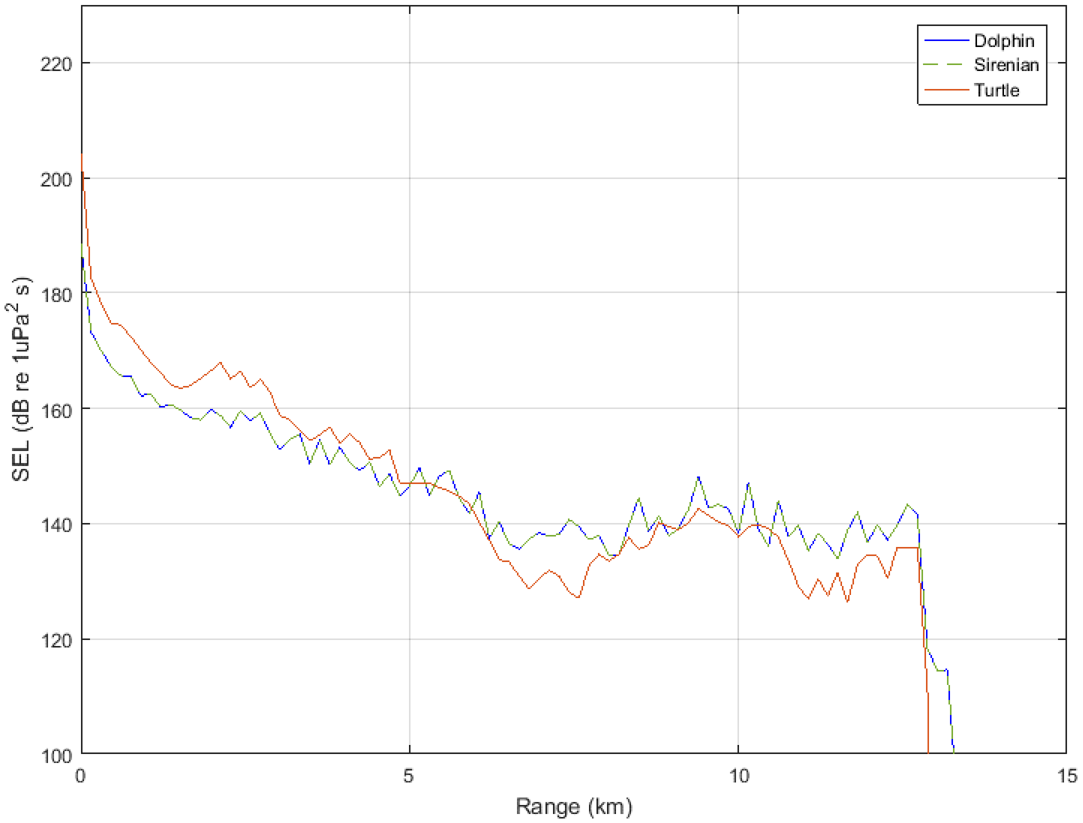

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1 Introduction

This report summarises the outcomes and recommendations of an underwater noise modelling study undertaken for the proposed Darwin Ship Lift and Marine Industry (SLAMI) Project.

1.1 Aim

The aim of this report is to provide modelling results of predicted underwater noise levels from construction activities (i.e. piling and dredging) associated with the SLAMI Project (the project).

1.2 Scope

This report will summarise the method and results of underwater noise modelling undertaken. It excludes an assessment of potential impacts on fauna.

1.3 Applicable Documents

1. Southall et al, Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects, Aquatic Mammals 2019, 45(2).
2. Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing, National Oceanic and Atmospheric Administration (NOAA), July 2016.
3. Criteria and Thresholds for Adverse Effects of Underwater Noise on Marine Animals, Science Applications International v2.0, 2018.
4. 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.
5. McCauley et al, 'Marine Seismic Surveys- A study of Environmental Implications' APPEA Journal 200, pg 692-708.
6. Casper, B.M. ,2006, The hearing abilities of elasmobranch fishes. Graduate Theses and Dissertations, University of South Florida.
7. A. Popper, et al,2014, Sound Exposure Guidelines for Fishes and Sea Turtles, ANSI, ASA S3/SC1.4TR-2014.
8. D. Cato, Ambient Sea Noise in Australian Waters, Fifth International Congress of Sound and Vibration, 1997.
9. Dunlop et al., Determining the behavioural dose-response relationship of marine mammals to air gun noise and source proximity.
10. Whiting, S. D., 2003, Marine mammals and marine reptiles of Darwin Harbour, proceedings of the Darwin Harbour Public Presentations, Darwin Harbour Plan of Management.

2 Background

The Northern Territory Government (NTG) identified the need to develop a marine maintenance and servicing facility in Darwin for Defence and Australian Border Force vessels, along with commercial and private vessels, to support the region's status as a growing logistics and marine services hub for northern Australia.

In August 2019, the NTG committed to building a ship lift and associated marine infrastructure (SLAMI) in Darwin (see Figure 2-1). The project will involve both wet and dry berth vessel maintenance facilities in support of Darwin's position as a logistics and marine services centre for Defence, Australian Border Force and major industries, including oil, gas and marine industries, within and around the Northern Territory region.

The project will include delivery of a common user ship lift (see Figure 2-2), landside infrastructure, wet berths for vessel maintenance, waterside infrastructure, vessel transfer equipment, dredging, reclamation, shore protection and aids to navigation. The location, which covers approximately 56 ha incorporates both land and water components within Darwin Harbour.

The SLAMI facility will include:

- A ship lift, capable of lifting vessels out of the water for dry docking and maintenance works.
- A common user area, being a hardstand area available for ship repair and maintenance works.
- Wet berths constructed on NTG and Paspaley sites to enable in water repairs, maintenance and loading.

Construction activities will include:

- Dredging of material.
- Piling.

Figure 2-1 : Overview Map (Proposal Location and Current Land Uses (Source NOI)

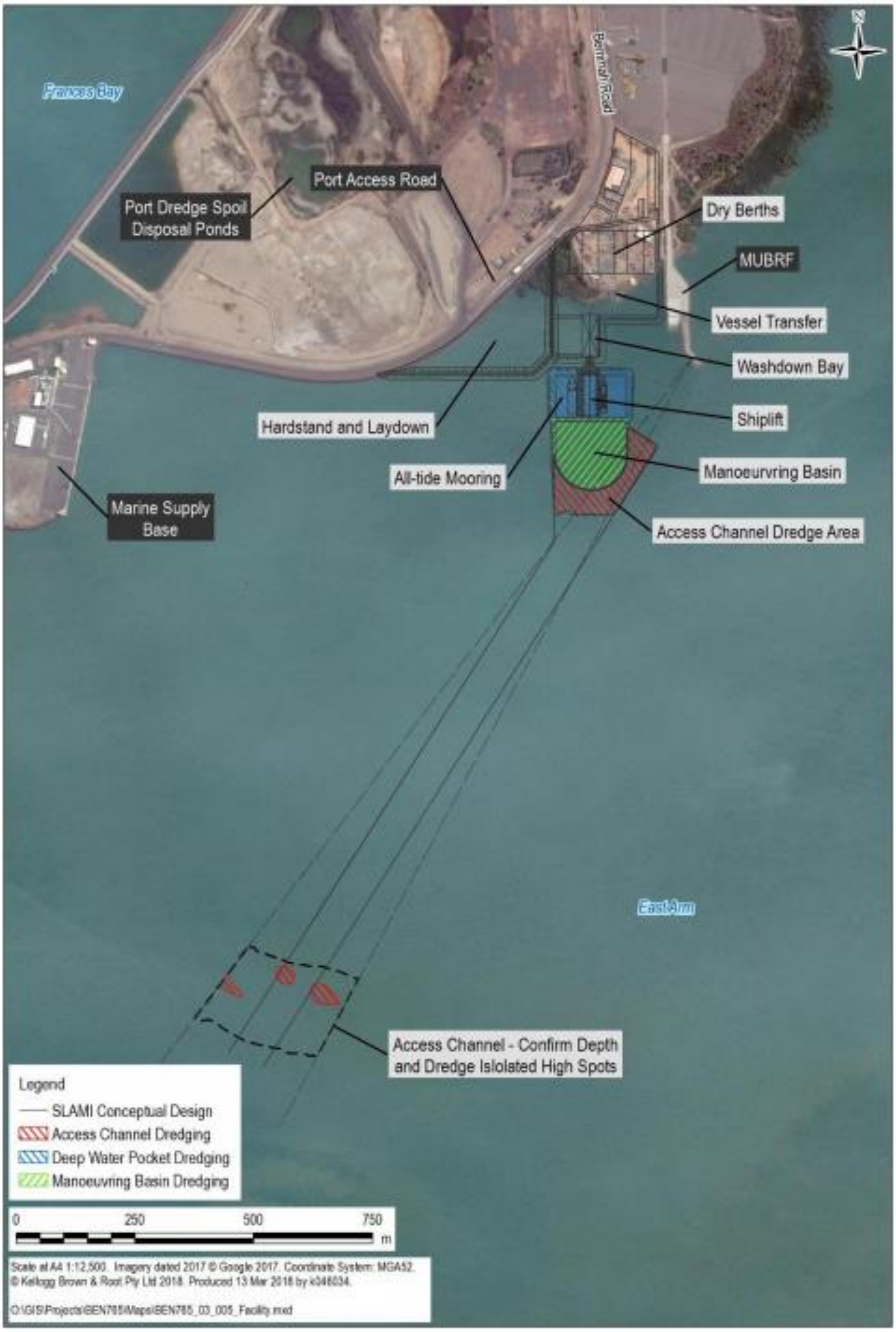
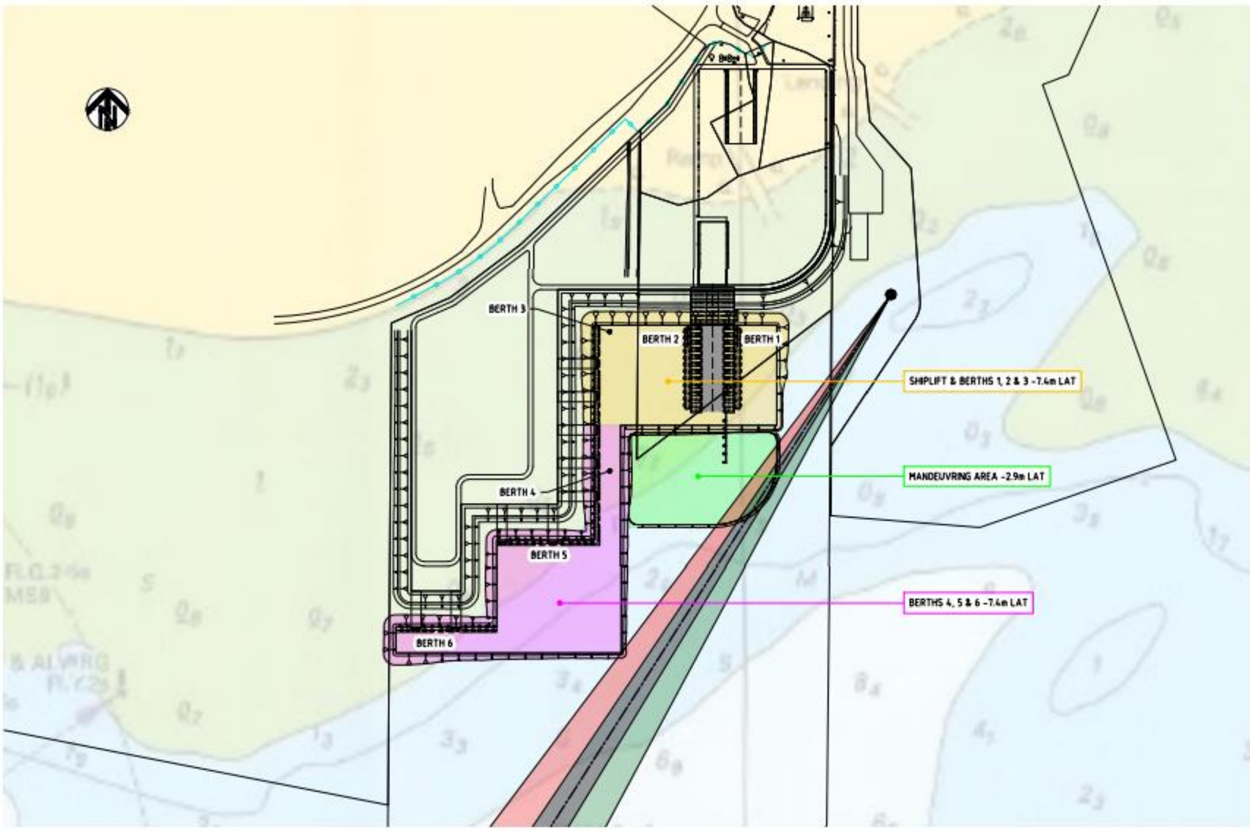


Figure 2-2 : Proposed Project Site and Dredging Areas (Source NOI)

2.1 Construction Overview

2.1.1 Dredging

Due to the location of the SLAMI, dredging is required to allow vessels to have sufficient under keel clearance and room to navigate and manoeuvre in and out of the berth pockets. The proposed berths and manoeuvring area are detailed in Figure 2-3. Dredging is a continuous underwater noise source which operates between 12 and 24 hours a day.



LAYOUT
SCALE 1:2500

	RVI < 8.8	RVI 8.8 TO 21.1	RVI > 21.1	TOTAL
SHIPLIFT & BERTHS 1, 2 & 3	116,348	67,812	44,774	228,934
MANOEUVRING AREA	36,374	2,528	-	38,902
BERTHS 4, 5 & 6	85,657	46,207	76,775	208,639
APPROACH CHANNEL	-	-	-	-

Figure 2-3 : Proposed Dredged Berth Pocket / Basin for SLAMI (Source: SMEC).

2.1.2 Piling

Piling is the most significant source of underwater noise identified for the construction activities of the project. The number and type of piles that will be used in the development of SLAMI is given in Table 2-1 and Figure 2-4 shows the pile layout.

Tubular piles will be both drilled using an auger or pneumatic drill and driven in using a hydraulic hammer. It is estimated that a maximum of two piles will be driven in per day, and that pile driving will take approximately 240 days.

The activity of cutting and grinding piles has not been included as it is assumed minimal dressing of the piles will be required.

Table 2-1 : Pile Types and Sizes

Size	Total
900x20 (Steel)	485 Piles
1050x20 (Steel)	
1050x40 (Steel)	

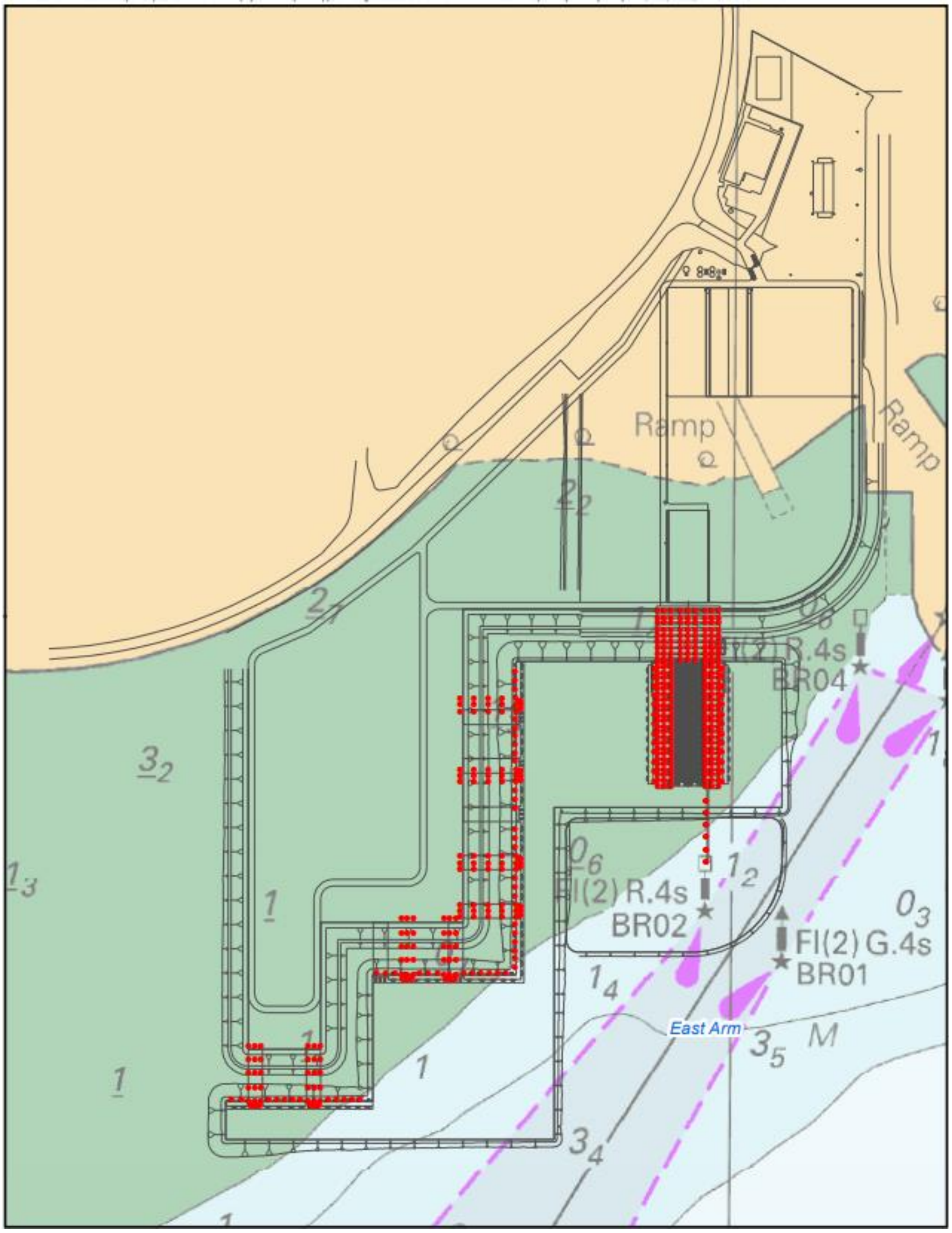


Figure 2-4 : SLAMI Pile Design and Configurations (source: SMEC 15/09/2020)

3 Underwater Noise

As shown in Figure 3-1, the ocean is a noisy place, comprised of sounds from both natural and anthropogenic sources. Natural underwater noise occurs from marine life and naturally occurring events such as waves, storms and underwater earthquakes. Anthropogenic noise sources result from activities such as vessel traffic, seismic exploration, underwater construction and military activities.

The ambient underwater soundscape tends to be consistent and widespread across large areas of ocean, however, anthropogenic noise generating activities can often form localised noise sources. These localised noise sources, if sufficiently loud, may be detrimental to certain marine species under some circumstances. The degree of impact is influenced by many factors, including the sound's persistence, amplitude and frequency, the distance between the sound source and marine life, the total time that the marine life is exposed to the sound and the sensitivity of marine life to the combination of these factors.

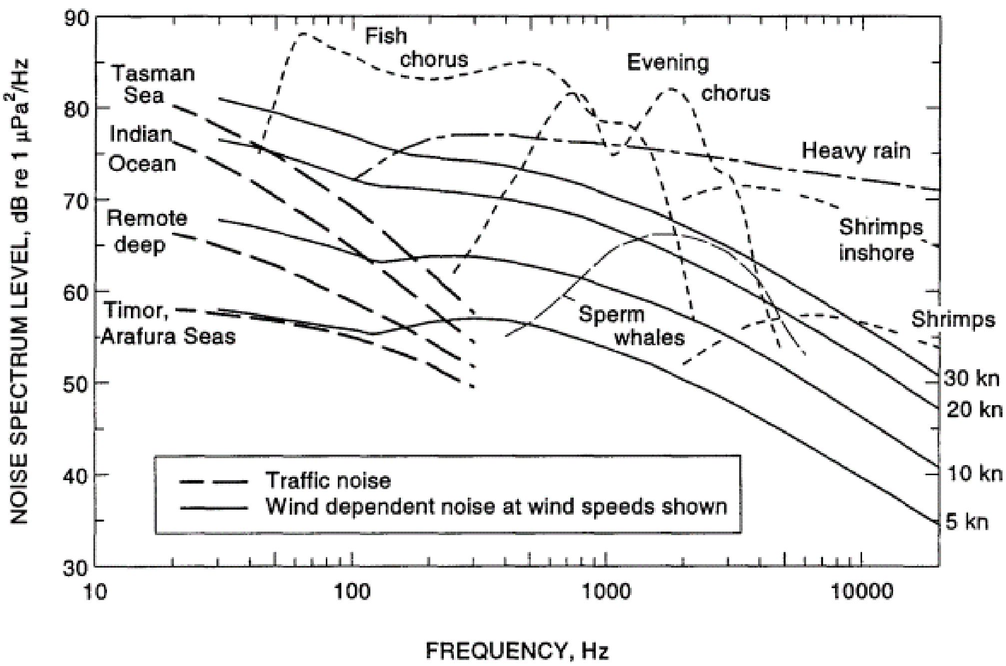


Figure 3-1 Ambient Sea Noise in Australian Waters [8].

In deep water sound travels further in the ocean than in air due to the natural duct created between the surface and the seabed, and the refractive properties of the oceans water column. Additionally, the higher sound speeds in water result in longer wavelengths than in air, which result in low frequencies travelling far distances before they are absorbed to levels below ambient noise levels.

In shallow water, sound attenuates a lot faster than in the open ocean as the natural duct created between the surface and the seabed is very narrow, resulting in the acoustic pressure wave reflecting multiple times off the seabed and surface. Every reflection resulting in the pressure wave losing energy. Additionally, in very shallow water, low frequencies below a cut off frequency[1] attenuate very quickly, thus not having any impact at distance from the source.

[1] Cut-off frequency is determined by depth and the sound speed of the seabed.

4 Marine Fauna

4.1 Species of Interest

The conservation significant species which were identified as being at most risk from underwater noise related impacts have been provided by AECOM and are listed in Table 4-1.

Table 4-1 : Marine Fauna – Species of Interest for this study

Marine Fauna Type	**Species**
Dolphins	• Coastal Dolphin • Australian Snubfin Dolphin • Bottlenose Dolphin • Australian Humpback Dolphin
Turtles	• Hawksbill Turtle • Green Turtle • Olive Ridley
Sirenians	• Dugongs
Crocodiles	• Saltwater Crocodile

This study has relied on the following literature:

- **Dolphins**. For dolphins, it is assumed that the threshold levels for Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) for low and mid frequency Cetaceans as defined in Southall et al [1] and NOAA's 'Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing' [2], are appropriate for this study.
- **Sirenians (Dugongs).** There is very little known about the response levels for dugongs. However, the threshold levels for Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) for Sirenians as defined in Southall et al [1] and NOAA's 'Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing' [2], have been used.
- **Turtles**. For marine turtles, the threshold levels for TTS and PTS will be adopted from work undertaken by CMST[2] for behavioural disturbance response of turtles to seismic airguns[3]. The threshold levels in Popper et al, [7], were considered, but the CMST levels were more conservative and therefore adopted for the study.
- **Saltwater Crocodiles**. The saltwater crocodiles occur in Darwin Harbour. Because only limited nesting sites for the saltwater crocodile are available inside Darwin Harbour, the area is not considered critical habitat for crocodile survival in the NT [10]. As a result, noise impacts on crocodiles has not been included in the study.

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[2] Centre of Marine Science and Technology.

[3] 'Marine Seismic Surveys: analysis and propagation of air-gun signals and effects of exposure on humpback whales, sea turtles, fishes and squid' [3] and 'Criteria and Thresholds for Adverse Effects of Underwater Noise on Marine Animals for injury' [2].

4.2 Assessment Criteria

Table 4-2 presents the assessment criteria adopted for whales, dolphins, turtles, dugongs and sawfish for this study.

The assessment criteria for each fauna type are divided into different TTS and PTS criteria depending on whether the noise being generated is classed as impulsive or non-impulsive.

- **Impulsive** – sounds produced are typically transient, brief (less than one second), broadband and consistent of high peak pressure with rapid rise time and rapid decay (NOAA, 2018). This noise source is associated with activities such as pile driving, seismic activities and underwater blasting and results in some of the most powerful sounds produced underwater (Gordon et al. 2004, cited in Hastie et al. 2019).
- **Non-impulsive** – sounds produced can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent and typically do not have the high peak sound pressure with rapid rise / decay times that impulsive sounds do (NOAA, 2018). This noise source is associated with activities such as dredging, vessel noise, drilling and some construction activities.

Behavioural disturbance response levels are also provided. Similar to human environmental noise impacts, behavioural disturbance levels are not based on cumulative exposure but rather on a single strike for impulsive noise sources and a SEL, determined from an RMS level, for non-impulsive sources.

Table 4-2 : Behaviour, TTS and PTS Onset Thresholds for Non-Impulsive and Impulsive Noise [4].

Marine Fauna Type	Marine Mammal Hearing Group	Hearing Bandwidth	Noise Type	SEL Onset (Weighted) dB re 1µ Pa^2.s		Possible Behavioural Distrubance dB re 1µ Pa^2.s
				TTS	PTS	
Sirenians (Dugongs)	SI	100 Hz to 50 kHz W(SI) Error! Bookmark not defined.	Non-Impulsive	186	206	140[5]
			Impulsive	175	190	
Dolphins	High Frequency	150 Hz to 160 kHz W(MF) Error! Bookmark not defined.	Non-Impulsive	178	198	
			Impulsive	170	185	
Turtles [5] and	Turtles and Sawfish	100 Hz to 1 kHz	Non-Impulsive	175	183	175[6]
			Impulsive	175	183	

[4] Threshold levels were obtained from Southall et al [1] and hearing response curves from NOAA [2].

5 Dunlop et al., Determining the behavioural dose-response relationship of marine mammals to air gun noise and source proximity.

6 McCauley et al, 'Marine Seismic Surveys- A study of Environmental Implications' APPEA Journal 200, pg 692-708 [4] and 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.

Sawfish						

5 Methodology

5.1 Overview

The desktop study has been undertaken using a computer noise model to simulate underwater noise emissions. The underwater software calculation kernel utilises the Monterey Miami Parabolic Equation (MMPE which was developed by the University of Miami and Naval Postgraduate School Monterey in the USA). The model can predict transmission loss from multiple noise emission sources simultaneously in both broadband and narrowband frequency ranges.

Underwater propagation models require inputs including bathymetric data, geo-acoustic information and oceanographic parameters to produce 3D estimates of the acoustic field at any depth and distance from the source. The quality of the model prediction is directly related to the quality of the environmental information used in the model.

The model has been setup to assume worst case environmental conditions for all scenarios (i.e. the conditions which result in the greatest propagation of noise from source to receiver) and therefore provides conservative predictions.

5.2 Noise Sources

5.2.1 General

Construction will involve various noise generating activities and equipment. The most significant noise generating activities that have been identified are piling and dredging which form the basis for the modelling.

The noise source levels used for modelling have been calculated based on a combination of client proposed operational data and source levels from a database of underwater noise sources. All source levels include overall and spectral levels.

5.2.2 Existing Anthropogenic Noise

Darwin Harbour's proximity to the Asian region makes it an important hub for industry and trade for mining, defence and energy. It provides a service for international and domestic trading vessels, cruise ships, gas export, livestock export, defence, and dry and liquid bulk trades. The harbour handles between 2 and 4.5 million tons and between 1472 and 3178 large vessels per year.

The existing shipping activity in the harbour area has not been included in the model as it forms part of the existing background noise. Considering the shipping volumes, it is expected that the existing background noise will mask dredging activities related to the project. Source levels for typical merchant ships are included in this section, so that they can be compared with that of the dredging activity.

Figure 5-1 shows typical bulk carrier source levels as determined by DSTO. If these levels are compared with those of the dredger the dredgers source levels above 50 Hz are very similar to those of the bulk carriers. Below 50 Hz the dredger's source levels become higher. As the dredger is dredging in shallow water it is expected that these lower frequencies will attenuate rapidly. The dredger will therefore likely be masked by background noise.

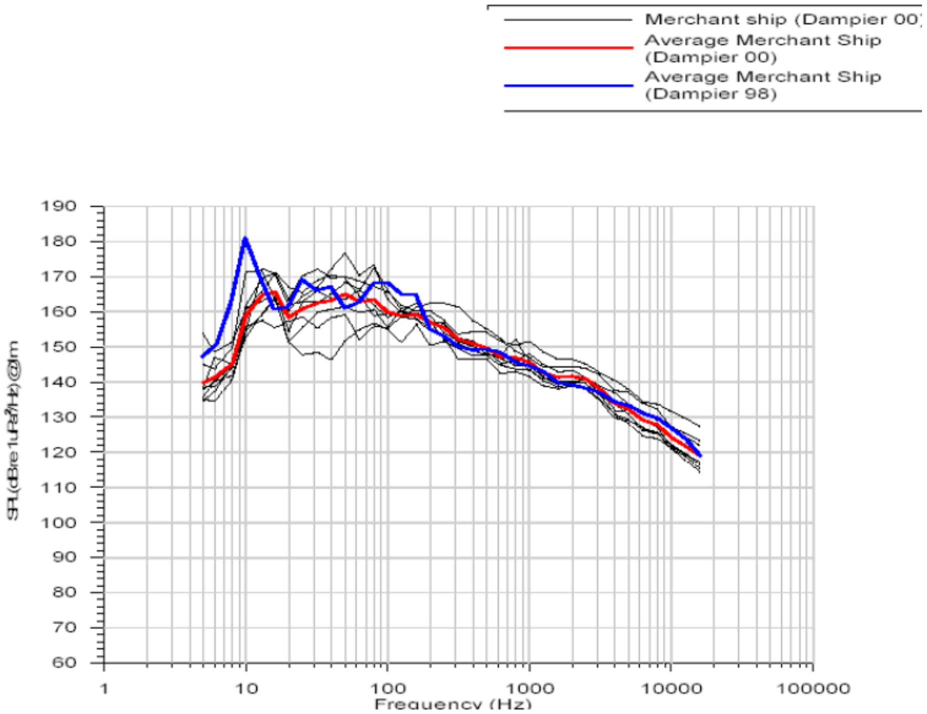

Figure 5-1 Bulk carrier source levels as determined by DSTO.

5.2.3 Dredging Noise Source Level

Dredging is an underwater excavation activity used to increase the water depth for shipping purposes. This excavation is carried out by gathering up bottom sediment and disposing of this material to a different location.

It is assumed that this project will utilize a small cutter suction dredger. A cutter suction dredger is a ship that includes a cutter head used to loosen the material and a suction mouth, inlet and pump used to transfer the material from the seabed through piping and onto the vessel or separate barge for transportation and disposal. The source level used for modelling of dredging activities is detailed in Table 5-1 and Figure 5-2.

Table 5-1 : Cutter Suction Dredger noise source

Parameter	Value SPL RMS[7]
SPL Source Level (SL)	166 dB re 1µPa @ 1m

7 Sound Pressure Level Root Mean Square

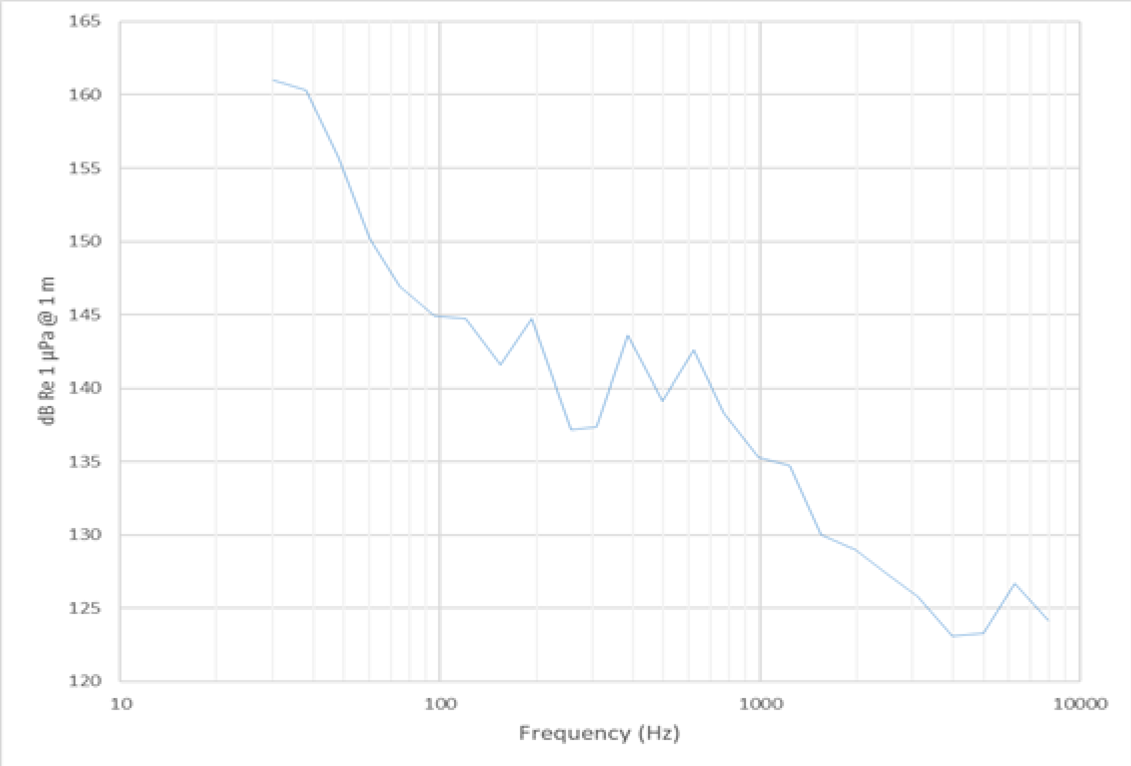

Figure 5-2 : Small Cutter Suction Dredger Noise Source Characteristics

5.2.4 Piling Noise Source Level

Pile driving involves hammering a pile into the seabed to the point of refusal. The noise emanating from a pile 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 a pile into the seabed excites bendy[8] waves in the pile that propagate along the length of the pile and transfer into the sea and seabed. The compression component of the wave propagates into the ocean, while both compression and transverse components propagate into the seabed. Once in the seabed, the energy will then propagate outwards as compression and shear waves.

Piles can be driven using various methods such as vibration, gravity and hydraulic 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 a combination of drilling and hydraulic impact hammering will be used for this piling operation of which hydraulic impact hammering generates the highest noise levels. 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 impulsive noise.

The pile driving specifications that have been used to calculate the source levels for modelling are given in Table 5-2.

8 Bendy wave is a wave that comprises of a compression wave and a transverse wave.

Table 5-2 : Pile driving specifications

Parameter	Value
Pile diameter	900 mm and 1050
Hammer Type and Weight	16t Hydraulic
Hammer Energy	235 kJ
Blow rate	30 bpm
Hammer Model	HHK 16S

Table 5-3 and Figure 5-3 present the pile driving source level for maximum hammer energy. A typical hydraulic hammer energy profile shows that the hammer energies start off low and only achieve maximum energy in the last stages of the piling before the point of refusal. This maximum energy is sustained for approximately 7 minutes. As a result, the exposure level has been determined assuming maximum energy for ~7 minutes (i.e. 200 hammer strikes). The cumulative impacts from piling have therefore be determined using the maximum single strike energy levels provided in Table 5-2 and adding these cumulatively over 7 minutes to give an overall cumulative SEL.[9].

Table 5-3 : Piling noise source level for maximum hammer energy

Parameter	**Value** SEL for a single strike
SEL Source Level (SL)	193 dB re 1µPa2.s @ 1m

[9] 10*log10(N) where N is the number of hammer strikes.

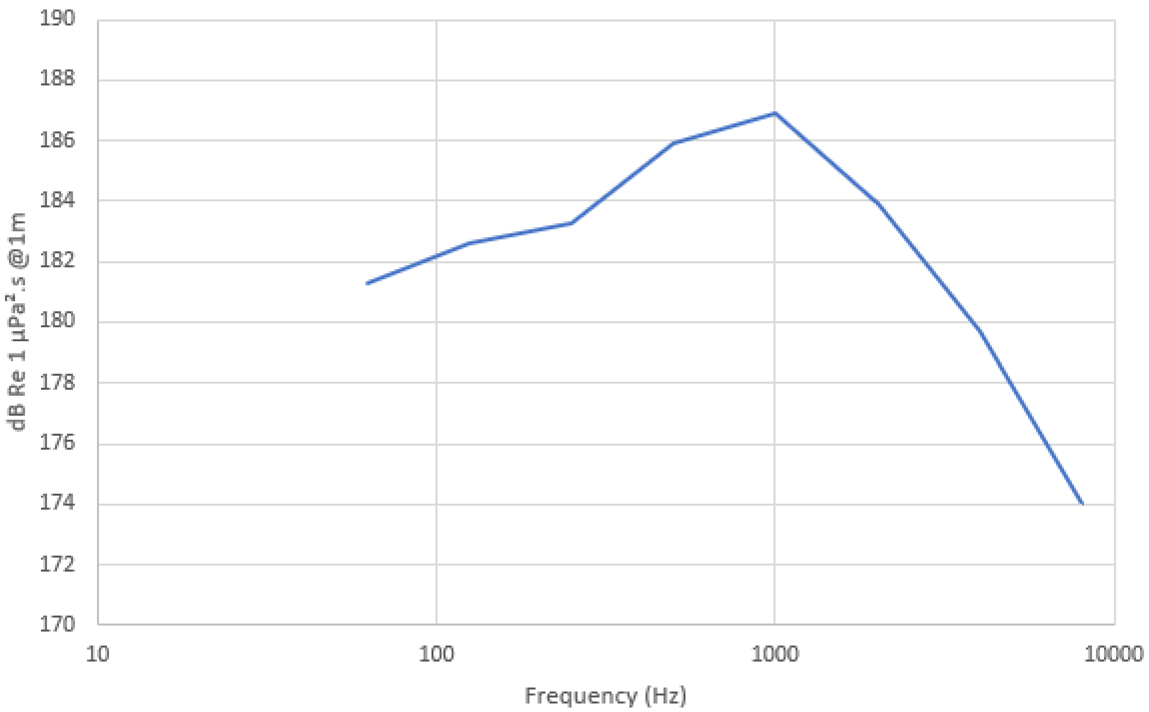

Figure 5-3 : Pile Driving source characteristics (235KJ)

5.2.5 Noise Model Source Locations

Table 5-4 and Figure 5-4 shows the locations of the piling and dredging noise source relative to the coast. The modelled noise sources were inserted in the deepest possible location. For the Piling source, it has been assumed that the dredge depth has been achieved prior to piling.

All model scenarios have been run for hightide (i.e. 4.1m above Australian Height Datum (AHD)) and low tide (i.e. 4.1m below (AHD)). As the sources have been modelled at the deepest point, the modelling outputs can therefore be considered as conservative and worst case.

Table 5-4 : Noise Source Model locations

Location Name	MGAz52	
	Eastings	Northings
Piling	706118.48	8618125.56
Dredging	706326.66	8618279.09

Figure 5-4 : Modelled Pile and Dredge Location

5.3 Bathymetry

The bathymetry applied to the model for the Darwin area was sourced from Talis' bathymetry database and is shown in Figure 5-5. The bathymetry around the SLAMI was compared with AECOM's high-resolution bathymetry for the SLAMI. Additionally, the bathymetry was modified to include the proposed dredge pockets. As can be seen in the figure the water depth is shallow within the project area and progressively gets deeper towards the channel's centre and seaward side. The bathymetry in the project area ranges from ~5 to ~9 m.

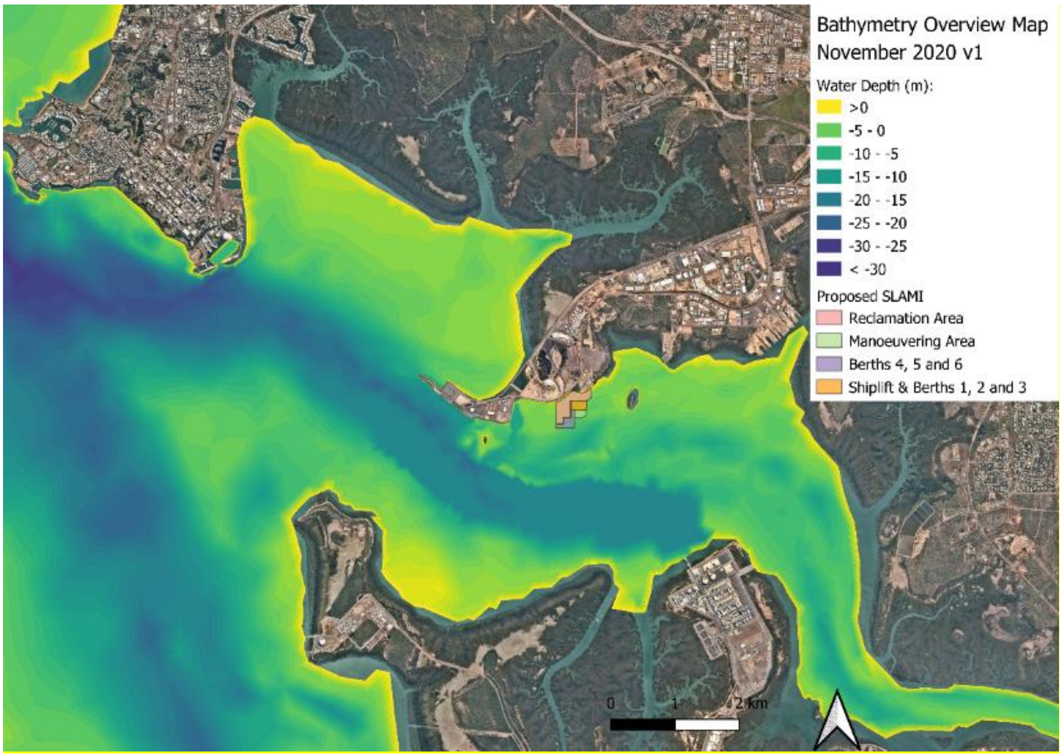

Figure 5-5 : Bathymetry Overview Map

5.4 Seabed Types

A sandy seabed (see Table 5-5 for seabed properties) has been assumed for Darwin. This is a conservative assumption because sand is more reflective in shallow water environments (i.e. shallow grazing angles) than limestone and other hard materials that absorb more of the pressure waves energy with each reflection due to the excitation of both compression and shear waves in the material.

Table 5-5 : Seabed properties used in the model

Type	Sound Speed (m/s)	Density (g/cm3)	Sound attenuation (dB/m/kHz)		Shear Speed (m/s)
			Compression	Shear	
Fine to medium sand	1774	2.05	0.37	0	0

5.5 Sound Speed Profile

The area of interest for the modelling is in shallow water (maximum bathymetric depth in the data provided is approximately 25 m). As a result, it is expected that the temperature profile through the water column will be isothermal. Therefore, the sound speed profile used for modelling is for a constant water temperature of 30°C and a constant salinity of 35 parts per thousand (ppt).

5.6 Hearing Threshold Weighting Curves

Hearing weighting curves for Low Frequency (LF and High Frequency (HF) Cetaceans[10] have been applied to all predicted received levels in accordance with NOAA's technical guidance [2]. For turtles a flat response between 100 and 1000 Hz has been assumed.

5.7 Data and Model Limitations

The following limitations apply to the noise modelling:

- **Reflection** - Specular reflection due to rough seabed surface and wave action is not accounted for in the model.
- **Airborne Noise** - A small component of the airborne noise generated above the sea surface will be transferred into the water column, however this has not been accounted for in the model.
- **Salinity and Sound Speed Profiles** - The water depth in the modelling area is relatively shallow. It has therefore been assumed that the water column is isothermal. Additionally, salinity will have negligible effect on the sound speed profile. Variation in the sound speed profile has been limited to the effects of water column pressure.
- **Bathymetry** - For near shore modelling, both bathymetry and topography were used in the model.
- **Model Contour Depth** - The model can produce horizontal noise contours for any depth and distance. However, it is not practical for the report to include plots for each depth.

[10] It has been assumed that the SI hearing curve will be the same as the HF cetacean's curve.

6 Noise Model Results and Discussion

The following sections provide a summary of the modelling outcomes and include unweighted[11] noise contour maps and maximum predicted levels with range for dredging (section 6.1) and piling (section 6.2). Unweighted noise contour maps are provided as they provide the highest predicted level expected from each scenario.

Results are provided for low tide (LAT 4.1m below Australian Height Datum) and high tide (HAT 4.1 m above AHD). Additionally, all sources have been positioned at the deepest point possible, and therefore, the modelling predictions can be considered as conservative and worst case.

Various assumptions have been made regarding the source levels and exposure duration. These assumptions should be verified through measurement once the Project commences.

Assessment criteria has been used to determine distances from the noise sources that result in assessment criteria being exceeded.). This has been done to assist with the determination of potential risks and identification of possible mitigation strategies.

6.1 Dredging

Dredging is a continuous noise source and is therefore considered as non-impulsive. It is expected that dredging will operate continuously for 12 or 24 hours a day. It has been assumed that the maximum exposure of the fauna considered in the study will be 1 hour. The SPL source level was therefore converted to a 1-hour SEL by adding 36dB.

The graph in Figure 6-1 shows the maximum cumulative predicted received level with range for each fauna group considered in the study. Figure 6-2 shows the SEL[12] graph for determining behavioural disturbance.

Table 6-1 provides the ranges at which TTS, PTS and behavioural disturbance are expected to be exceeded for each hearing group. The distances at which the noise levels are predicted to exceed a TTS threshold level at high tide are between 90 and 240m. It is also anticipated the existing background noise will mask the noise from the dredge.

[11] i.e. no hearing weighting applied.

[12] Based on converting an RMS to SEL.

Table 6-1 : Behavioural, TTS and PTS Onset Thresholds from Non-Impulsive Noise at HAT (Worst Case)

Marine Hearing Group	SEL Onset (Weighted) dB re 1µ Pa².s		Potential Behavioural Disturbance	Tide	TTS Distance Limit (metres)	PTS Distance Limit (metres)	Behavioural Disturbance Distance (metres)
	TTS	PTS					
Sirenians (SI)	186	206	140	High	90	-	50
				Low	-	-	-
Dolphins (HF)	178	198	140	High	170	-	50
				Low	-	-	-
Turtles	175	183	175	High	240	110	-
				Low	100	30	-

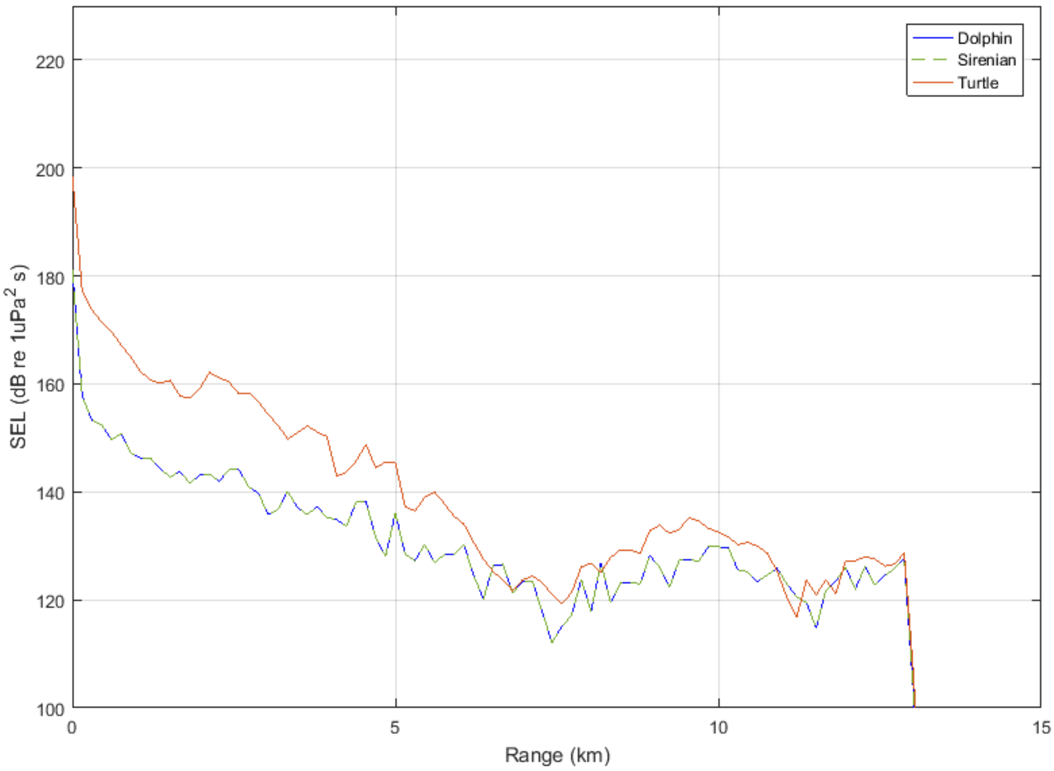

Figure 6-1 : CSD SEL with range for cumulative exposure (High Tide).

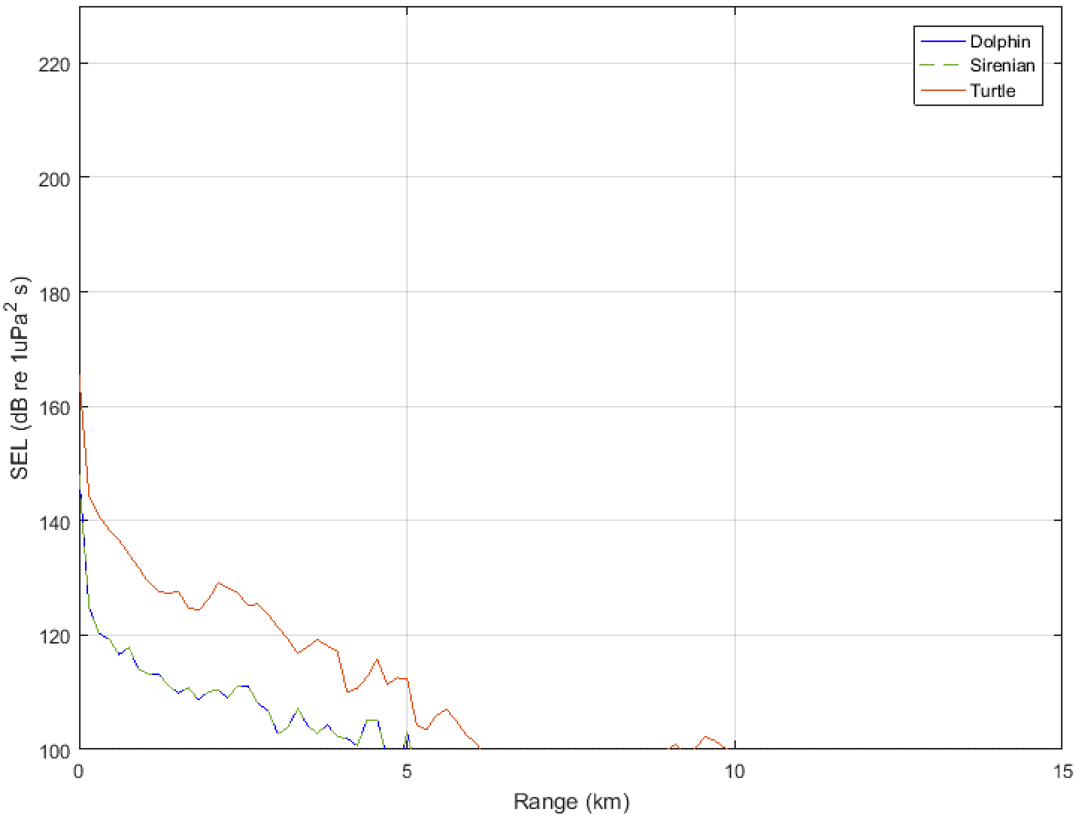

Figure 6-2 : CSD SEL with range for behavioural disturbance (High Tide).

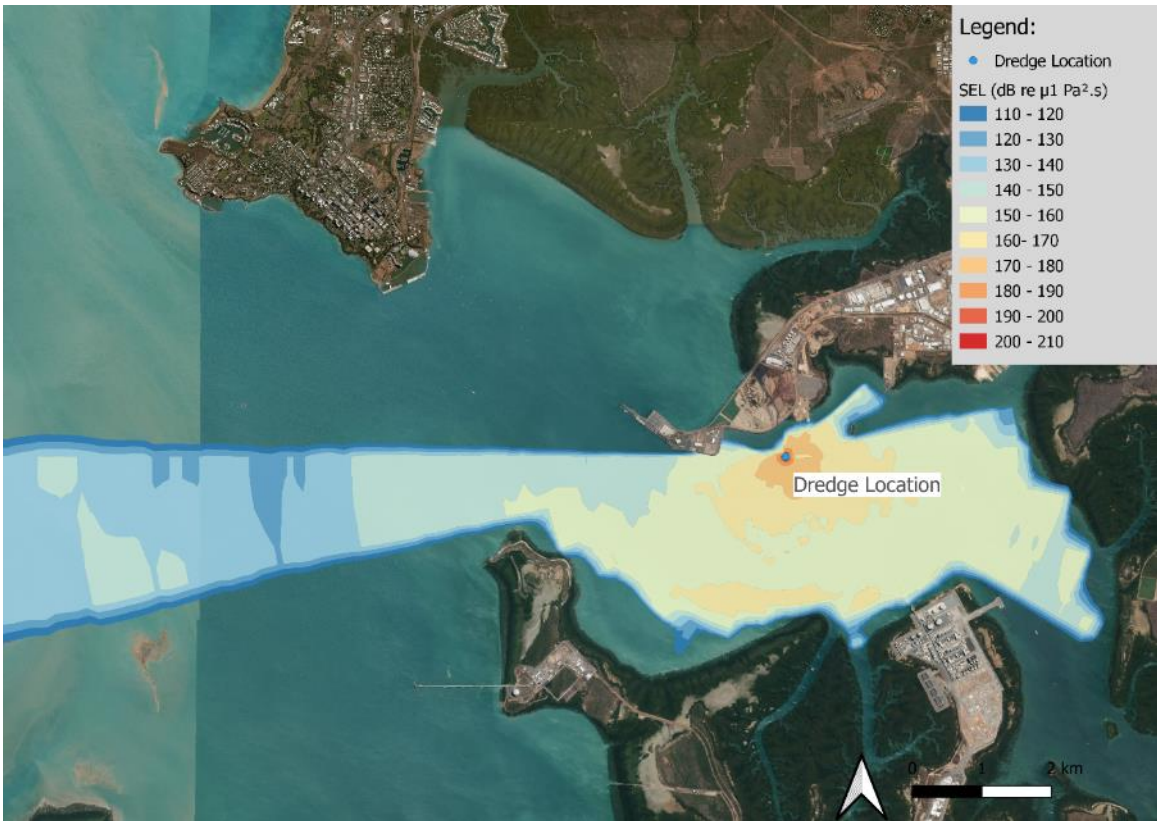

Figure 6-3 : Noise Contour – Dredging Operations – Unweighted maximum cumulative SEL (i.e. no frequency weighting curve applied)(High Tide)

6.2 Piling

Piling is an impulsive noise source involving multiple pile strikes. The maximum hammer energy has been determined to be applied over a period of 7 minutes which equates to 200 hammer strikes. Maximum predicted exposure levels have therefore been determined using 200 strikes.

Table 6-2 shows the predicted maximum ranges from the pile that noise levels will exceed TTS, PTS and behavioural disturbance thresholds for each mammal group. The exposure ranges at which TTS thresholds are exceeded for low tide are 120m for Sirenians, 360m for Dolphins and 175m for Turtles. In comparison, high tide ranges are 100m for Sirenians, 300m for Dolphins and 450m for Turtles. This indicates that scheduling piling activities around low tides could potentially be used to reduce exposure distances.

Figure 6-4 and Figure 6-5 provides the predicted HAT and LAT maximum SEL levels with range for each hearing group. Figure 6-7 and Figure 6-8 show the unweighted (i.e. no hearing curve applied and therefore worst case) cumulative SEL predicted noise contours for piling for LAT and HAT.

Based on the pile design in Figure 2-4, many of the piles are in very shallow water. For these piles it can be expected that the TTS and PTS ranges in Table 6-2 will be shorter allowing for small management zones to be used.

Table 6-2 : Behavioural, TTS and PTS Onset Thresholds from Impulsive Noise

Marine Mammal Hearing Group	**SEL Onset (Weighted) dB re 1µ Pa².s**		Potential Behavioural Disturbance Limit	**Tide**	**TTS Distance Limit (metres)**	**PTS Distance Limit (metres)**	**Behavioural** Disturbance **Distance (metres)**
	TTS	**PTS**					
Sirenians (SI)	178	190	140	Low	120	-	2,200
				High	100	-	1,050
Dolphins (HF)	170	185	140	Low	360	40	2,200
				High	300	30	1,050
Turtles	175	183	175	Low	175	100	-
				High	450	150	70

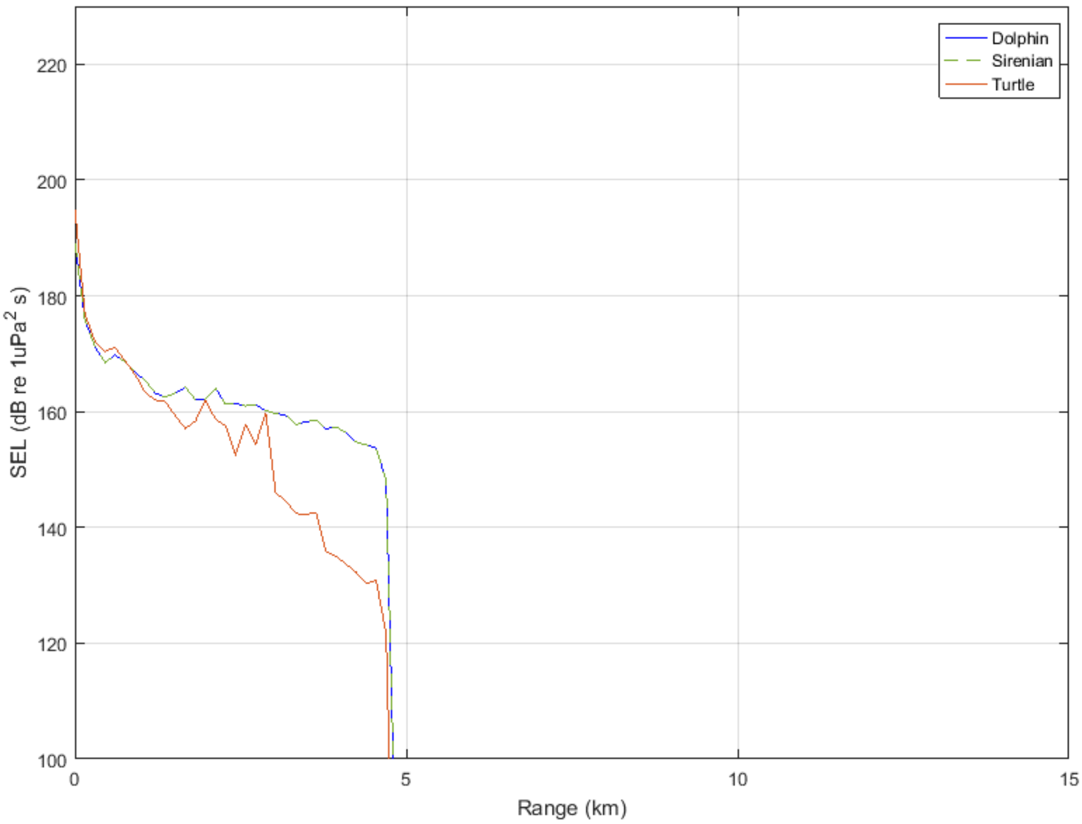

Figure 6-4 : Piling cumulative SEL with range (Low Tide).

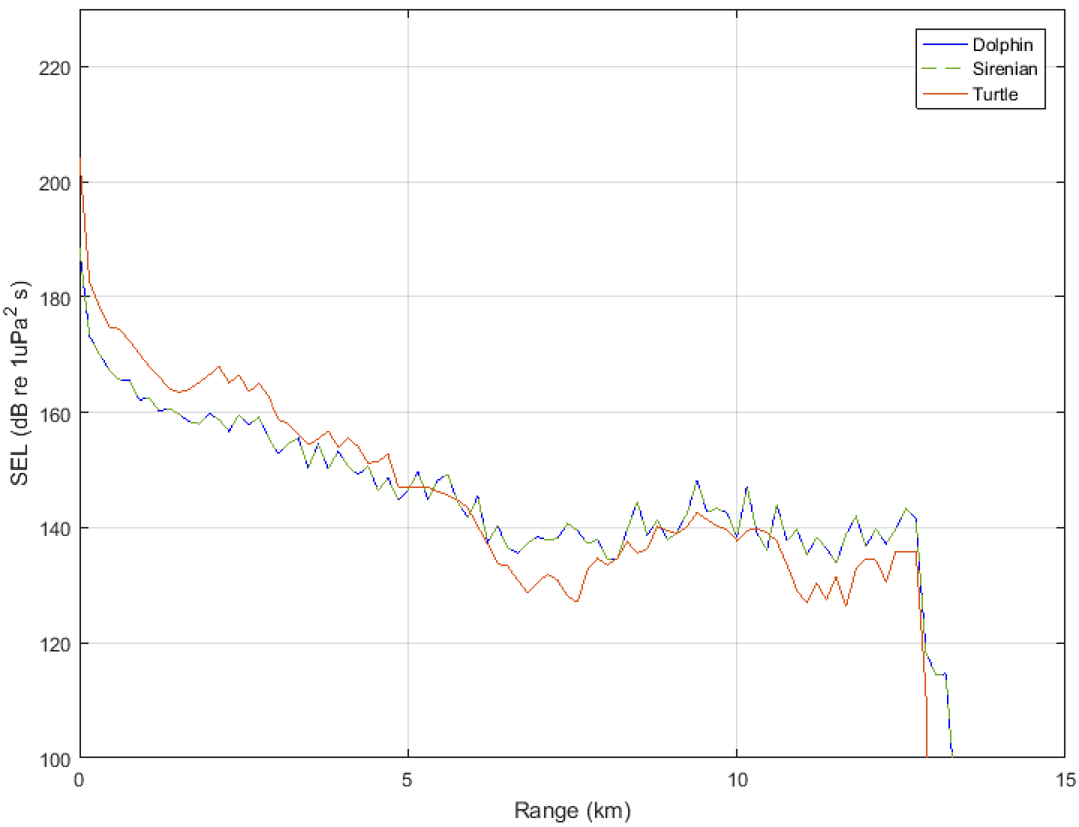

Figure 6-5 : Piling cumulative SEL with range (High Tide).

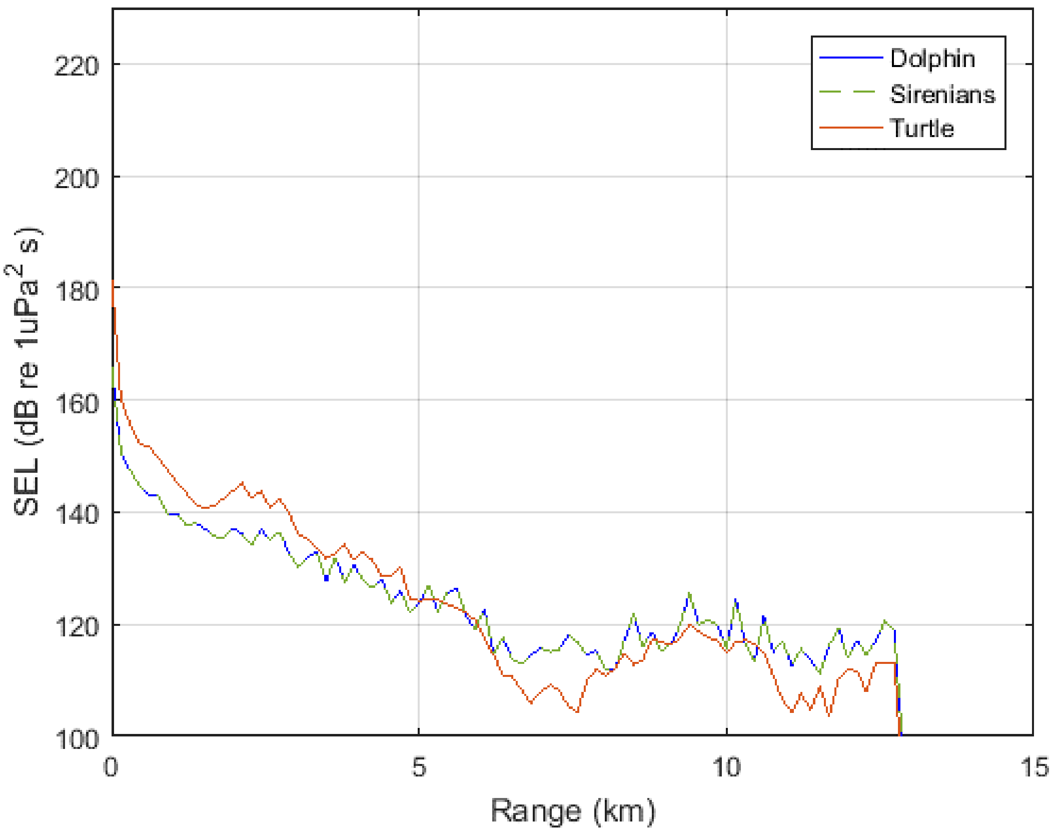

Figure 6-6 : Piling Single Strike SEL with range for Behavioural Disturbance (High Tide).

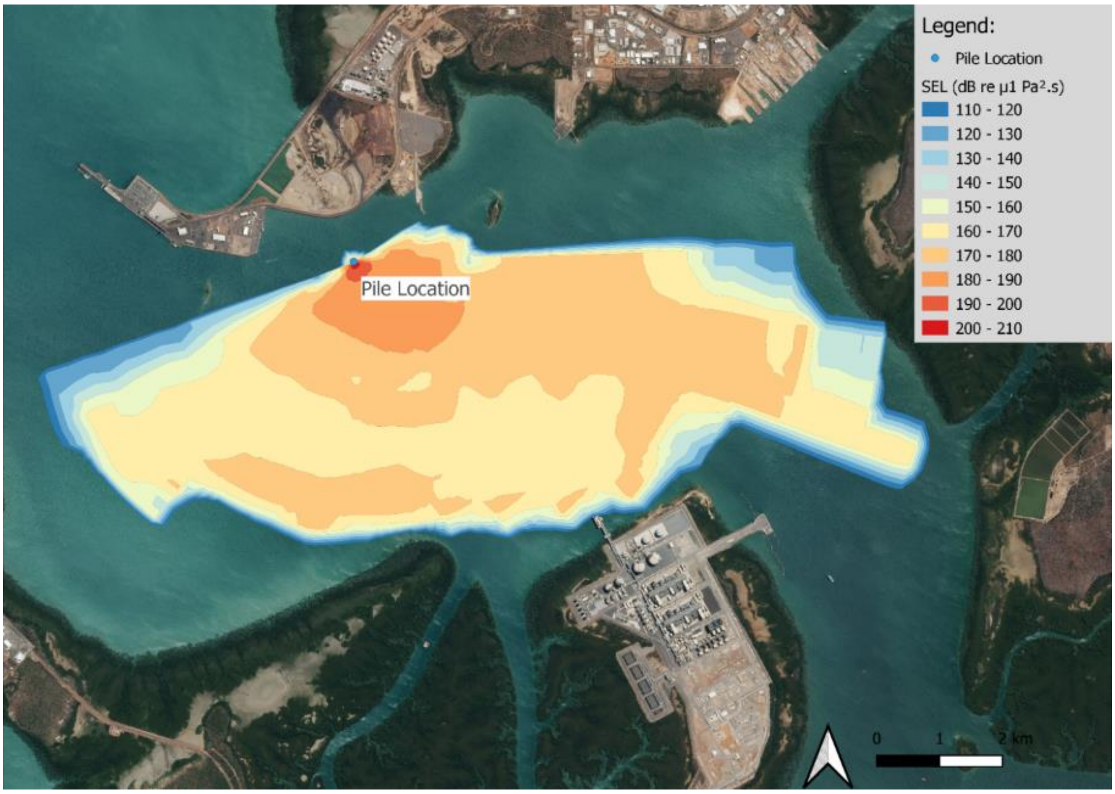

Figure 6-7 : Cumulative Noise Contour –Piling Operations - Unweighted (i.e. no frequency weighting curve applied) SEL (Low Tide)

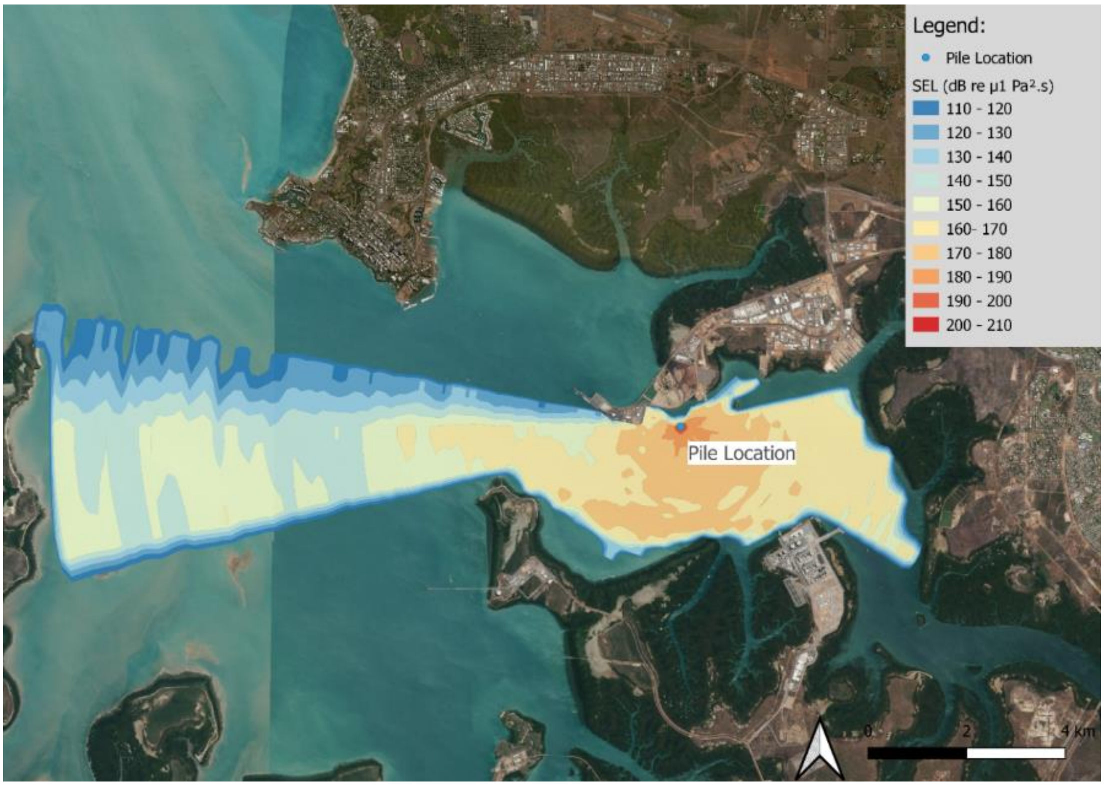

Figure 6-8 : Cumulative Noise Contour –Piling Operations - Unweighted (i.e. no frequency weighting curve applied) SEL (High Tide)

7 Conclusion

An underwater model has been created for the Project to predict potential noise levels at distance from the noise sources. The noise sources have been placed at the deepest point of the Project and it is therefore expected that the model outcomes will be conservative. Various assumptions have been made regarding the source levels and exposure duration. As a result, these levels should be verified through measurement once the Project has commenced.

Based on the model results for the Project, the following can be concluded:

- **Existing Anthropogenic Noise.** The existing shipping activity in the harbour area has not been included in the model as it forms part of the existing background noise. Considering the shipping volumes for Darwin Harbour, it is expected that the existing background noise will mask dredging activities related to the project.
- **Dredging** – The fauna that have been considered (i.e. dolphins, sirenians and turtles) are reasonably mobile, it has therefore been assumed that their maximum exposure to dredging will be approximately 1 hour as they move through the Project area. The model predicts that distances at which the noise level will exceed a TTS level for high tide are between 90 and 240m.
- **Piling** – For piling the exposure ranges at which TTS levels are exceeded for low tide are 120m for Sirenians, 360m for Dolphins and 175m for Turtles. In comparison, high tide ranges are 100m for Sirenians, 300m for Dolphins and 450m for Turtles. This indicates scheduling piling activities around low tides could potentially be used to reduce exposure distances. Additionally, for the pile design in Figure 2-4, many of the piles are in water that is surrounded by shallower water than the pile that was modelled for this study. For these piles it can be expected that the noise will be more contained and that the TTS and PTS distances in Table 6-2 will be shorter allowing for small management zones to be used.

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