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Augusta Boat Harbour

Marine Noise Management Plan

September 2011

Augusta Boat Harbour

Marine Noise Management Plan

Prepared for

Shire of Augusta—Margaret River

Prepared by

Oceanica Consulting Pty Ltd

September 2011

Report No. 458_004/1

Client: Shire of Augusta—Margaret River

Revisions history

Version	Author	DISTRIBUTION			REVIEW	
		Recipients	No. Copies & Format	Date	Reviewer	Date
A	K. Holloway	B. Hegge L. Twomey	1 x electronic	17/03/2010	L. Twomey B. Hegge	18/03/2010 16/02/2010
B	K. Holloway	L. Adams	1 x electronic	15/04/2010	P. Boreham	07/05/2010
Rev0	K. Holloway	DoT SAM Oceanica DEWHA	1 x electronic 2 x hardcopy 1 x electronic 1 x hardcopy 1 x electronic 2 x hardcopy 1 x hardcopy 1 x electronic	12/05/2010	DSEWPC (DEWHA)	31/05/2010
Rev1	K. Holloway	B. Hegge L. Adams	1 x electronic	22/11/2010	B. Hegge L. Adams	30/11/2010 23/11/2010
	K. Holloway	DoT DSEWPC Oceanica	1 x electronic 1 x electronic 2 x hardcopies	30/11/2010	DSEWPC	16/12/2010
Rev2	K. Holloway	B. Hegge L. Adams	1 x electronic	18/01/2011	B. Hegge L. Adams	19/01/2011 19/01/2011
	K. Holloway	DoT DSEWPC Oceanica	1 x electronic 1 x electronic 2 x hardcopies	20/01/2011		
Rev3	A. Sinden	B. Hegge	1 x electronic	02/08/2011	B. Hegge	04/08/2011
	A. Sinden	DoT	1 x electronic	04/08/2011	S. Smith	04/08/2011
	A. Sinden	DoT DSEWPC	1 x electronic 1 x electronic	08/08/2011		
Rev4	A. Sinden	B. Hegge	1 x electronic	05/09/2011	B. Hegge	05/09/2011
	A. Sinden	DoT DSEWPC Oceanica	1 x electronic 1 x electronic 1 x electronic	05/09/2001		
Rev5	A. Sinden	DoT DSEWPC Oceanica	1 x electronic 1 x electronic 2 x hardcopies	08/09/2001		

Status
This report is "Draft" until the author and director have signed it off for final release. A "Draft" report should not be used for any purpose other than to be reviewed with the intention of generating a "Final" version.

Approved for final release:

Authors

Director

Cover
Main image: Flat Rock, Augusta (Oceanica Consulting);
Minor images: Whale tail (Oceanica Consulting); Flat Rock, Augusta (Oceanica Consulting).

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1. Introduction

1.1. Background

The proposed Augusta Boat Harbour development (Figure 1.1) is a community driven project, arising from the need for a boating facility to provide commercial and recreational small craft safe navigation and mooring in the Southern Ocean waters off Augusta. The project has been subject to comprehensive technical and environmental investigations, and extensive community consultation.

On 20 October 2008, the proposal was approved under the *Environmental Protection Act 1986* (EP Act) by the Environmental Protection Authority (EPA) as "Not Assessed—Public Advice Given and Managed Under Part V of the EP Act (Clearing)".

In October 2008 the Augusta Boat Harbour proposal was submitted to the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC, previously the Department of Environment, Water, Heritage and the Arts; DEWHA) for approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). On 6 November 2008, the proposal was deemed a controlled action under the EPBC Act, requiring assessment and approval under that Act. The controlling provisions were identified as Listed Threatened Species and Communities (Sections 18 and 18a). In advising the Shire of Augusta-Margaret River of this decision, DSEWPC requested additional information Among the additional information requested was a requirement for 'a plan for minimising the impact of blasting and construction noise upon cetaceans likely to be in the project area, including how the plan will be implemented and monitored.' This document addresses this request, and has been written in accordance with the requirements of the EPBC approval 2008/4506.

1.2. Scope

The Marine Noise Management Plan (MNMP) includes the following components:

- Details of the quarry blasting and marine drilling operations;
- Management actions; and
- Contingency measures.

This MNMP has also been prepared with reference to the EPBC Act Policy Statement 2.1 (Interaction between offshore seismic exploration and whales) (DEWHA 2008).

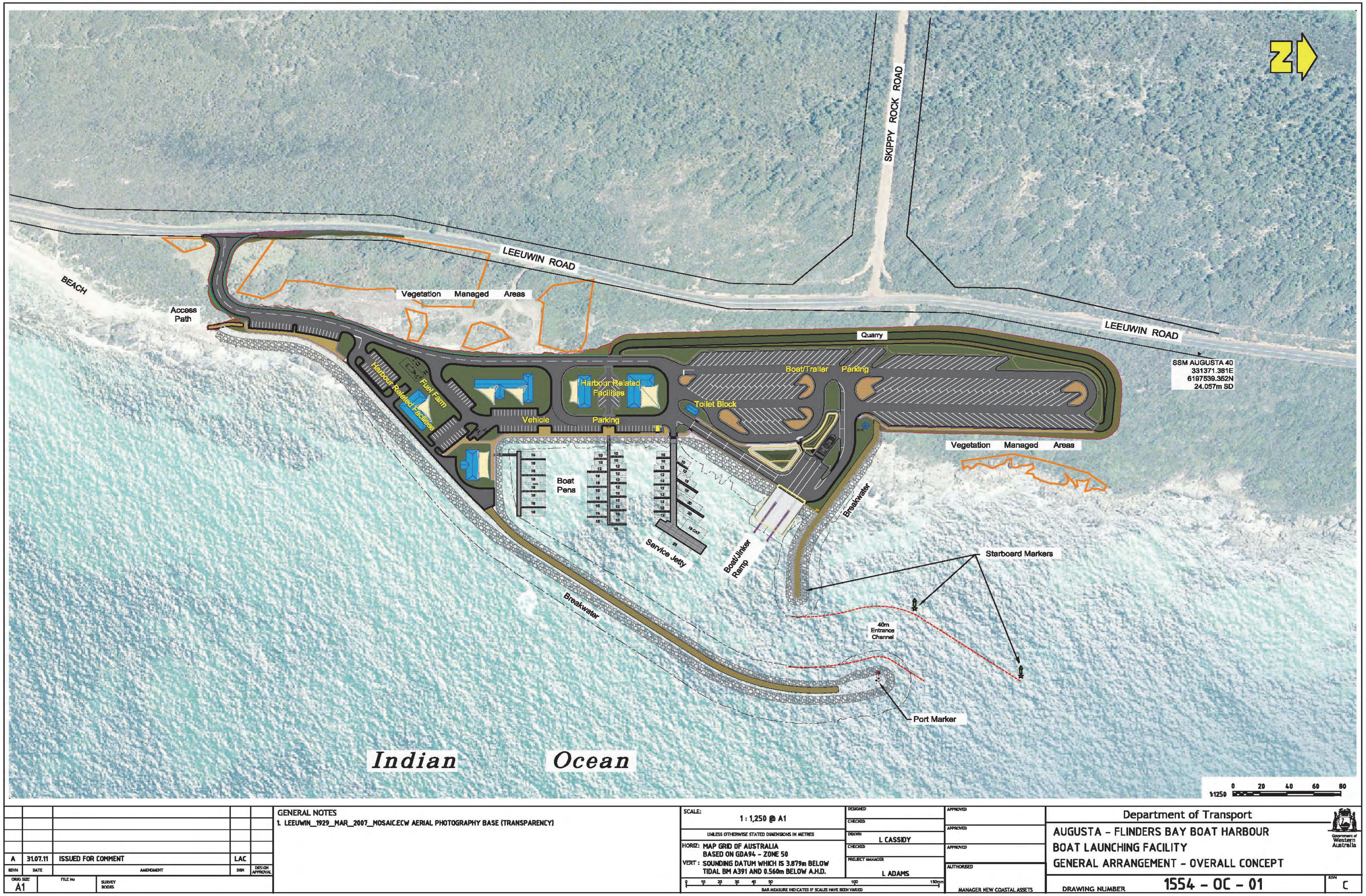

Figure 1.1 Augusta Boat Harbour Concept Design and Layout

2. Background

2.1. Quarry blasting

Potential impacts from quarry blasting consist of air-blast overpressure and ground vibration. The potential impact of the blast can be influenced by the degree of fracturing of the rock, the orientation of the face, the size of the blast and the weather conditions (Stephens 2008). Therefore, blast impacts are often variable.

The Augusta Boat Harbour quarry site extends approximately 425 m along the shore, is approximately 100 m wide and is up to 20 m high. The site comprises massive, coarse grained granulite with extensive areas of exposed rock and boulders (Coffey Geosciences 2005). Approximately 250,000 m^3 will be excavated from the site, to be used for breakwater armour and core stone. Typical quarrying, earthmoving and blasting techniques will be used to construct the quarry. The orientation and location of the active face away from the seaward edge of the quarry will result in a tendency for the air-blast to travel east and the ground vibration to travel west (i.e. back into the land mass) (Stephens 2008).

Air-blast noise is controlled by the Department of Environment and Conservation (DEC) under the *Environmental Protection (Noise) Regulations 1997.* The regulations stipulate that 9 out of 10 consecutive blasts are to be less than 120 dB with no blast exceeding 125 dB (linear, peak). Ground vibration is controlled by *Australian Standard AS2187 (1993) Explosives—Storage, Transport and Use*, which specifies a maximum of 10 mm/sec for dwellings and 20 mm/sec for commercial premises. AS2187 also provides structured guidelines on blasting.

Both air-blast and ground vibration typically show a distinct drop-off in impact with distance from the blast site. Normal procedure is to undertake several test blasts and monitor the blast levels. From the data, adjustments can be made to the drilling and blasting pattern as necessary.

2.2. Marine drilling

Piles are required for construction of the boat pens and service jetty within the boating facility. Due to the hard granite substrate, marine drilling will be required for pile insertion. Pile construction will occur after the breakwaters have been installed, and where possible, will be carried out between the months of October to May.

Potential impacts from marine drilling consist primarily of noise emissions. Drilling noise is considered a non-pulse, or continuous signal, dominated by low-frequency noise, with a peak level at around 60 Hz (SVT 2010). Drilling noise at the Augusta Boat Harbour site will be shielded by the harbour breakwaters.

Drilling noise is covered under construction noise in the *Environmental Protection (Noise) Regulations 1997.* The regulations stipulate that construction noise must be carried out in accordance with noise control practices set out in Australian Standard 2436-1981 (“Guide to Noise Control on Construction, Maintenance and Demolition Sites”).

2.3. Impacts on marine fauna

The zone of influence of a sound is the range at which noise will be detectable by the receiving fauna. The size of the zone of influence is defined by the intensity and temporal characteristics of the source and environmental conditions including water depth, benthic substrate, salinity and temperature (RPS Energy 2006). For underwater noise impacts on marine fauna, two effects within the zone of influence are of interest, which leads to the designation of two sub-sections within the zone of influence (SVT 2010):

1. The area of possible physical injury—in this area, there is a possibility that the animal may suffer physical/auditory injury and/or permanent hearing damage; and
2. The area of possible behavioural disturbance—in this area there is a possibility that the animal may experience auditory masking and/or behavioural change and/or avoid the area.

Southall *et al* (2007) developed a series of noise exposure criteria for both behavioural and injurious response for individual marine mammals exposed to discrete noise events. For cetaceans these vary between 224 and 230 dB re: 1 µPa[1] (peak, flat) for a single pulse event (Southall *et al* 2007). Criteria have also been developed for pinnipeds, with both in-water and in-air criteria provided (Southall *et al* 2007).

Very loud noises may cause some cetacean species to be displaced to some degree during the noise-production phase, especially from high-energy blasting and drilling. This noise is also capable of inducing physiological damage and even death to cetaceans if they are very close to the source of noise i.e. within 1 to 10 m. However, the nature of the construction activities (i.e. blasting on land, drilling within an enclosed harbour) are unlikely to allow a cetacean close enough to induce physiological damage. In addition, construction will be localised and temporary in nature, and some species may temporarily shift their swimming direction or migratory pathways to avoid these activities, but this is unlikely to impact on their population.

2.4. Incidence of sensitive marine fauna

Flinders Bay represents a seasonally important habitat for humpback and southern right whales during their northern migrations (May-October). Other whale and cetacean species are known to exist in the area, however specific data and information on temporal and spatial distribution is not well known (Burton 2010). Burton (2010) provides a full review on the species of whales and cetaceans that may occur in Flinders Bay. The EPBC Protected Matters Search Tool also identifies threatened and migratory marine fauna which may occur in the Flinders Bay region, and these are shown in Table 2.1.

[1] *Units refer to the reference pressure for underwater sounds of 1 µPa rms.*

Table 2.1 Threatened and migratory species, identified as protected matters under the EPBC Act, which may occur in the Flinders Bay region

Threatened Species	Status	Type of Presence
Blue Whale (*Balaenoptera musculus*)	Endangered Migratory	Species may occur within area
Southern right whale (*Eubalaena australis*)	Endangered Migratory	Breeding known to occur within area
Humpback whale (*Megaptera novaeangliae*)	Vulnerable Migratory	Congregation or aggregation known to occur within area
Bryde's whale (*Balaenoptera edeni*)	Migratory	Species may occur within area
Pygmy right whale (*Caperea marginata*)	Migratory	Species may occur within area
Killer whale, Orca (*Orcinus Orca*)	Migratory	Species may occur within area
Dusky dolphin (*Lagenorhynchus obscurus*)	Migratory	Species may occur within area
Australian sea-lion (*Neophoca cinerea*)	Vulnerable	Species may occur within area
Loggerhead turtle (*Caretta caretta*)	Endangered Migratory	Species likely to occur within area
Green turtle (*Chelonia mydas*)	Vulnerable Migratory	Species likely to occur within area
Grey nurse shark (*Carcharias taurus*)	Vulnerable	Species may occur within area
Great white shark (*Carcharodon carcharias*)	Vulnerable Migratory	Species likely to occur within area
School shark, eastern school shark, snapper shark, tope, soupfin shark (*Galeorhinus galeus*)	Conservation Dependent	Species may occur within area
Whale shark (*Rhincodon typus*)	Vulnerable Migratory	Species may occur within area

2.5. Bathymetry

The bathymetry of Flinders Bay (Figure 2.1) consists of nearshore high- and low-relief reef which drops away quickly to deep waters (>10 m depth within 400 m of the shoreline).

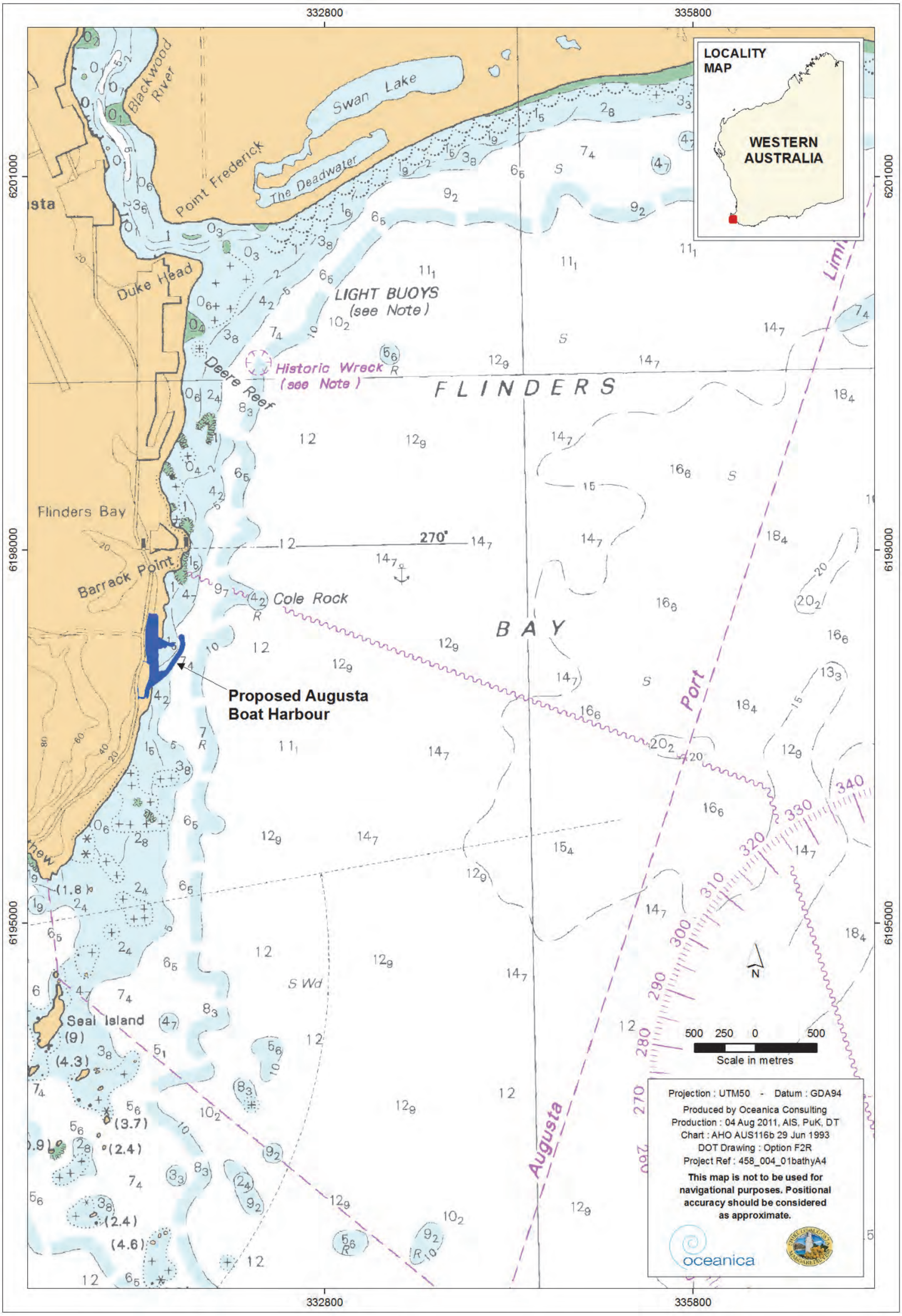

Figure 2.1 **Bathymetry of Flinders Bay within five kilometres of the proposed Augusta Boat Harbour**

3. Estimation of Physical Injury and Behavioural Disturbance Zones

SVT Engineering Consultants carried out a screening assessment of quarry blasting and marine drilling noise likely during construction of Augusta Boat Harbour; this report is presented in full in Appendix A. The purpose of the screening assessment was to use analytical formulae and assumptions to estimate the received sound levels at various ranges from the blasting and drilling activities (SVT 2010). For the purpose of impact assessment, it was assumed that 100% of acoustic energy would be transmitted into surrounding seawater, to represent the worst-case scenario of impact on marine fauna.

3.1. Quarry blasting

The sound exposure levels (SELs) and peak pressure levels were calculated for distances of 20 m, 100 m, 500 m and 1,000 m from quarry blasting (based on one 50 kg detonation of Powergel emulsion) (Table 3.1 and Table 3.2). The calculations predicted a zone of possible physical injury of between 20-100 m from the blast location. The zone of behavioural disturbance was predicted as less than 1,000 m from the blast location.

Table 3.1 Calculated SEL received levels at various distances from quarry blasting (SVT 2010)

Sound Exposure Level (SEL)	Distance from source	In-water sound speed	In-bottom sound speed	Absorption in water	Bottom Loss	Cylindrical spreading loss	Received Level
dB re 1 µ Pa^2 .s	m	m / s	m / s	dB	dB	cB re 1m	dB re 1 µ Pa^2 .s
212	**20**	1,500	1,708	0	0	13.0	**194.99**
212	**100**	1,500	1,708	0	11.40	20.0	**177.14**
212	**500**	1,500	1,708	0	16.17	27.0	**165.38**
212	1,000	1,500	1,708	0	18.80	30.0	159.74

Note: 1. Orange text indicates the zone of possible behavioural disturbance

Table 3.2 Calculated received sound pressure levels at various distances from quarry blasting (SVT 2010)

Sound Pressure Level (SPL) Peak	Distance from source	In-water sound speed	In-bottom sound speed	Absorption in water	Bottom Loss	Cylindrical spreading loss	Received Level (Peak)
dB re 1 µ Pa^2 .s	m	m / s	m / s	dB	dB	cB re 1m	dB re 1 µ Pa^2 .s
258	**20**	1,500	1,708	0	0	13.0	**240.99**
258	100	1,500	1,708	0	11.40	20.0	223.14
258	500	1,500	1,708	0	16.17	27.0	211.38

Note: 1. Red text indicates the zone of possible physical injury

3.2. Marine drilling

As drilling will be carried out after construction of the breakwater, the acoustic energy will be significantly mitigated and is not expected to have any impact on marine fauna in surrounding waters (SVT 2010). Acoustic energy will be attenuated very quickly due to interaction with the seabed, and neither physical injury nor behavioural disturbance for cetaceans is likely to be induced by underwater noise from drilling activities (SVT 2010).

4. Marine Noise Management Actions

4.1. Timing

The key migration period of humpback and southern right whales is May through October; these are the sensitive marine fauna most likely to be encountered within Flinders Bay (Burton 2010). Although Burton (2010) has indicated and observed that the primary whale migration period in Flinders Bay extends between May through October, it is noted within the Humpback Whale Recovery Plan 2005 – 2010 (DEH 2005a) and Southern Right Whale Recovery Plan 2005 – 2010 (DEH 2005b) that whales may be present within the south-west region of Western Australia, including the Augusta region, between May through November.

Therefore, although quarry blasting is unlikely to be undertaken during the primary whale migration period between the months of May through October inclusive, a 1,000 m exclusion zone (see Sections 4.3.1 and 4.5) will remain in place at all times between May through November should any blasting be required during this period. If any quarry blasting is required outside the months of December through April, particular care must be taken to conduct monitoring to ensure no sensitive marine fauna enter the 1,000 m exclusion zone (Section 4.3.1).

4.2. Blast methodology

Air-blast noise is controlled by the DEC under the *Environmental Protection (Noise) Regulations 1997*. The regulations stipulate that 9 out of 10 consecutive blasts are to be less than 120 dB with no blast exceeding 125 dB (linear, peak). Ground vibration is controlled by *Australian Standard AS2187 (1993) Explosives—Storage, Transport and Use*, which specifies a maximum of 10 mm/sec for dwellings and 20 mm/sec for commercial premises. AS2187 provides structured guidelines on blasting and therefore the guidelines on blasting and the methodology to be used will be followed at the Augusta Boat Harbour site. Blasting and quarrying will also be carried out in accordance with the relevant sections of the Mining Act 1978, The Dangerous Goods Handling and Storage Regulations 1992 and other regulations as required including the requirement for a DEC Works Approval and Licence for Crushing and Screening. As the works are for government, blasting is not specifically bound by the Mines Safety and Inspection Act 1994 and Regulations 1995, but they will be compliant in regard to safety issues.

Normal blasting procedure is to undertake several test blasts and monitor the blast levels. From the data, adjustments can be made to the drilling and blasting pattern as necessary. Management methods could include which face is fired, the design of excavation, the amount of rock fired, the depth of drill holes, the spacing of the drill patterns, the number of blasts, time of firing and the time delay patterns.

A sub-surface acoustic logger can provide useful information on received acoustic sound levels in the vicinity of operations, and should be deployed if possible. This would also provide information which would aid in future near-shore quarry blasting approvals.

A detailed (logistical) blasting plan will be prepared prior to undertaking any quarry blasting, based on specific site characteristics (e.g. area and depth to be blasted, rock hardness etc) and environmental guidelines. This document shall detail methods to be used, in accordance with AS2187, the blasting/design locations and noise management and monitoring measures. Blasts are not to exceed permitted overpressure and vibration limits, and all quarry blasting should be carried out as defined within this Marine Noise Management Plan.

As quarry blasting is being carried out to yield large armour material for breakwater construction, particular blasting techniques are used to produce rock of the required size. These techniques are in line with 'optimized' blasting techniques, which minimize the environmental impact of the blast. Optimized blasting includes (Bennett 2010):

- Varying the shooting pattern to take advantage of natural bedding and jointing, achieving efficient production;
- Reducing the total weight of explosive by considering the media and the material properties;
- Increasing the number of delays to allow movement of material prior to causing additional material to displace; and
- Increasing confinement with added stemming to assure that premature venting of gases does not occur.

All blast operators will be briefed, prior to quarry blasting commencing, on environmental issues, blasting management actions and contingencies as documented in the Marine Noise Management Plan.

4.3. Marine fauna monitoring

Marine fauna monitoring is based on the estimation of zones of possible impact in Section 3.

4.3.1. Quarry blasting

A trained, shore-based observer should keep a look out for sensitive marine fauna within 1,500 m of the blast site (Figure 4.1), commencing at least 15 minutes prior to, and continuing throughout, quarry blasting. All sightings within 1,000-1,500 m of blasting will be recorded and monitored during blasting. If a marine mammal is spotted within 1,000 m, or moves into the 1,000 m exclusion zone (Figure 4.1), blasting must immediately be delayed until the animal has left the area, or has not been seen within the exclusion zone for the preceding twenty minutes. A post-blast inspection for injured fauna should also be carried out. In the event of detection of injured or dead marine fauna[2], directly attributable to the quarry blasting operations, DEC will be notified immediately, the blasting operation will cease, and a review of the blasting procedures carried out to the satisfaction of the DEC. As specified in Section 4.1, the 1,000 m exclusion zone will remain in place between the months of May through November inclusive.

In the event that the 1,000 m exclusion zone cannot be observed fully, due to poor weather or any other reason, if marine fauna have been observed in the exclusion zone during the previous day, then quarry blasting will not proceed. If marine fauna were not observed in the exclusion zone during the previous day, then quarry blasting may proceed with caution.

[2] *Fish excepted. Dead fish observed floating on the surface will be removed to avoid predation.*

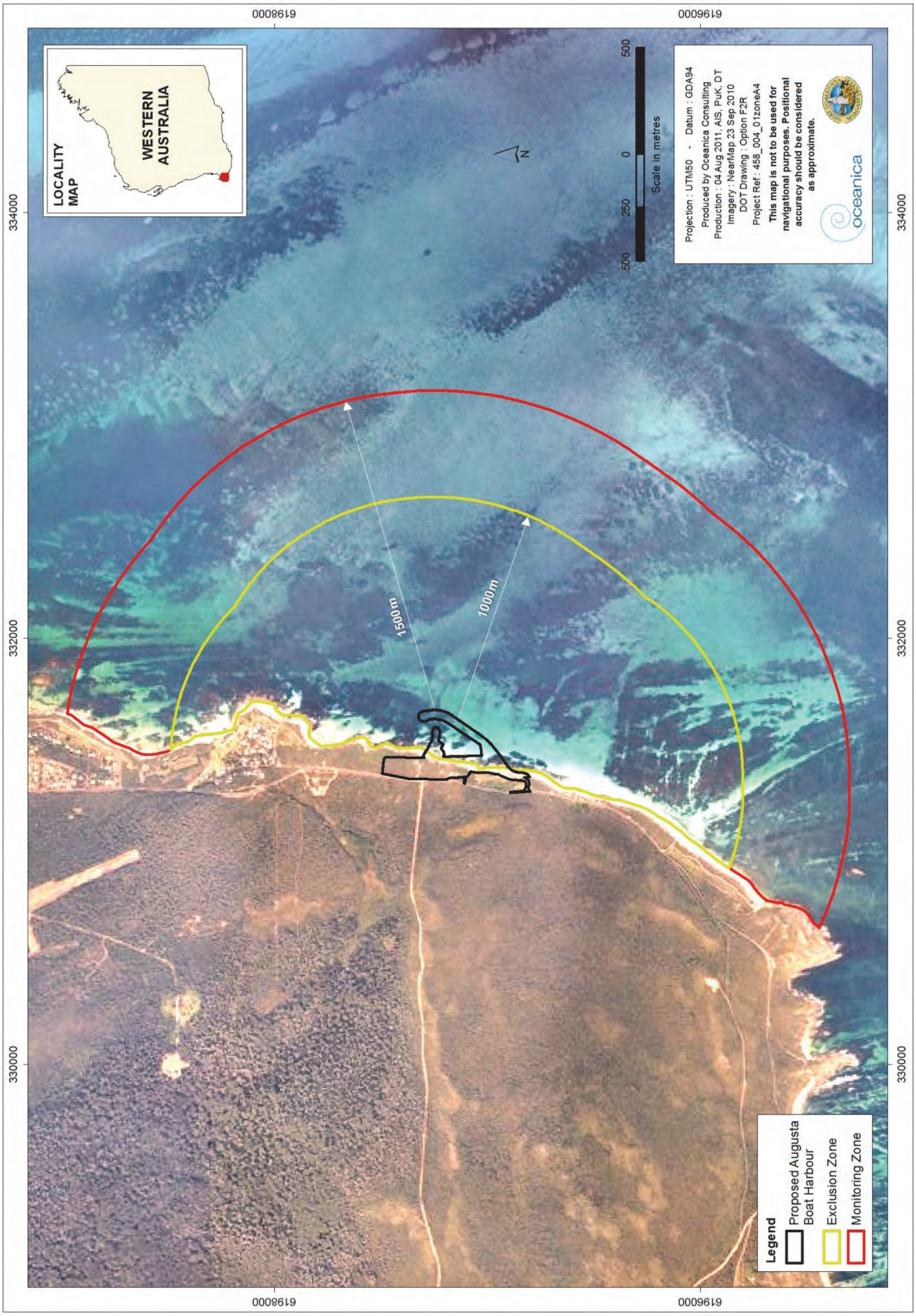

Figure 4.1 **Marine fauna exclusion and monitoring zones**

4.4. Reporting

Reporting will be in place for the duration of quarry blasting. All marine fauna sightings, including detection of injured or dead fauna, will be recorded, including the date, time and location of sighting and the name, qualifications and experience of the shore-based observer. Environmental/weather conditions should also be recorded, as well as any reasons that observations may have been hampered, for example poor visibility, inclement weather etc. In the event of detection of injured or dead marine fauna, a report should be provided to DSEWPC in writing within 24 hours, including details of the incident or risk, the measures taken and the success of those measures in addressing the incident or risk, as well as any additional measures proposed to be taken.

4.5. Summary

The management actions to be employed during quarry blasting are summarised in Table 4.1.

Table 4.1 Management actions to be in place during quarry blasting for the Augusta Boat Harbour construction

Management Measures	Responsibility	Timing
Blasting should be minimised as far as practicable	DoT	Planning stage
Blasting as far as practicable to be carried out during November-April (i.e. not during the whale migration season).	DoT	Duration of blasting programme
Blasting to be carried out only during daylight hours	Blast Operator	Duration of blasting programme
Blasting is to be carried out according to the relevant Regulations and Guidelines	Blast Operator	Duration of blasting programme
Blast management plan to be prepared and implemented	Blast Operator	Duration of blasting programme
Environmental briefing of blast operators	Blast Operator	Commencement of blasting programme
During blasting, a marine fauna exclusion zone of 1,000 m, and a monitoring zone of 1,500 m, is to be maintained around the blast zone	Blast Operator	Duration of blasting programme
Visual lookout to be maintained by a shore-based observer during quarry blasting	Blast Operator Construction Manager	Duration of blasting programme
A post-blast fauna inspection survey is to be carried out after each blasting period to identify any dead or injured fauna	Blast Operator	Duration of blasting programme
A written report will be provided to DSEWPC within 24 hours of in the event of detection of injured or dead marine fauna.	DoT	Duration of blasting programme
Records of all marine fauna sightings, weather conditions and details pertaining to the blasting are to be maintained	Blast Operator Construction Manager	Duration of blasting programme

5. Conclusions

The management actions, as outlined in Section 4.5 and summarised in Table 4.1 will be employed for the duration of the quarry blasting during construction of the Augusta Boat Harbour.

In summary, conducting quarry blasting outside the migration period for the two key whale species known to occur in Flinders Bay (humpback and southern right whales), will likely avoid any impacts to these species. Additionally, ensuring a 1,000 m exclusion zone is monitoring during any blasting which may be required to be undertaken between the months of May through November inclusive will further serve to reduce potential impacts on these species. The marine fauna observer programme will avoid impacts on all species that may occur in Flinders Bay and the records of these observations will help to build the knowledge of marine fauna occurring in this region.

6. Acknowledgements

This report was prepared by **Kellie Holloway** (Oceanica), updated by **Alannah Sinden** (Oceanica) and reviewed by **Bruce Hegge** (Oceanica), **Larry Adams**, **Peter Boreham** and **Stephen Smith** (DoT). Information to guide this report was sourced from **Chris Burton** (Western Whale Research), **Granger Bennett** (SVT Engineering) and the Flat Rock Boating Facility Environmental Referral Document, prepared by **Michelle Carey** (Oceanica). The report was formatted by **Rachael Hillman** (Oceanica).

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Appendix A

SVT Screening Assessment

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03 November 2010

Doc No: 1052856-Let01 Rev0 - 3 Nov 2010

Oceanica Consulting Pty Ltd
PO Box 462
Wembley
WA 6913

Dear Bruce

RE: SCREENING ASSESSMENT OF BLASTING & DRILLING NOISE DURING CONSTRUCTION OF THE FLAT ROCK BOAT HARBOUR

1. BACKGROUND

This briefing note is an underwater noise impact assessment associated with the blasting and drilling activities planned for the construction of the Flat Rock boat harbour in Flinders Bay, Augusta, Western Australia. Figure 1 shows the schematic diagram of the proposed boat harbour. The bathymetry for the surrounding shallow water region is shown in Figure 2.

1.1 Blasting

The inland blasting activities during the boat harbour construction phase are expected to take place in the footprint/carpark area, as shown in Figure 1. The blasting will be undertaken before the construction of the breakwater, and as such no shielding can be expected.

1.2 Drilling

The drilling rigs are expected to be operating after the construction of the breakwater, in both footprint/carpark area as well as on the breakwater. The breakwater is expected to provide acoustic shielding of the drilling noise emission being radiated out to the east of the harbour.

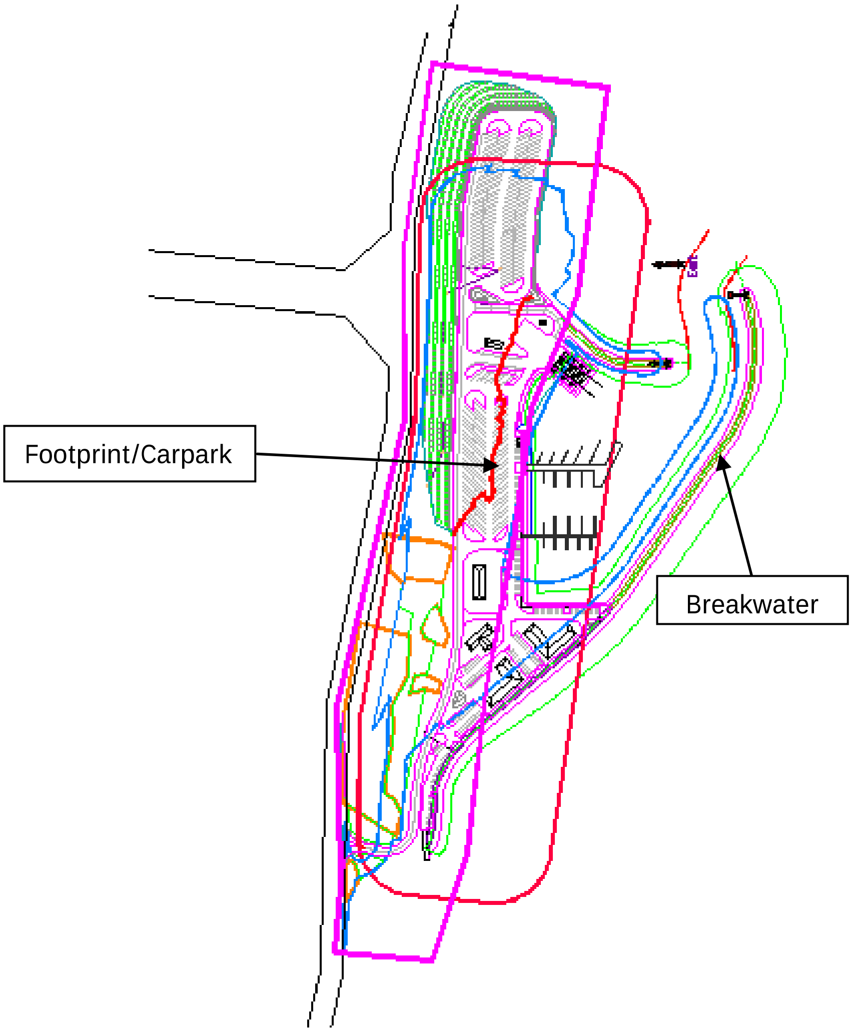

Figure 1 Schematic diagram of the proposed flat rock boat harbour in Flinder Bay, Augusta, Western Australia.

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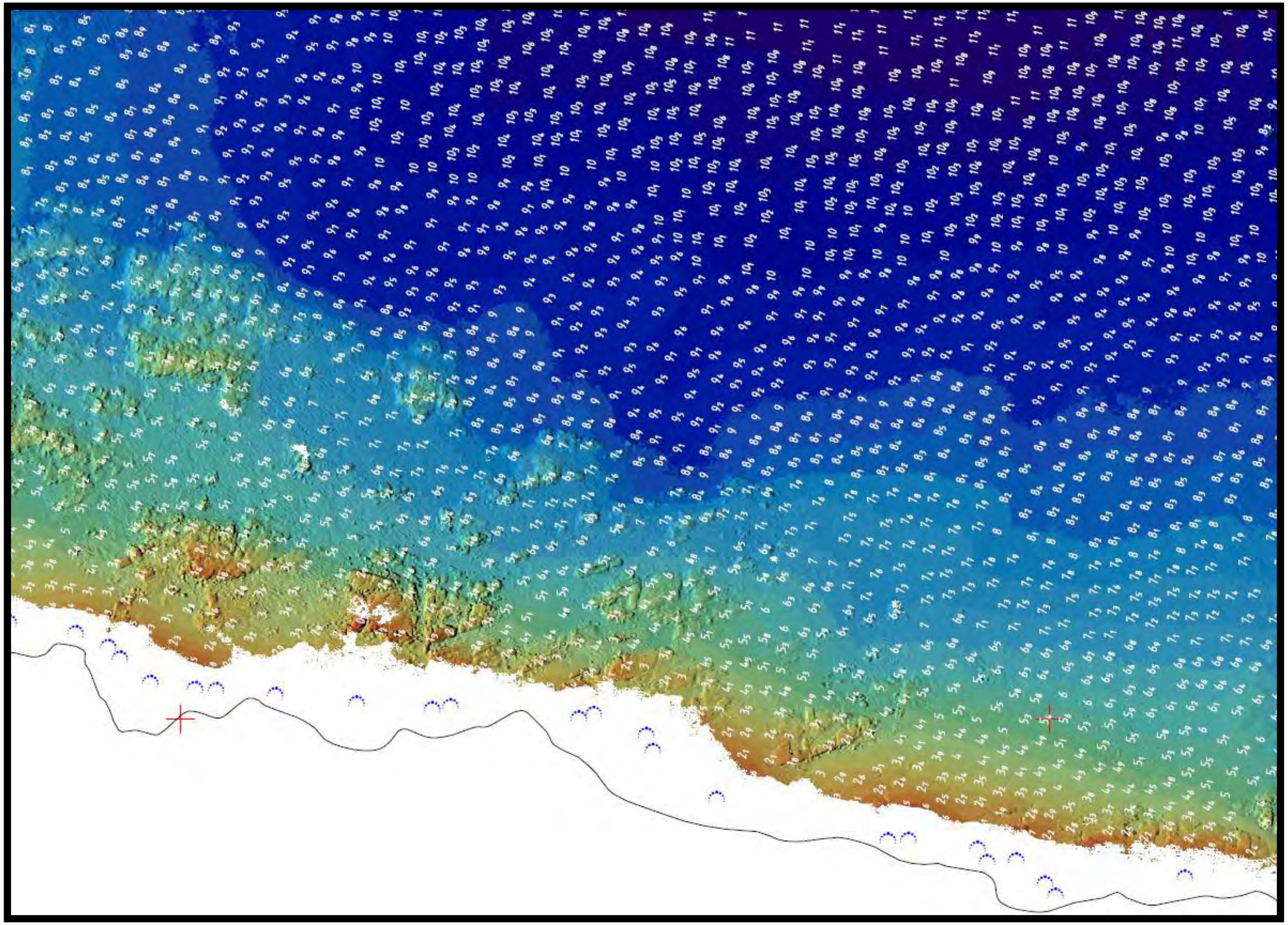

Figure 2 Extract of the bathymetric survey of Flinder Bay, August, Western Australia

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2. NOISE SOURCES

2.1 BLASTING

Explosives, which are regarded as pulse signals, have two important components that are of interest to underwater noise. They are as follows:

- **Shock wave**. Important in unconfined explosions (e.g. Severing steel, Seismic, bolder breakage, ordinance testing)
- **Gas component**. Generally the more useful component (e.g. mass demolition by displacement of material with stemming)

As can be seen from the above each component is used to perform a different type of mechanical work. Explosives can be designed to release different total energy fractions of Shock wave and Gas component depending on the mechanical work to be performed. All explosions have some fractions of both. This is an important consideration as the shock wave component of a blast is the most critical component for physical injury.

Explosive blasts are typically broadband, non-linear effects with large peak pressures and extremely fast rise and fall times. An analytical formula can be used (if the TNT equivalent of the explosive is known) to determine the peak SPL per charge mass as shown in Figure 3.

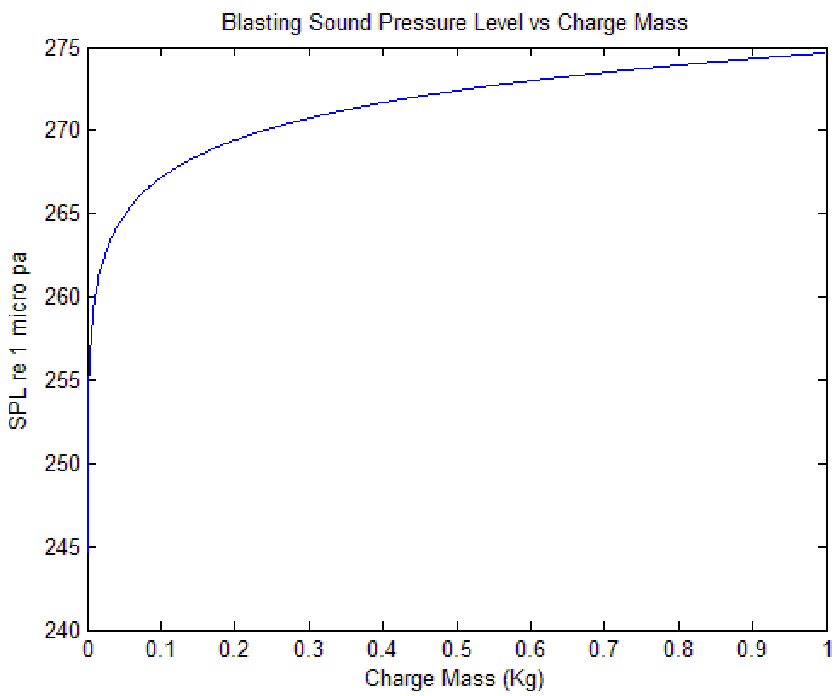

Figure 3 Blast Sound pressure level achieved per charge mass.

For this study, it is assumed that the blasting explosive to be used by future proponents in the Flat Rock Boat Harbour will be an emulsion that is used in the mining industry ('Powergel'). This emulsion has a TNT equivalent of 0.31. Detonating 50 kg of Powergel gives a peak value of 8.026766 MPa at a distance of 1 m using D. Ross's formula[1]. This translates into a peak pressure value of 258 dB re 1 μPa @ 1 m. The duration of the pulse can be calculated to be 24.5 μs which gives a SEL of 212 dB re 1 μPa²·s. The source spectrum curve of the blasting follows the research outcome from Weston[2].

2.2 Drilling

Drilling noise can be regarded as a non-pulse or continuous signal. The spectrum and the spectrogram of a typical drilling noise from SVT's database are shown in Figure 4 and Figure 5. As can be seen, drilling noise is dominated by low-frequency noise, with the peak level at around 60 Hz.

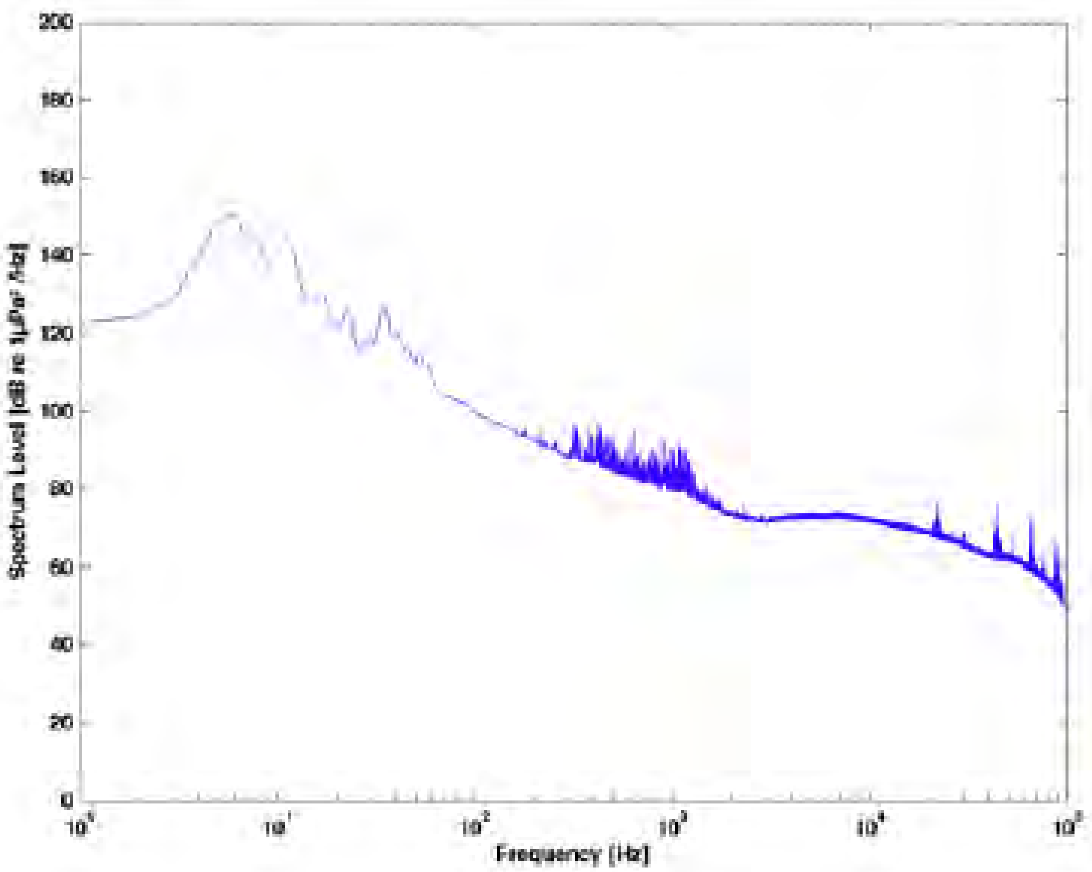

Figure 4 Spectral source level) of a typical drill.

[1] Donald, Ross: Mechanics of Underwater Noise. Peninsula Publishing, Los Altos California, USA.

[2] Weston, D.E.: Underwater Explosions as Acoustic Sources, *Proc. Phys. Soc.* London, 76(pt.2):233 (1960)

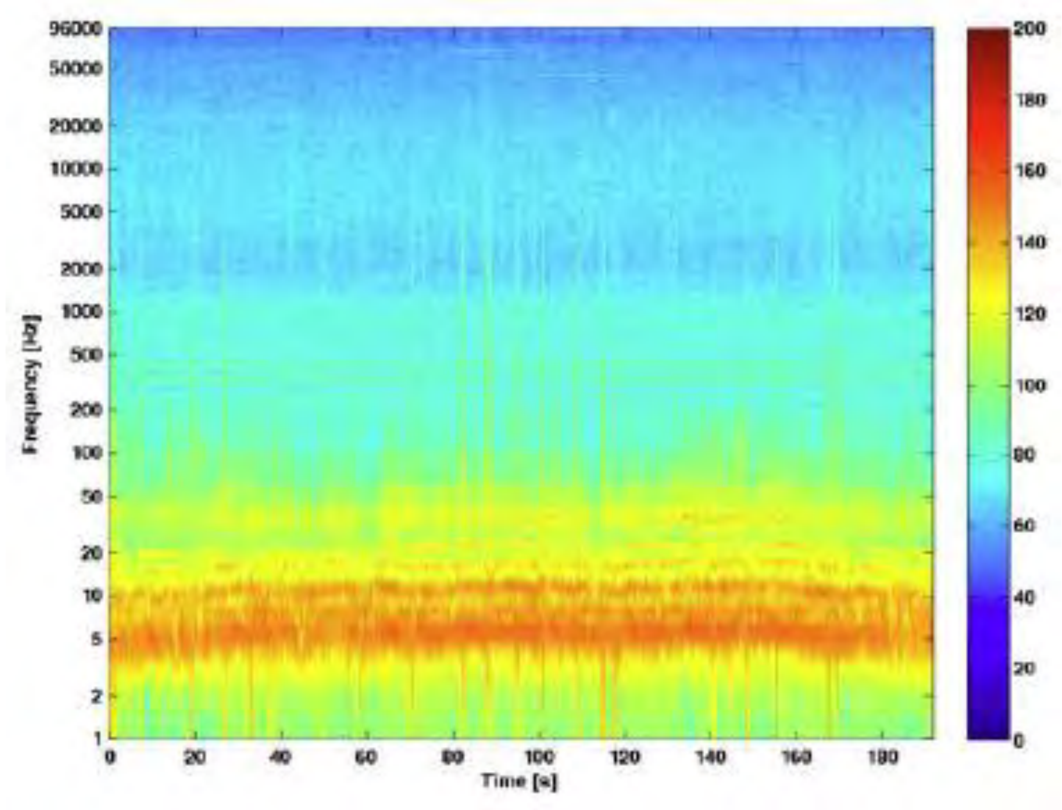

Figure 5 Spectrogram showing the variation of the noise from a drill over time.

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. As a result assessment levels in this letter 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 behavioural disturbance. 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/auditory injury and/or permanent hearing damage.
2. **Area of Possible Behavioural Disturbance**. In this area there is a possibility that the animal may experience auditory masking and/or behavioural change and/or avoid the area.

3.2 CETACEANS

The criteria that will be used for the assessment of cetaceans are given in Table 1. They are based on the criteria recommended by Southall *et al*[3] and the EPBC Act policy statement 2.1[4]. 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. humpback whales) and high frequency mammals the data for mid frequency mammals is recommended by Southall *et al* to be used for low and high frequency mammals.

The SEL criteria in Table 1 for possible physical injury are M-weighted based on M-weighting functions for low-, mid-, and high-frequency cetaceans shown in Figure 6. As most of the energy of the noise sources considered in this assessment are within the frequency range of both low and mid frequency cetaceans where the response curve is flat (i.e. are most sensitive), this study took a conservative approach by considering the SEL criteria for possible physical injury as un-weighted.

The criteria of possible behavioural disturbance recommended by both Southall *et al* and the EPBC Act policy statement 2.1 are based on observational data predominantly 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 blasting and drilling activities. However, as there is no data available that can be used to determine the criteria for blasting and drilling, the criteria for seismic surveys will be used.

Table 1 Received threshold levels for peak pressure, RMS sound pressure level (SPL) and sound exposure level (SEL) above which there would be a possibility of physical injury or behavioural effect for Cetaceans.

Metric	Possible Physical Injury		Possible Behavioural Disturbance	
	Single pulses	Non-pulses	Single pulses	Non-pulses
Peak Pressure	230 dB re 1µPa (un-weighted)	230 dB re 1µPa (un-weighted)	224 dB re 1µPa (un-weighted)	Not applicable
RMS SPL	Not applicable	Not applicable	Not applicable	120 dB re 1µPa
SEL	198 dB re 1µPa^2.s (M-weighted)	215 dB re 1µPa^2.s (M-weighted)	160 dB re 1µPa^2.s (unweighted)	Not applicable

[3] Southall *et al*, Marine mammal noise exposure criteria: initial scientific recommendations, Aquatic Mammals, Volume 33, Number 4, 2007, ISSN 0167-5427

[4] EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales. Australian Government, Department of the Environment, Water, Heritage and the Arts. September 2008.

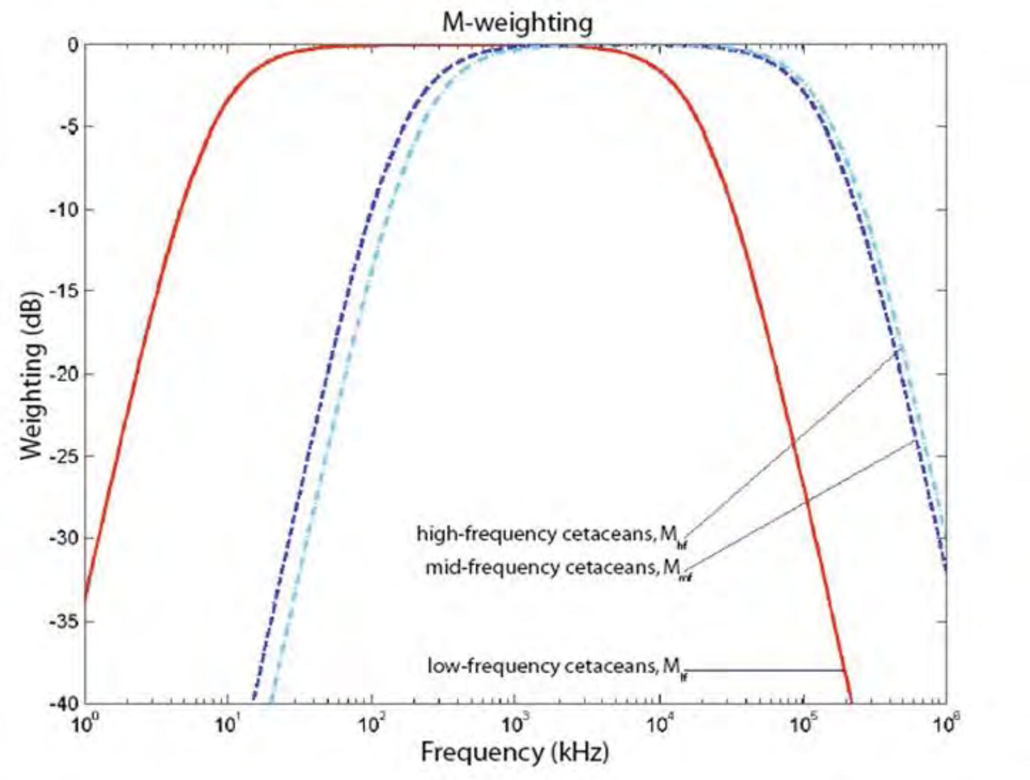

Figure 6 The M-weighting functions for low-, mid-, and high-frequency cetacean.

4. ESTIMATION OF PHYSICAL INJURY AND BEHAVIOURAL DISTURBANCE ZONES

4.1 FORMULAE AND ASSUMPTIONs

The following analytical formulae and assumptions were used to estimate the received levels at various ranges from the blasting and drilling operations.

4.1.1 ACOUSTIC ENERGY TRANSMISSION FROM INLAND TO UNDERWATER

The substrate type of the seabed is generally dominated by high compressional speed (higher than sound speed in water) which will result in high transmission efficiency of acoustic energy from the substrate to the water. Considering the close range between the blasting/drilling activities and the shoreline and without undertaking any modelling, it is assumed that acoustic energy from the substrate will be 100% transmitted into surrounding seawater. This assumption represents the worst case scenario in terms of the impact assessment on marine fauna in the surrounding study area.

4.1.2 TRANSMISSION LOSS

An acoustic signal travelling through the ocean becomes distorted due to multipath effects and weakened due to various loss mechanisms. The standard measure in underwater acoustics of the change in signal strength with range is *transmission loss* defined as the ratio in decibels between the acoustic intensity $I(r,z)$ at a field point and the intensity I_0 at 1-m distance from the source, i.e.,

$$TL = -10\log\frac{I(r,z)}{I_0} = -20\log\frac{|p(r,z)|}{|p_0|} \qquad \text{[dB re 1uPa @ 1 m]}$$

The formula has made use of the fact that the intensity in a plane wave is proportional to the square of the pressure amplitude.

4.1.3 MODE CUTOFF FREQUENCY

A common feature of all acoustic ducts is the existence of a low frequency cut-off. Hence, there is a critical frequency below which the shallow-water channel ceases to act as a wave guide, causing energy radiated by the source to propagate directly into the bottom. The *cut-off frequency* can be calculated using

$$f_0 = \frac{c_w}{4D\sqrt{1-(c_w/c_b)^2}}$$

This expression is exact only for a homogeneous water column of depth D and sound speed c_w overlying a homogeneous bottom of sound speed c_b. The modal cut off frequency for the various water depths is estimated in the following section. For the assessment the acoustic energy in the cut-off frequencies is removed from the source level.

4.1.4 ABSORBTION

The frequency dependence of attenuation can be roughly divided into four regimes of different physical origin. The lowest frequency regime, region I, is still not completely understood but it is conjectured that it is related to low frequency propagation-duct cut-off, or in other words, leakage out of the deep sound channel. The main mechanisms associated with regions II and III are chemical relaxations of boric acid $B(OH)_3$ and magnesium sulphate $MgSO_4$, respectively. Region IV is dominated by the shear and bulk viscosity associated with salt water.

A simplified expression for the frequency dependence (f in kHz) of the attenuation is,

$$\alpha' \cong 3.3\times10^{-3} + \frac{0.11f^2}{1+f^2} + \frac{44f^2}{4100+f^2} + 3.0\times10^{-4}f^2 \quad \text{[dB/km]}$$

Where f is the frequency in kilohertz.

4.1.5 GEOMETRIC SPREADING

As the area of assessment is in shallow water *Cylindrical spreading loss* will be used to estimate geometric spreading. This is given by

$$TL = 10\log r \qquad \text{[dB re 1 m]}$$

4.1.6 SEABED CHARACTERISTICS

It was assumed that the seabed is medium sand half space. The geo-acoustic properties are shown in Table 2.

Table 2 Geo-acoustic properties of the seabed.

Sound speed	Density	Attenuation
1774 m s^{-1}	2.05 g cm^{-3}	0.374 dB m^{-1} kHz^{-1}

4.1.7 SEABED ABSORBTION

When sound interacts with the seafloor, the structure of the ocean bottom becomes important. Ocean bottom sediments are often modelled as fluids which mean that they support only one type of sound wave – a compressional wave. The *reflection coefficient* R at the seabed interface determines how much acoustic pressure is reflected back into the ocean. R is given by,

$$R = \frac{\rho_2 c_2 / \sin\theta_2 - \rho_1 c_1 / \sin\theta_1}{\rho_2 c_2 / \sin\theta_2 + \rho_1 c_1 / \sin\theta_1},$$

Where ρ is the densities of the two mediums at the interface and θ is the angle of incidence or transmittance. Each time the acoustic wave is reflected off the seabed it incurs a loss which is called *bottom loss* and is given in decibels as

$$BL = 10\log|R|^2 + 10\log N$$

Where R is the reflection coefficient and N is the number of times the wave reflects off the seabed.

4.1.8 PEAK PRESSURE

Received peak pressure was estimated from the SEL using an empirical formula

$$SPL_{peak} = SEL + 10\log(T1/T2) + 18$$

where T1=1s and T2= duration of pile pulse. Peak pressure was estimated from the RMS sound pressure (SPL RMS) using an empirical formula

$$SPL_{peak} = SPL_{RMS} + 18.$$

5. ESTIMATED RECEIVED LEVELS AND ZONES OF POSSIBLE AVOIDANCE AND POSSIBLE PHYSICAL INJURY

The zones of possible physical injury and possible behavioural disturbance have been calculated using analytical techniques. This has many limiting factors over modelling. For example it is impossible to accurately estimate the broadband transmission loss over the entire bandwidth of the noise source, the bottom loss estimation is not as accurate as that of a model, the effect of bathymetry cannot be evaluated properly and the auditory bandwidth of the animal can't be taken into account. However, considering that the apparent risk of impact to marine fauna appears to be reasonably low the analytical approach could be considered appropriate.

5.1.1 BLASTING

The blasting activities in the area of footprint/carpark area shown in Figure 1 are in proximity to the very shallow water region with water depth less than 10 m as shown in Figure 2. Based on a conservative consideration, it was assumed that the acoustic energy from blasting will be 100% transmitted into a water column of 10 m. In addition, the water depth in the whole Flinders Bay was assumed as uniform of 10 m.

Table 3 and Table 4 show the calculated SEL and peak pressure level respectively using the analytical formulas at 20 to 1000 m for blasting. All calculations are based on one 50 Kg detonation of a Powergel emulsion.

In the tables the zone of physical injury (cells highlighted in red) for cetaceans was determined using the SEL and peak pressure levels given in Section 3.2. From the calculations it can be expected that the zone of possible physical injury will be between 20 m and 50 m from the blast as indicated in Table 4. The zone of behavioural disturbance (cells highlighted in yellow) for cetaceans has been determined using the SEL value and can be expected to up to 1000 m from the blast, as shown in Table 3.

Table 3 Calculated SEL received levels at various ranges from blasting.

SEL	Distance from source	In-water sound speed	In-bottom sound speed	Absorption in water	BL	Cylindrical spreading loss	Received Level
[dB re 1 µ Pa^2.s]	[m]	[m/s]	[m/s]	[dB]	[dB]	[dB re 1m]	[dB re 1 µ Pa^2.s]
212	20	1500	1708	0.00	0.00	13.0	194.99
212	100	1500	1708	0.00	11.40	20.0	177.14
212	500	1500	1708	0.00	16.17	27.0	165.38
212	1000	1500	1708	0.00	18.80	30.0	159.74

Table 4 Calculated received levels at various ranges from blasting.

SPL Peak	Distance from source	In-water sound speed	In-bottom sound speed	Absorption in water	BL	Cylindrical spreading loss	Received Level (Peak)
[dB re 1 µ Pa]	[m]	[m/s]	[m/s]	[dB]	[dB]	[dB re 1m]	[dB re 1 µ Pa]
258	20	1500	1708	0.00	0.00	13.0	240.99
258	50	1500	1708	0.00	7.48	17	229.17
258	100	1500	1708	0.00	11.40	20.0	223.14
258	500	1500	1708	0.00	16.17	27.0	211.38

5.1.2 DRILLING

As drilling activities will be undertaken after the construction of breakwater, and the depth of the water area is very low (less than 5 m), consequently the acoustic energy from the inland drilling will be mitigated significantly and therefore it is not expected to have any impact on marine fauna in surrounding water region.

For the drilling activities on the breakwater, the acoustic energy was assumed to be 100% transmitted into the surrounding water column. The cut-off frequency of acoustic propagation is around 70 Hz based on 10 m water depth, medium sand seabed type and iso-speed profile, which means the acoustic energy below 70 Hz will be attenuated very quickly in a very short range due to the interaction with the seabed. The source spectrum levels of frequencies above 70 Hz are all below 120 dB re 1uPa, as shown in Figure 5. Therefore, neither physical injury nor behavioral disturbance for cetaceans will be induced by underwater noise from drilling activities on the breakwater during the construction of the flat rock boat harbour.

Yours sincerely

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