HUSON & ASSOCIATES

REPORT

UNDERWATER NOISE IMPACT ASSESSMENT

GLADSTONE LNG PROJECT

CLIENT: URS Australia Pty Ltd

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UNDERWATER NOISE IMPACT ASSESSMENT

GLADSTONE LNG PROJECT

EXECUTIVE SUMMARY

Sound pressure levels produced underwater from construction and ongoing operations of the proposed Gladstone LNG Project are not predicted to have any long term detrimental effects upon marine fauna identified within the area. Short term avoidance of areas surrounding pile driving or dredge activities is expected.

Short term avoidance of areas surrounding piling activities is expected inside a range of 350m from the pile. It is recommended that observations of the area around piling operations (350m radius) be made before commencement of work on any given day to ensure the area does not contain dugong, whale shark, humpback whale or dolphin that may be startled, or alternatively the use of soft start procedures to piling operations can be used.

The areas where short term avoidance would be expected during certain construction activities do not contain any significant seagrass beds and the avoidance areas would only affect migration across a small part of Port Curtis. The overall impact of dredging operations for the GLNG Project caused by underwater noise is similar to that caused by a single ship traversing Curtis Bay.

Sonar having a transducer operating frequency above 200kHz is recommended to minimize interference with dolphin and dugong.

If the barge and ferry option (in lieu of a bridge) is used there would be no significant underwater acoustic impact on marine fauna.

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INTRODUCTION

L Huson & Associates Pty Ltd has been commissioned by URS Australia Pty Ltd (URS) to assess the underwater acoustic impacts associated with the construction and operation of a liquefied natural gas (LNG) facility and associated bridge access roads and marine facilities on Curtis Island near Gladstone, Queensland.

This assessment reviews the impact of construction activities and future operations and forms part of an environmental impact statement for the Gladstone Liquefied Natural Gas (GLNG) project that has been prepared by URS for Santos Ltd.

PROJECT LOCATION

Curtis Island is approximately 45km long and 14km wide with its southern tip approximately 6km NW from Gladstone CBD.

The LNG facility is proposed to be located on the south-western side of the southern tip of Curtis Island, approximately one-third of the distance between Hamilton Point and Laird Point.

Figure 1 shows the location of the LNG facility on Curtis Island with the spur channel that will link onto the main Targinie and Clinton access channels that serve Fishermans Landing Wharves and the RG Tanna Coal Terminal. Figure 2 shows the LNG facility and berths in more detail.

The waterways from Fishermans Landing Wharves to Wiggins Island Coal Terminal, RG Tanna Coal Terminal, Barney Point and Auckland Point Terminals past the Boyne Smelter Wharves support the passage of many types of bulk carrier ships.

The latest (2008) 50-year Gladstone Ports Corporation Strategic Plan describes the future cargo capacity of the Gladstone Port harbour. The harbour is expected to increase total capacity to 300 (Mt) of export product within the next 50 years. The berths from which the LNG facility will load its export cargo are in the Western Basin. The Western Basin Development is the focus for future growth at the port and there are plans to increase the number of berths at Fishermans Landing to cater for Panamax ships with carrying capacity of 50,000 to 90,000 dead weight tonnes (DWT). Capesize vessels (carrying capacity over 100,000 DWT) are planned to use 6 new berths at Wiggins Island that will carry coal and nickel.

The Wiggins Island Coal Terminal has recently been given approval by the Queensland Government to expand its operating capacity up to 150 million tonnes (Mt) of coal throughput per year by 2013. Hamilton Point on Curtis Island would be developed for bulk, container or break bulk trade providing safe passage for Capesize vessels. The Strategic Plan also includes the provision of LNG exports from Curtis Island.

The development is in the Great Barrier Reef World Heritage Area although not in the Great Barrier Reef Marine Park. However, parts of the new access road bridge across the Narrows is in the Mackay/Capricorn Marine Park.

Figure 3 shows the proposed bridge and pipeline routes across the Narrows.

Parts of the GLNG Project lie within the Rodds Bay Dugong Sanctuary (Figure 4).

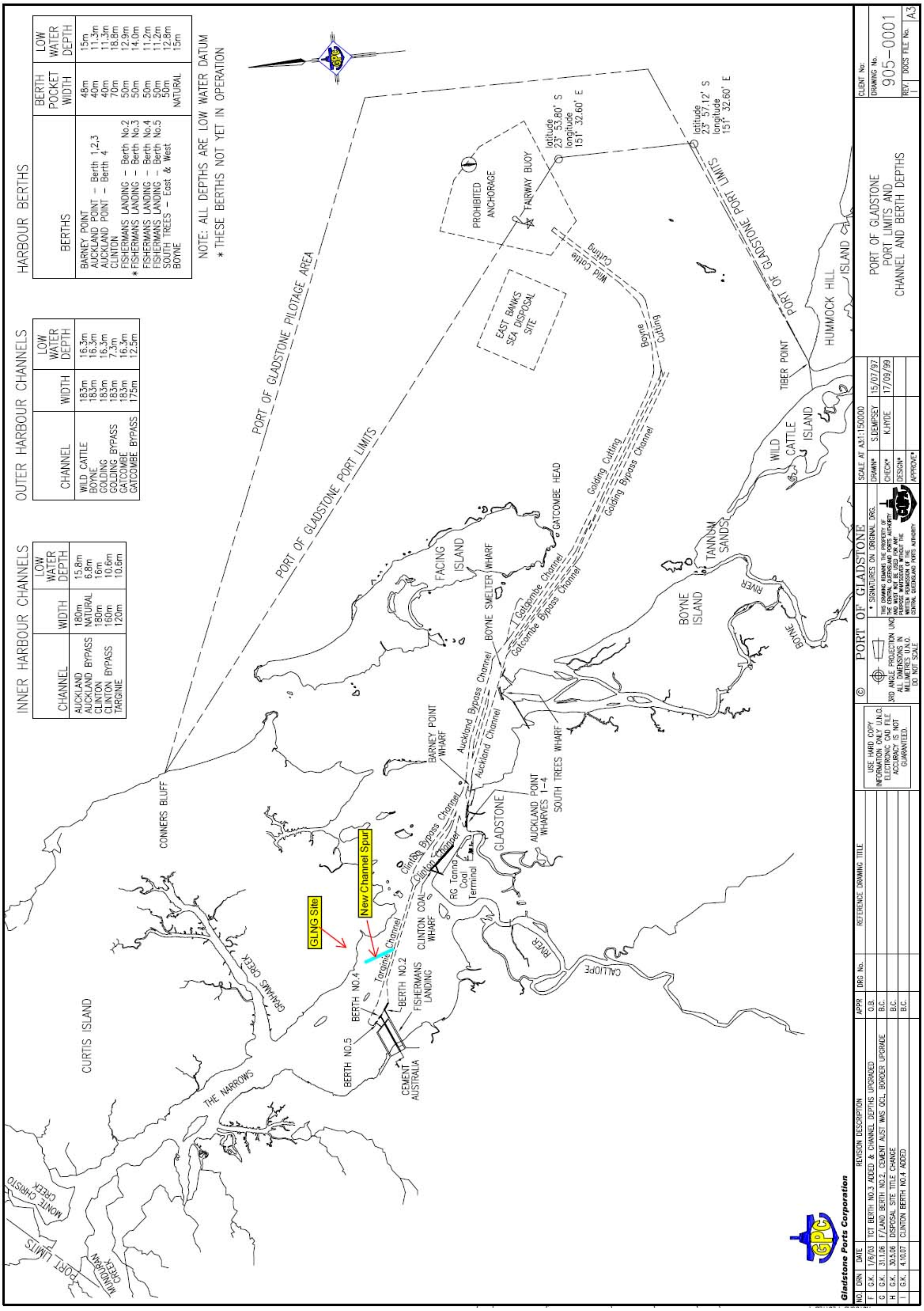

Figure 1 Site Location

Source 1: Copyright Bechtel Corporation 2008. All rights reserved. Contains confidential information proprietary to Bechtel not to be disclosed to third parties without Bechtel's prior written permission. Site Plan GLNG Project Curtis Island Australia - Dwg Number SK-000-00001.DGN Revision A Date 17-02-2009
Source 2: With regard to Product Loading Facility and Material Offloading Facility - These layouts are subject to alteration during detailed design development and ongoing consultation with the Gladstone Ports Corporation and the Gladstone Regional Harbour Master to ensure issues of navigation safety are appropriately addressed.
Source3: This map and other Figures in this report may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright

Figure 2 Location of LNG Facility and Berths

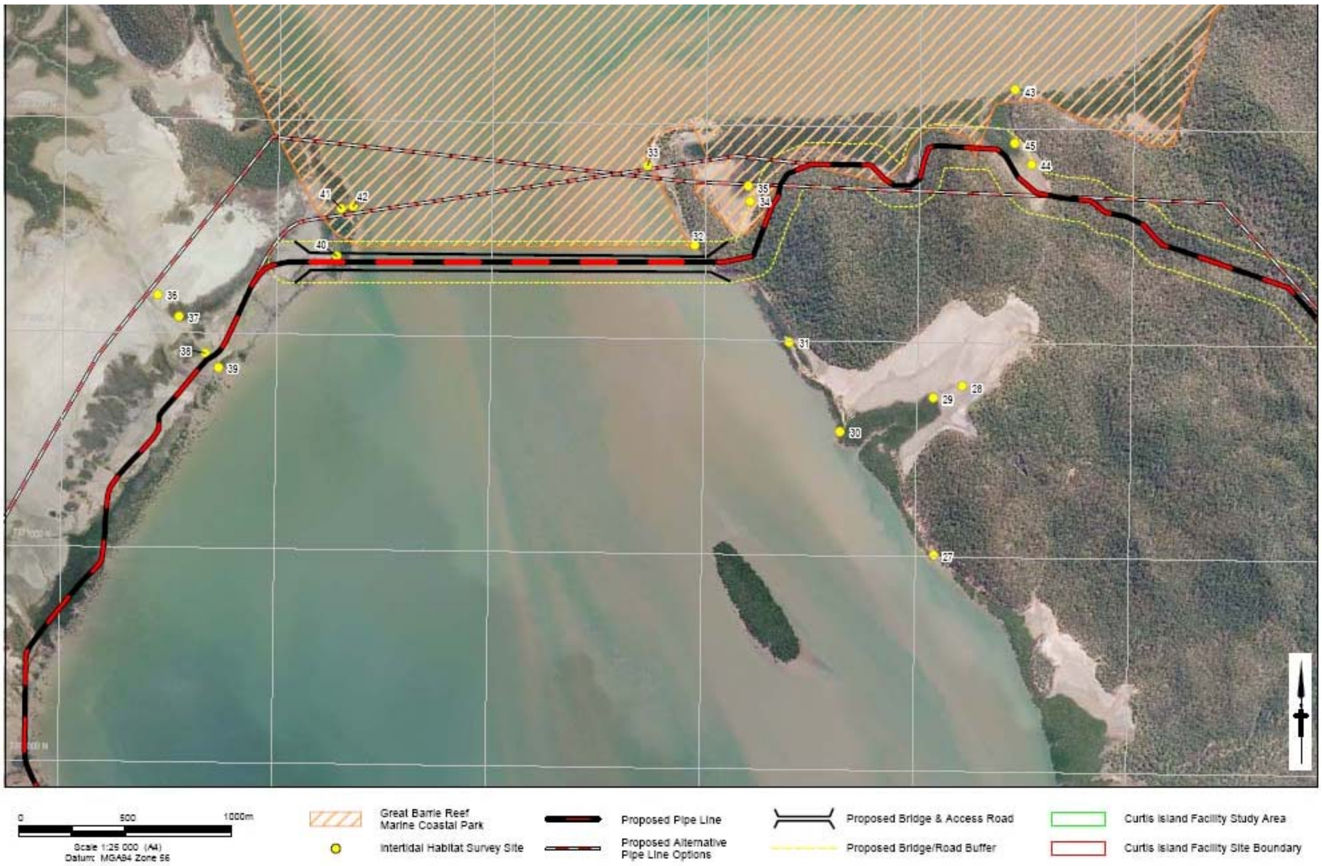

Figure 3 Location of proposed Bridge, Pipeline and Access Road

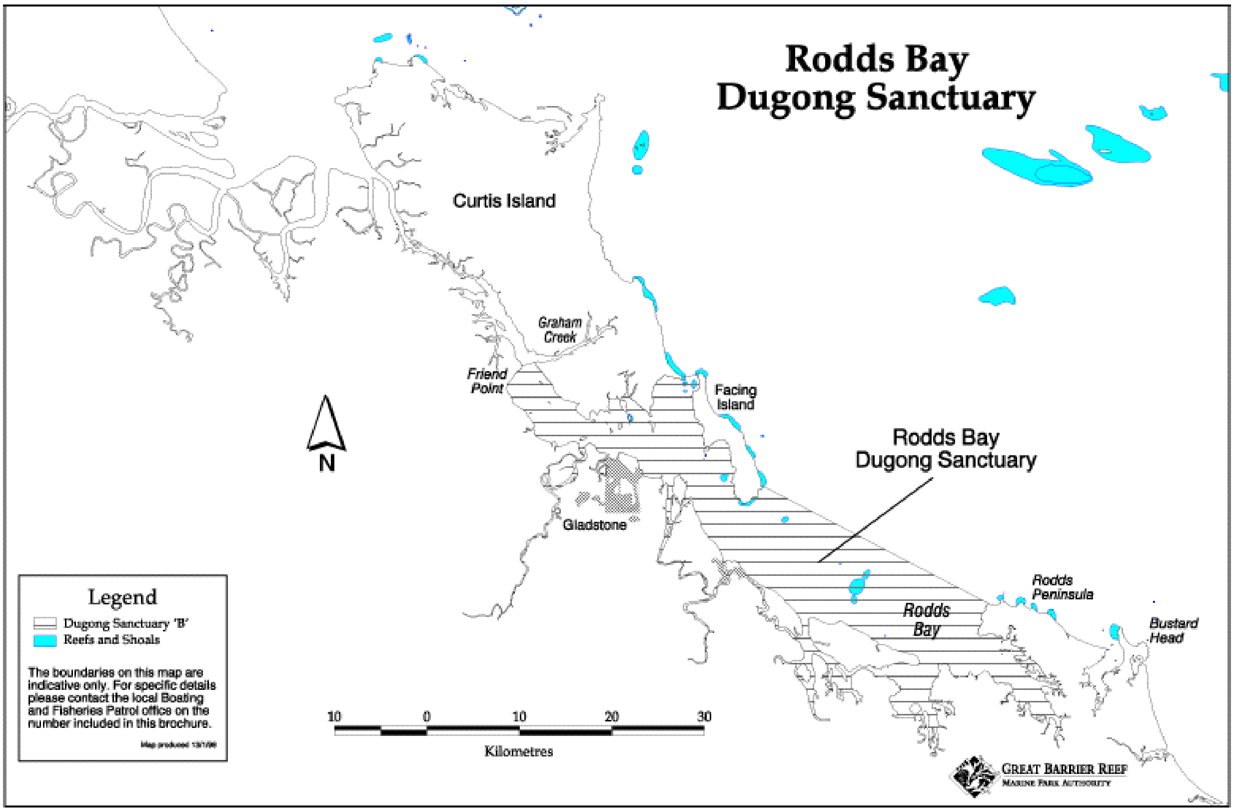

Figure 4 Location of Rodds Bay Dugong Sanctuary

PROJECT DESCRIPTION

Coal seam gas (CSG) is to be extracted from development wells in the Surat and Bowen Basins of Central Queensland and piped to a LNG liquefaction and export facility on Curtis Island. The gas transmission pipeline and general road bridge access to Curtis Island from the mainland will go from Friend Point to Laird Point (across "The Narrows"). Whilst a bridge will be constructed in this location to carry road traffic, the gas transmission pipeline across The Narrows will be laid in a trench across the floor of The Narrows at the side of the road bridge.

After liquefaction, the LNG product will be loaded onto specially designed ships via the main Product Loading Facilities (PLF) which will comprise an access trestle extending 400m over open water to the Loading and Marine Operations Platforms and a series of 6 Moorings and 4 Breasting dolphins. A Materials Off-loading Facility (MOF) will be required to support onshore and offshore construction. The proposed site for the MOF is on Hamilton Point West and is likely to consist of:

- A navigation channel;
- 3 separate berths to accommodate a wide range of construction vessels; and
- Wharf structures, mooring and breasting dolphins.

Dredging will be required in the region between Passage Islands and Hamilton Point to allow for a manoeuvring area (swing basin) and access channels to the MOF and PLF. Figure 2 shows the location of the LNG facility, MOF, PLF and the local bathymetry leading onto the Targinie Channel.

The Targinie Channel currently has a low water depth (LWD) of 10.6m and parts of this channel may need to be dredged to an access LWD of 13m from the swing basin and PLF.

At full production there will be one LNG shipment every two to three days. Each ship loading operation at the PLF would take approximately 16 hours.

Construction of the bridge across the Narrows will require the setting of driller piers. This operation and the trenching works for the gas pipeline will require waterborne vessels.

Construction of the PLF and MOF may be completed from the structure as it is extended outwards from Curtis Island.

CONSTRUCTION AND OPERATION WITHOUT A BRIDGE

An alternative option to the construction of a bridge would be to barge materials to the construction site and ferry across the workforce for construction and operating phases.

Transportation of materials and equipment to the LNG facility at Curtis Island for the construction of Train 1 is estimated to require 2500 barge/vessel round trip movements across Gladstone Harbour from the mainland to Curtis Island and back (5000 ship calls).

It is further estimated that approximately 1200 barge/vessel round trips will be required for Train 2 and 1200 barge/vessel round trips for Train 3. This is based on approximately 8400 truck loads for Train 1 and approximately 4400 for Train 2, and 4400 for Train 3. This includes aggregate, cement, piping, structural steel, electrical and instrument bulks and the like based on 4 trucks per barge trip. Some of these trips will include the ferry designed to carry labour.

The movements for Train 1 will be spread over 24 months but are likely to be in clumps for the purpose of moving aggregate and cement. The tonnage of material is subject to change depending on the type of barge and the method to move aggregate. There may be some option of reducing the aggregate trucks by barging in aggregate if there is quarry material adjacent to a suitable load out location along the coast.

Construction of the LNG facility will require a workforce of approximately 3000 people. Accommodation for the workforce will be located on Curtis Island, therefore a ferry service is required to move the workforce on and off Curtis Island. The construction workforce will work on a 10 days on 4 days off rotation. A Marine Transport Strategy developed by Cardno Eppell Olsen (CEO) (2008) provided four options, but the preferred option is a ferry service from Auckland Point on the Mainland to the MOF on Curtis Island. This option requires 21 ferry trips to transport the construction personnel during each shift change and the total number of ferry trips for a 14-day work cycle.

During the operational phase of the LNG facility it is estimated that there will be 2 (includes return) ferry trips per day from Auckland Point on the mainland to the MOF on Curtis Island. Ferry capacities are expected to be approximately 150 passengers and will accommodate the estimated 80 staff required for operation of Train 1, which will increase up to approximately 130 staff for Train 3.

PARAMETERS USED TO DESCRIBE UNDERWATER SOUND

Underwater noise is converted to the decibel ratio (dB) using a different reference pressure to that in air. The difference in reference pressures mean that the same sound pressure underwater appears to be 26dB greater than the equivalent pressure in air due to the different reference pressure used to calculate the decibel. Decibels in air use a reference pressure of 20 micro Pascals (dB re 20µPa) and decibels underwater use a reference pressure of 1 micro Pascal (dB re 1µPa). For example, a sound pressure level of 131dB re 1µPa underwater is equivalent to a sound pressure level in air of 105dB re 20µPa.

Another difference between sound in air and underwater is the medium through which the sound travels. The intensity of sound is the average amount of sound energy per unit time transmitted through a unit area in a particular direction. The sound power (intensity) transmitted through a medium (air or water) is measured in units of Watts per square metre. The intensity of a sound wave depends upon the density of the medium and speed through which it travels. For the same pressure measured in air and water the intensities in water are lower than that in air by approximately 35.5 dB.

The intensity (or rate of energy transfer per unit time) of a sound is the best parameter to use when assessing loudness or damage from exposure to sound, however, most sound level measurement instruments produce a voltage output proportional to pressure from which the magnitude of intensity can be calculated. The decibel is defined as ten times the logarithm to the base 10 of the ratio between two quantities of power. As the sound power is related to the square of the sound pressure the sound intensity amplitude can be determined.

For the same sound intensity in air and water, when account is made for the different reference pressures used to calculate the dB pressure level and the different density of the medium and sound speeds within each medium, then a sound pressure in air using dB re 20µPa is 61.5dB lower numerically than a sound pressure in water using dB re 1µPa. For example, 90dB re 20µPa in air has the same sound intensity as 151.5dB re 1µPa in water.

Sound pressure levels mentioned in this report will relate to the decibel using 1 µPa reference sound pressure unless stated otherwise.

EXISTING ACOUSTIC ENVIRONMENT

Marine vessels create underwater sound and are a large contributor to overall background noise in the open seas and this is also true for port areas where shipping movements are more concentrated. Vessel noise is a combination of both tonal frequency specific sounds and broad band sounds with energy spread over a range of frequencies. Sound pressure levels and frequency depend on vessel speed, design and size.

CURRENT GLADSTONE HARBOUR TRAFFIC

Maritime Safety Queensland (MSQ) publishes monthly shipping movements for the Gladstone region. The movements relate to piloted movements into and out of the area and also within the ports for larger shipping (50m or more). The annual average to June 2008 for such movements in the Gladstone region is 3303 movements. MSQ estimate that 99% of the movements within the Gladstone region (Gladstone, Rockhampton and Bundaberg) are for the Gladstone Port, which is a total of 3270 movements for the year ending June 2008. The yearly number of movements has been increasing over the past 6 years with 2007-2008 showing an increase of 4% on the previous year.

Smaller vessels use Gladstone harbour and these include commercial enterprises such as fishing, tourism and ferries.

Gladstone Harbour Control (GHC) is informed of vessel movements above 10m, although not all movements are registered with them. The number of registered movements for boats between 10m and <50m varies with fishing vessels numbering between 20 to 35 movements per week being typical. These movements are those entering or leaving the harbour. Movements within the harbour are generated by ferry operations with one operator (Curtis Ferry Services) estimating 20 movements per week within the harbour. Other tourist vessels are also registered. Overall GHC estimate a total weekly average number of movements into or out of the Gladstone harbour at 70 (3640 per year). This number does not include tug movements since they are attendant on the larger ships. Five tugs operate in Gladstone harbour and between 2 and 3 tugs are attendant on each large ship.

The largest number of vessels moving in the Gladstone harbour is from recreational activities. The Volunteer Marine Rescue Gladstone (VMRG) organisation states in their October 2008 newsletter that there are over 5000 registered boats around Gladstone with over 1440 being members of the VMRG. Members of the VMRG typically have boats less than 10m long and the Chief Controller (Jim Purcell OAM) estimates that weekends would have in excess of 1000 boats and each weekday would have generally 25 boats moving in the Gladstone harbour. The monthly newsletters of the VMRG show details of the rescues they performed in the period. The October 2008 newsletter cites 6 rescues on a particular Sunday with boats being typically between 5.2m and 8m, most commonly powered by outboard motors.

Based on the boating volumes provided by VMRG we estimate that annual movements would total 58,500 around Gladstone harbour with the bulk of those movements occurring at weekends.

Recreational boat speeds are up to 35 knots, tugs with larger ships are below 10 knots in the inner harbour and the ferries operate at up to 8 knots within the Gladstone harbour. The tourist catamaran operates at about 25 knots.

Ambient sound pressure levels for various sound sources have been compiled by Wenz (1962).

Ambient sounds in shallow waters vary with Sea State, precipitation and wind that can have significant effects at low frequency (140dB in the frequency range from 1Hz to 10Hz). Ambient sound levels from light rain is typically broadband up to 25kHz at around 90dB and for heavy rain it is 130dB. In addition to the ambient sound levels caused by wind and rain in shallow waters there are sounds caused by the general traffic in Gladstone Harbour. The largest source of sound is caused by weekend recreational craft. High speed recreational craft are not limited to operation along the deeper channels at high tide and the movement of such craft would be the dominant source of underwater sound in Gladstone Harbour. An average sound pressure of 150dB at 10m was measured from 100hp and 115hp outboard engines moving at 5mph and personal watercraft generated 160dB at 10m (Miksis-Olds, 2006). Higher speeds generate higher sound levels and change the dominant frequency of the sound emissions. The sound emissions from larger slow moving vessels (dredge movements, general shipping, tugs and barges/ferries) have lower frequency dominant sound emissions than recreational craft with outboard motors, for example.

Noise from construction activities can cause noise levels above ambient levels. Impulsive sounds from pile driving and steadier sounds from dredge operations are considered in this assessment.

Maintenance dredging is a common feature in the channels that access the various wharves in Gladstone Port. Construction at Fisherman's Landing Wharf has recently commenced for an extension to berth two. The work involves piling, which will continue for approximately five months started in early September 2008. Dredging works will create access to the new berths. Dredged material will be used to reclaim an area of land to the north of Fisherman's Landing (see Figure 5). These construction activities have received approval without special underwater noise related conditions and are similar in scope to those proposed for the GLNG Project.

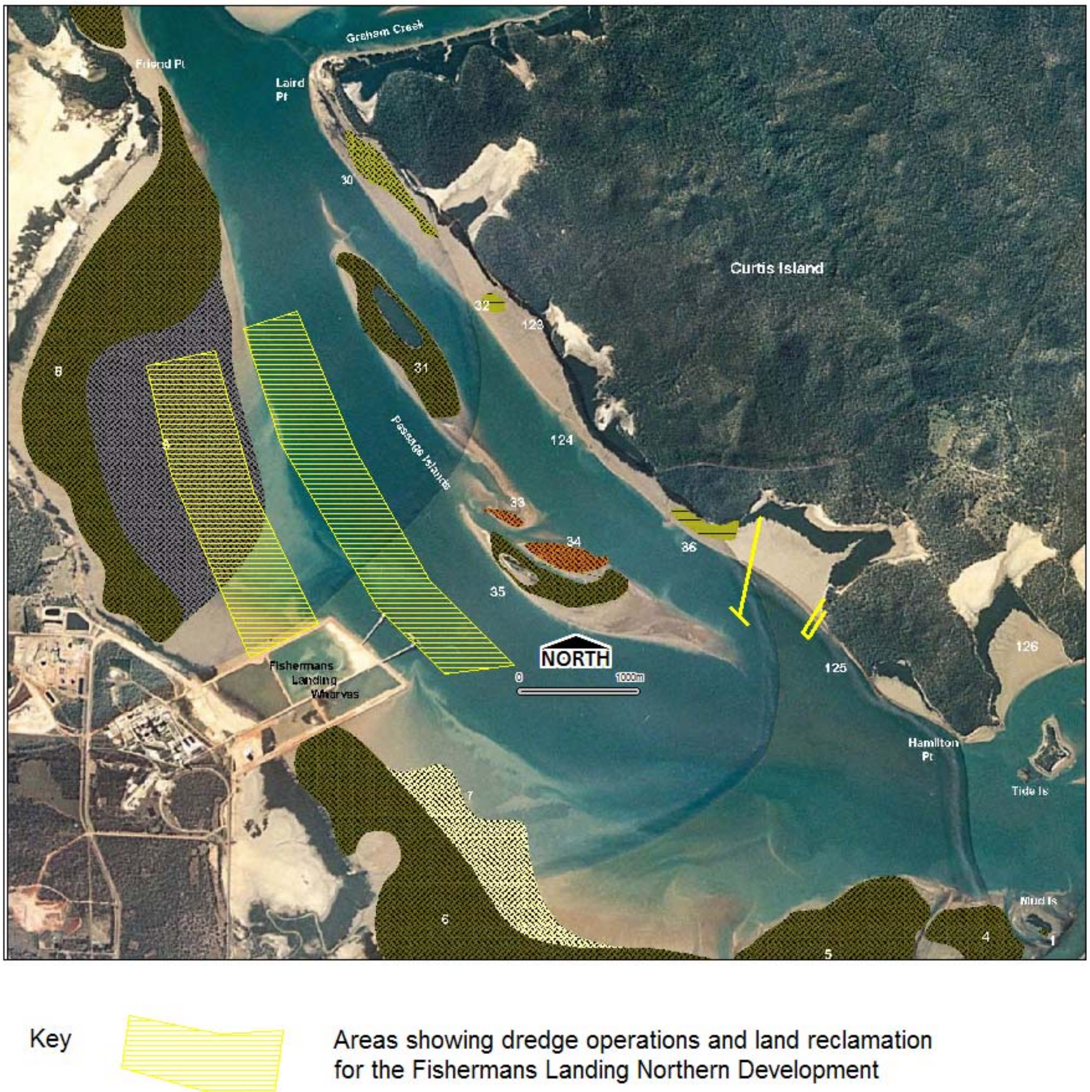

Figure 5 Reclaim area of land and dredge work area to the north of Fishermans Landing

UNDERWATER NOISE REGULATIONS

The GLNG Project requires approval under the Environment Protection Biodiversity Conservation Act 1999 (EPBC Act). The Terms of Reference issued in August 2008 under Part (4) of the Queensland State Development and Public Works Organisation Act 1971 (SDPWO Act) for the GLNG Project lists species and communities that must be considered within the requirements of the EPBC Act.

The construction of the PLF, MOF, access channels and bridge (including gas transmission pipeline trenching across the The Narrows) all have the potential to produce underwater noise. The ongoing operations of the GLNG Project will produce underwater noise from the movement of vessels exporting the LNG product.

The regulation of underwater noise in Queensland is governed by the Nature Conservation Act (NC Act) 1992 and Section 88 of supporting Regulations 1994 in which reference is made to conservation management plans and noise impact, and the Environmental Protection Act (EP Act) 1994 which defines noise as "environmental nuisance". Environmental nuisance is unreasonable interference or likely interference with an environmental value, such as amenity.

Under the EPAct, the environment which is to be protected includes ecosystems and their constituent parts, including people and communities, all natural and physical resources and the qualities and characteristics of locations, places and areas, however large or small, that contribute to their biological diversity and harmony. The Environmental Protection Regulation 2008 outlines the scope for application of applying noise criteria. A "noise sensitive place" is classed as a "protected area" which includes areas protected area under the Nature Conservation Act 1992

The EPAct defines environmental harm to include environmental nuisance, however, environmental harm and nuisance are excluded from section 440 (Offence of causing environmental nuisance) and section 440Q (Offence of contravening a noise standard) in Schedule 1, Part 1 (1) for noise from ships including shore and ship based port operations for ship loading / unloading. A further exclusion is provided for maintaining public infrastructure which could include maintenance dredging, for example

The Environmental Protection (Noise) Policy 2008 (Noise EPP) provides the regulatory detail under the EP Act but an underwater noise limit is not specifically detailed. The environmental values to be considered in the Noise EPP are the ‘health and biodiversity of ecosystems’ and the acoustic quality objective is achieved by preserving the ‘amenity’ of the area (Marine Park, for example). In the absence of a definitive noise policy relating to underwater noise, reference has been made to recent guidelines and other legislation to determine the likely impact of the project.

Research concerning the effects of noise generated by humans on marine mammals has resulted, directly or indirectly, from the US Marine Mammal Protection Act (US MMP Act) of 1972 and other US laws and regulations. In Australia, all marine mammals receive total or partial protection under various Acts. The EPBC Act provides a dataset that can list threatened species, their status and type of presence for defined areas. Table 1 shows a list of marine fauna prepared from the dataset for the study area around the GLNG Project.

Table 1 EPBC Act list of threatened species for the GLNG Project area

Threatened Species	Threat	Type of Presence
Mammals		
Megaptera novaeangliae Humpback Whale	Vulnerable	Breeding known to occur within area
Xeromys myoides Water Mouse, False Water Rat	Vulnerable	Species or species habitat likely to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle	Endangered	Species or species habitat may occur within area
Chelonia mydas Green Turtle	Vulnerable	Species or species habitat may occur within area
Dermochelys coriacea Leathery Turtle, Leatherback Turtle, Luth	Vulnerable	Species or species habitat may occur within area
Egernia rugosa Yakka Skink	Vulnerable	Species or species habitat likely to occur within area
Eretmochelys imbricate Hawksbill Turtle	Vulnerable	Species or species habitat may occur within area
Lepidochelys olivacea Pacific Ridley, Olive Ridley	Endangered	Species or species habitat may occur within area
Natator depressus Flatback Turtle	Vulnerable	Breeding known to occur within area
Paradelma orientalis Brigalow Scaly-foot	Vulnerable	Species or species habitat may occur within area
Sharks		
Rhincodon typus Whale Shark	Vulnerable	Species or species habitat may occur within area
Dugon dugon Dugong		Dugong conservation area

Of the list of species listed in the area using the EPBC database only the turtle and dugong are singled out for particular consideration in the Terms of Reference for the GLNG Project.

The Queensland Nature Conservation (Whales and Dolphins) Conservation Plan 1997 has a section relating to noise (terrestrial or underwater) as follows:

> **7 Protection of whales and dolphins**
> **(1)** A person must not, without reasonable excuse, do any of the following to a whale or dolphin in the wild—
> (a) deposit rubbish near the whale or dolphin;
> (b) make a noise that is likely to disturb the whale or dolphin;
> (c) make a noise that is likely to attract the whale or dolphin;

The issue considered in this impact assessment is whether sounds from construction (pile driving, dredging) and future operations at the new bridge across the Narrows and new berths are likely to disturb whales, dugong, dolphins, turtle or fish.

All six species of turtle found in Queensland are listed as either ‘Endangered’ or ‘Vulnerable’ under the Nature Conservation (Wildlife) Regulations 1994. The Act provides for the development of conservation plans for wildlife. The Marine Parks Act 1982 also provides for the protection of marine turtles through zoning and the issuing of permits, similar to the Great Barrier Reef Marine Park Act.

POTENTIAL NOISE IMPACT

The likelihood of an adverse acoustic impact upon a species depends upon the likelihood that the species will be in an area that contains high sound levels.

If a species is likely to be within an area influenced by high sound pressure levels depends upon available food sources or documented migration paths, for example, that are in or traverse the area.

The water rat and yakka skink would inhabit only very near coastal areas and are unlikely to be impacted by underwater sound levels from construction activities and are not considered further.

Turtle, dugong, dolphin, whale shark and humpback whale are considered in this assessment insofar that they *could* be present within the area. The most likely coincidence of species and the areas identified to have elevated underwater noise levels relate to turtle, migrating dugong and dolphin. Notwithstanding this, the mitigation measures suggested would also protect whale shark and humpback whale.

NOISE SOURCES

In general, for a given frequency, any noise above an ambient background level has the potential to disrupt communication between marine mammals and can cause avoidance of an area. However, communication between different mammals is achieved in different frequency ranges and with often different time scales. For example, a dolphin communicates with repetitive short clicks whereas a whale communicates in song having longer relative time duration. This fact is important since noise from pile driving, for example, may not affect the communication between whales as much as it may between dolphins. Furthermore, the higher frequency communication of the dolphin may be affected over a smaller area by pile driving operations because higher frequencies are attenuated very quickly with distance of propagation in shallow water.

Until recently, there has been little detailed measurement of underwater noise emissions from dredge and piling operations. The Port of Melbourne Channel Deepening Project for Port Phillip Bay in Victoria has been scrutinised extensively and estimates of underwater sound emissions have been required to be measured under different trial dredge and piling studies that have formed part of the review process for the approvals. The conditions under which these trial studies have been performed are representative of the conditions in which works in Port Curtis Bay are proposed (depth of water for trial piling operations is similar to that around proposed piling operations at the MOF and PLF, for example). In addition, underwater noise emissions from general shipping in Port Phillip Bay have been measured.

DREDGING

It is proposed to use cutter suction dredge (CSD) equipment for the berth pockets and swing basins and trailer suction hopper dredge equipment (TSHD) for the channel areas. For simplicity, similar sound emission levels during construction work at the The Narrows has been assumed.

The size of equipment proposed is:

- CSD 10,000 to 15,000kW with 800mm diameter discharge pipe; and
- TSHD 13,000 to 17,000m^3 hopper capacity with pump-out facility.

The dredges proposed for this project are slightly larger than previous capital works projects to widen and deepen the channels and berths in Gladstone.

Sound levels for large TSHD equipment (Queen of the Netherlands, 23000m^3 hopper capacity) have been measured recently in Port Phillip Bay, Victoria. The sound levels measured were typically between 143dB and 154dB (Port of Melbourne Channel Deepening Project, report number AA/0172/DC/G01) at a distance of 100m and this confirms general findings summarised by Richardson et. al. (1995). These sound levels are up to 5dB higher than general shipping noise emissions.

SHIPPING

The range of ships in the Port of Gladstone is not dissimilar in size to those in Port Phillip Bay, Victoria. Underwater sound levels from passing ships at 100m were measured for the Port of Melbourne Channel Deepening Project. Report number AA/0172/DC/G01 provided the following data.

Ship	Underwater sound pressure level (short term maximum dB re 1μPa)
ANL Bass Trader	143
British Laurel	149
Contship Aukland	150
CSL Kelang	145
Gerdt Oldendorff	154
Medi Monaco	150
MSC New Plymouth	152
Tasman Chief	145

On average, the typical maximum short term sound emission level is 149 dB (4dB standard deviation) at a distance of 100m.

BARGES AND FERRIES

Barges and ferries would be used in lieu of constructing a bridge for the “No Bridge” option. The barges would be used to deliver construction materials and ferries would be used to transport the workforce. Both barges and ferries have shallow draughts and would operate below 8 knots. Sound emissions from barges and ferries (other than high speed catamarans) are less than that from general shipping movements due to the lower engine power. Specific barges or ferries have not been sourced at this stage but there is the option of using ferries that currently operate in the harbour. A typical ferry operator (Curtis Ferry Services) operates passenger services to South End of Curtis Island from the Curtis Ferry Terminal near Aukland Point in Gladstone via Farmers Point on Facing Island Other tourist cruises traverse the harbour from May through to September each year.

The additional ferry and barge movements for the “No Bridge” option are very small as a percentage of the annual vessel movements about the Gladstone harbour and no adverse underwater acoustic impact is predicted.

The pilots of Curtis Ferry Services report few sightings of dolphin, dugong and turtle and that when observed they steadily move away or are not in the path of the ferry. The ferry travels at a maximum speed of 8 knots.

PILING

Sound is generated from pile driving activities and this propagates underwater and in the air (terrestrial). The sound sources from piling operations include diesel engines, mechanical clatter from the pile driver mechanisms and the impact of the hammer on the top of the pile that transmits vibration along the pile into the sediment.

Underwater sound from piling activities is caused by a number of mechanisms. The interaction of the sediment 'ground' wave generated by the impacted pile propagates along the sediment/water interface as a Rayleigh wave. The energy from the Rayleigh wave is released into the shallow water as it propagates, producing small changes in water pressure (underwater sound). Other vibration waves are transmitted into the sediment and these can be reflected back to the sea bed due to reflection from changes in strata densities or refraction from changes in sediment densities. Airborne sound from the head of the pile at impact is also observed underwater. However, the dominant sound source is caused by the vibration of the pile in the water column during and after impact by the drop hammer.

The characteristics of the sound observed underwater from impact type piling are a mixture of the different sound propagation mechanisms and the results can be very complex. However, in general there will be a larger pressure pulse propagated at hammer impact on the pile that will be followed by a ringing of the pile followed by sediment vibration effects. The contribution of each of the sound generating mechanisms change as the pile is driven deeper. The natural frequency ring from the pile also changes as the pile penetrates deeper. The sound observed also changes with increased distance from the pile because sound is attenuated at higher frequencies as it propagates in the shallow water and different time delays come into effect from the propagation paths of vibration in the sea bed and water (speed of sound in water is approximately 1500m/s and the speed in sediment is generally higher around 1700m/s).

Diesel engine noise from the pile driver propagates in the air above the water and is observed as underwater sound, although the area that this influences is localised (typically <20m).

Pile driving sounds do not exhibit the potentially high pressure peaks associated with blasting but they are repetitive.

Recent measurements of underwater sound pressure levels caused by impact piling activities at Swanson Dock in the Port of Melbourne are relevant to this assessment. The sound pressure level measurements were taken at a depth of 6m in a water depth of 13m at different distances from piling operations. Different piling methods were measured whilst driving cylindrical steel piles similar to those proposed for the PLF and MOF. The measurements were used to check underwater noise level predictions made in a Supplemental Environmental Effects Statement for the works associated with the Port of Melbourne Channel Deepening Project (CDP SEES). The acoustic parameter chosen to represent underwater impact sounds is the mean squared sound pressure (msp) in dB re 1 µPa that occurs over 90% of any individual pulse from a pile impact event, denoted as dB msp.

The potential for hearing damage due to impulsive sounds is related to the total energy received by the hearing organs. In humans, for example, occupational health and safety requirements limit the total sound energy one is exposed to but also sets an upper level of peak sound above which immediate damage may occur. It is likely that the same form of damage regime would occur in marine mammals, indeed, many predictions of temporary or permanent threshold hearing damage in marine fauna are based upon human response studies.

The sound energy content of repeated impulsive sounds from pile driving relates to the energy within the pulse and the time between pulses. For pulses repeated immediately after each other the energy average would approximate to a constant sound level. For impulse sounds spaced, say 2 seconds apart and lasting only 20 milli-seconds, there would be a much lower total acoustic energy and the hearing organ has time to recover between each successive impulse.

It is not appropriate to simply compare continuous type sounds from passing ships or dredge operations to the msp sound level from piling operations when assessing temporary or permanent hearing damage. Conversely, irregular and infrequent impulsive sounds can produce a startle response at similar or lower sound levels to continuous sounds if those continuous sounds are stationary or changing slowly in level.

The Impact Evaluation and Risk Assessment for underwater noise from pile driving activities is not known for any fauna in terms of behavioural response, Temporary Threshold Shift (TTS), Permanent Threshold Shift (PTS) or Death. For behavioural response, based upon 100 impulses, it is expected that a source sound level of over 150 dB msp is a level that may be appropriate (Saldago Kent and McCauley, 2006). A pile driving sound level of 150 dB msp has been accepted in the review process for the Port of Melbourne Channel Deepening Project and is also used in this assessment to determine zones of impact for behavioural response around pile driving operations.

Underwater sound levels measured at 350m from piling operations at Swanson Dock were typically less than 150dB msp (interim reports from trial pile driving surveys by Rob McCauley, May 2008 [qtr0809_cmst(2008a).pdf] and July 2008 [www.channelproject.com/global/docs/technical_reports/ QRTR0809_CMST_(2008b).pdf]) and a zone of influence of 350m radius from piling operations has been used to predict noise impact.

SOUND PROPAGATION IN SHALLOW WATER

The attenuation with distance from each of the sound sources discussed above is important to understand. Measurements of the sound pressure level reduction with distance, r, from measurements of piling at Swanson Dock in the Port of Melbourne in 13m of water produced an attenuation factor of 28 log(r) from 53m to 350m. This is a reduction of 8.4dB per doubling of distance from the sound source. Piling sound emissions close to the pile contain high frequency sounds that are quickly attenuated with distance in water. Beyond 350m it would be expected that the attenuation rate would reduce to some 6dB per doubling of distance unless the water depth varies.

Sound propagation in Port Curtis is complex due to the array of sand banks and barrier islands. The proposed dredging activities in the region around the PLF and MOF are likely to propagate sound predominately in north west and south eastern directions along the new access channel spur onto the Targinie channel, with greater attenuation of sound to the west across South Passage Islands and towards the Curtis Island shoreline. Greater attenuation of sound is generally observed in shallow or seagrass covered areas, or when the wavelength of sound in water is similar to or longer than the depth of the water. Sound having frequencies above 115Hz could propagate along 13m deep channels but would quickly attenuate in the shallower waters either side of the channels. In shallow water, when the one-quarter wavelength of the sound exceeds the water depth, the remaining sound energy is attenuated very rapidly and propagation losses from a shallow sound source to a shallow receiver will show approximately 12dB per doubling of distance, r, (35log r) spreading loss (Richardson et al 1995).

Propeller noise is generally shielded to the bow of a vessel by the hull structure and only becomes a sound source when there is a ‘line of sight’ to the propeller from the receiver location. The shallow sound source in shallow water also produces surface interference effects that also exhibit a similar spreading loss of 35log r.

Sound emissions from dredge operations could travel along the channels and attenuation rates of typically 6dB per doubling of distance would be expected.

MARINE FAUNA RESPONSE TO NOISE

Manatee and dugong have similar vocalization and it is presumed that dugong have similar audiograms to manatee. A study of the effects of environmental noise on Manatee (Miksis-Olds, 2006) demonstrated a preference for sea grass habitat that has particular acoustic conditions. A preference was shown from observations and sound recording correlations that the grass beds manatees selected were those that had lower ambient noise below 1 kHz and above 2 kHz.

Broadband noise from snapping shrimp was avoided and the dominant frequency of Manatee vocalisation (Anderson and Barclay, 1995) was in the range of most efficient sound propagation within seagrass beds (around 2kHz). Snapping shrimp stun their prey using a "pop" generated by a cavitation event made by a specialised claw. Noise from snapping shrimp is a significant part of the total ambient sound energy in inshore shallow waters.

Ambient sound levels from light rain is typically broadband around 90dB and for heavy rain it is 130dB. Manatee vocalization lies in the range 90dB -138 dB at 1m (Nowacek et al., 2003; Phillips et al., 2004) and Manatee increase their call loudness in higher ambient background noise (Miksis-Olds, 2006).

Dugong vocalization is characterized into two general groups of sound. Low frequency barks (500Hz to 2.2kHz) and higher frequency clicks and chirps (3kHz to 18kHz) (Anderson and Barclay, 1995). Audiograms for the manatee show a lower frequency limit of 400Hz and an upper frequency limit of 46kHz (Gerstein et al, 1999) with optimal sensitivity in the 16kHz to 18kHz range. Gerstein suggests that the poor sensitivity of the manatee to sounds below 1kHz explains why slow moving vessels are not readily observed and localized by manatee. It would also suggest why manatees avoid shrimp crackle that has broad band frequency content throughout the most sensitive frequency range.

The manatee audiogram shows a threshold of audibility at 500Hz of 105dB and at 1kHz it is 80dB so dredge operations could be inaudible if dredge sound emissions predominate in the frequency range below 500Hz.

The sound level compensation ability for manatee/dugong and the vocalization frequency range means that they can still communicate during the manoeuvring operations of a dredge located less than 1km away in shallow water that will produce sounds below 1kHz. Sound level amplitude and frequency would not cause masking of communication sounds.

Dredge operations produce sound emissions that are also at frequencies where the audiogram of the bottlenose dolphin, for example, is less sensitive (Salgado Kent and McCauley, 2006). The threshold of hearing for a bottlenose dolphin is 130dB at 100Hz, 95dB at 1kHz and 50dB at 10kHz. It is most sensitive at a threshold of 40dB between 20kHz and 100kHz. The upper threshold hearing frequency is around 200kHz (Johnson, 1967).

The EPBC Act database lists the humpback whale as ‘breeding known to occur in the area’. The hearing response of the humpback whale is predicted to be between 700Hz and 10kHz with maximum sensitivity in the 2kHz to 6kHz range and follows the typical mammalian U-shape with lower sensitivity at the extremes of the audible range (Houser et al 2001).

A sound pressure estimate of 150dB at 10m was measured from 100hp and 115hp outboard engines moving at 5mph (Miksis-Olds, 2006). Frequency weighting of the sound to account for the hearing characteristics of the Manatee shows that such operations (outboard motor) provide peak audibility in the 2kHz frequency range, although maximum sound energy is below 1kHz. Playback of these sounds to wild manatee (150dB received level) showed no significant response; however sounds from typical personal watercraft approaches (typically 160dB received level), that contain similar high frequency sounds at some 15dB higher sound pressure level in the 5kHz to 20kHz region, showed significant response with 20% of the animals exposed leaving the area. The tests were completed using recordings played to manatees 10m away and under these circumstances high frequencies would not be attenuated significantly.

Sound emissions from larger ships are greater due to the higher power requirements (around 3000hp) but the frequency range that they emit is generally lower. Green (1987) reported that hopper dredges emit the highest sound levels during loading but that at all times low frequency sound energy predominates, this is confirmed from measurements in Port Phillip Bay, referenced above, showing dredge noise emission to be up to 5dB higher than general shipping.

Sonar is used to profile the dredge area and for normal depth sounding when travelling across the bay. Sonar equipment on the dredge could operate within the most sensitive audible region of the dolphin but high frequency sonar generally points towards the sea bed and at shallow angles laterally.

Sonar having a transducer operating frequency above 200kHz is recommended to avoid interference with dolphin and dugong.

NOISE IMPACT CRITERIA

We have used a continuous underwater sound pressure level of 150dB as the sound level above which avoidance of an area is certain for some species of marine fauna and a sound pressure level for impulsive pile driving sounds of 150 dB msp above which startle or behavioural response is likely for some marine species. This continuous sound pressure level underwater has the same sound intensity as 88.5dB re 20µPa measured in air.

The physical areas surrounding noise generating activities above which the sound pressure levels stated above are exceeded depends upon water depth and subterranean topography.

To err on the side of caution we have determined in general that an approximate radius of impact can occur (avoidance) 150m from dredge or bridge building activities for constant sound emissions and 350m radius from pile driving operations that generate impulsive sounds.

NOISE IMPACT DISCUSSION

Research on the effects of human generated noise on marine mammals has shown that there is some level of tolerance. Stationary sources seem to have less effect on whales and dolphins than mobile sources, and avoidance responses occur when received noise levels reach levels well above ambient sound levels. Some marine mammals appear to ignore or tolerate, for at least a few hours, continuous sound at levels above 120 dB. Avoidance commences when received levels start to exceed 120 dB, and it is doubtful whether many marine mammals would remain in an area with over 140 dB continuous or long term impulsive sound.

Reports on whales and dolphins exposed to seismic operations in northern hemisphere waters (e.g. Geraci & St Aubin, 1987; Myrberg, 1990), suggest that behaviour patterns may alter within 7 km of sudden, pulsed sound sources, and marked avoidance responses may occur within 2 km. No information has been found to suggest that dugong would not behave in the same manner. Marine turtles do not have an external hearing organ. However, it is thought that turtle may have an auditory perception through a combination of bone and water conduction.

Personal observation of a migrating dugong under the trestles of an outloading conveyor at Abbot Point demonstrates a tolerance to ship loading operations. At the time of the observation there were tug boats ready in attendance for an almost fully loaded ship ready to depart the berth. Travel within the dugong conservation area would not be impeded by shipping activities at the berth or beyond. Dugong in the Rodds Bay Sanctuary are accustomed to ship movements and the extra burden of one ship every two or three days is not significant.

Normal operating conditions for the PLF and MOF are not expected to produce noise levels significantly above ambient background levels such that there are communication problems or sound levels causing avoidance for marine mammals. Fish often inhabit the area beneath berths during loading although they do temporarily vacate such areas (personal observation) whilst tugs manoeuvred a loaded ship from a berth at Abbot Point coal terminal. The movements of tugs and vessels to the loading berth are short term events and are unlikely to produce long term evacuations from the area.

Whilst pile driving for the new PLF and MOF is in progress, it is unlikely that marine mammals passing offshore will be able to hear the construction work as the noise levels will not be much higher than ambient noise levels. However, it is likely that any dolphin or turtle near the new berth sites during piling will temporarily avoid the immediate area. Figure 6 shows the area surrounding the MOF and PLF and The Narrows crossings where temporary avoidance may occur during construction activities. These areas are determined from an approximate radius of influence 150m from dredge or bridge building activities for constant sound emissions and 350m radius from pile driving operations that generate impulsive sounds. The radii chosen relate to underwater sound pressure levels expected from construction activities of less than 150dB (constant type sounds) and 150 dB msp (impulsive pile driving sounds). The areas shown in Figure 6 assume a high tide with a pile in 13m of water. The sound emissions from piling are related to the depth of water through which the pile is driven. If a pile is in contact with a smaller water depth then the sound emissions underwater will be reduced. For a water depth of 6.5m through which a pile is being driven, it is expected that sound emissions underwater would be reduced by 3 dB compared to a water depth of 13m and the zone of potential impact would be reduced accordingly.

The sound levels from piling operations are not expected to harm marine fauna, even at close range. If any species identified in this assessment were close to a pile at the commencement of piling they would be startled and move from the immediate area. This type of response can be avoided by simple observation before commencement of piling or by using a ‘soft start’ to piling.

Similarly, dredging operations are likely to cause avoidance of the immediate area by mammals but fish may be attracted to the areas where sediment is disturbed. It is not uncommon for TSHD equipment to kill turtles that may be in channel regions through physical contact, however, there are mechanical turtle deflectors that can be used to prevent this. This fact suggests that turtle tolerate the sound from a typical TSHD and are not alarmed by its operation.

Underwater noise from dredge operations are up to 5 dB higher than that from normal shipping but the dredge remains at the dredge site whereas shipping traverse Curtis Bay. Despite the difference in noise emissions the overall impact upon marine fauna may be similar since sound sensitive species would avoid approaching a dredge yet sound sensitive species would need to vacate an area to avoid oncoming ships. The overall area of adverse impact from a moving ship would be larger than for static dredge operations but would last for a shorter time in a particular area.

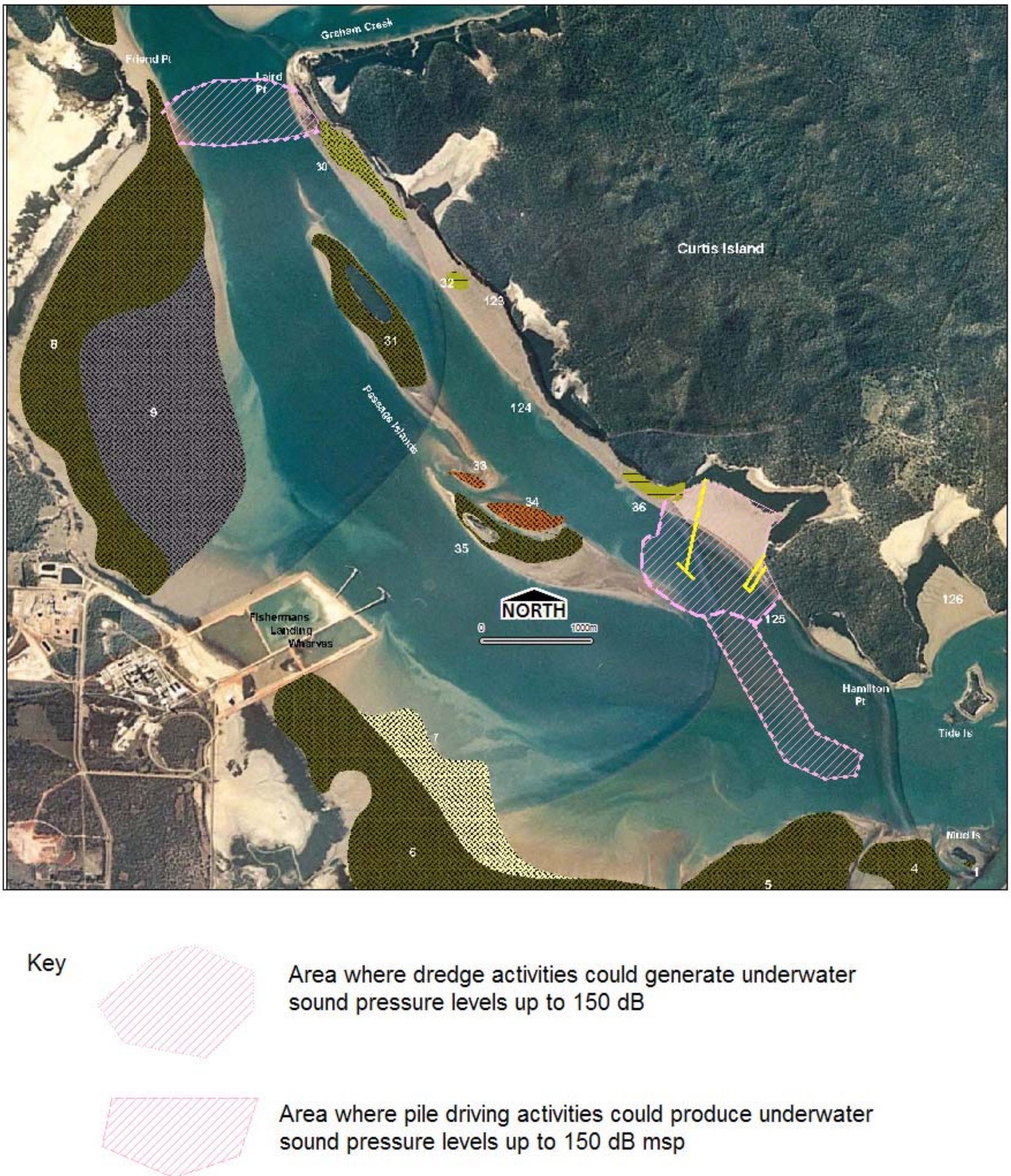

Figure 6 Areas where temporary avoidance may occur during construction activities

CONCLUSION

Sound pressure levels produced underwater from construction and ongoing operations of the proposed Gladstone LNG Project are not predicted to have any long term detrimental effects upon marine fauna identified within the area. Short term avoidance of areas surrounding pile driving or dredge activities is expected.

Short term avoidance of areas surrounding piling activities is expected inside a range of 350m from the pile. It is recommended that observations of the area around piling operations (350m radius) be made before commencement of work on any given day to ensure the area does not contain dugong, whale shark, humpback whale or dolphin that may be startled, or alternatively the use of soft start procedures to piling operations can be used.

The areas where short term avoidance would be expected during certain construction activities do not contain any significant seagrass beds and the avoidance areas would only affect migration across a small part of Port Curtis. The overall impact of dredging operations for the GLNG Project caused by underwater noise is similar to that caused by a single ship traversing Curtis Bay.

Sonar having a transducer operating frequency above 200kHz is recommended to minimize interference with dolphin and dugong.

MITIGATION STRATEGIES

The following summarises suggested mitigation strategies during construction.

- To prevent a startle response from dugong or dolphin at the start of impact piling in deeper water (>3m); observations should be made of an area approximately 350 m radius around the pile before commencement of impact piling on any day or after an extended time when piling has stopped. If dugong or dolphin is observed within the area then commencement of impact piling should be delayed until they clear the area. Alternatively, a soft start to piling may be considered.

- To prevent a startle response from dugong or dolphin, impact piling in water (<3m); observations should be made of an area approximately 150 m radius around the pile before commencement of impact piling on any day or after an extended time when piling has stopped. If dugong or dolphin is observed within the area then commencement of impact piling should be delayed until they clear the area. Alternatively, a soft start to piling may be considered.

- Impact piling operations on land (when at low tide for example) do not require any observation or soft start procedures.

- Sonar devices on dredges should have operating frequencies above 200kHz to minimise the impact upon dolphin and dugong.

- To prevent entrapment of turtles in suction dredge equipment, physical turtle deflectors should be installed.

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