GREAT SOUTH BASIN CHECKSHOT SURVEY

Marine Mammal Impact Assessment

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EXECUTIVE SUMMARY

OMV GSB Limited (**OMV**) will be undertaking a multi-well Exploration and Appraisal Drilling (**EAD**) Programme within the Great South Basin (**GSB**); hereafter referred to as the GSB EAD Programme. The GSB EAD Programme is expected to commence in Q1 2020 with the drilling of the Tāwhaki-1 well. Drilling activities associated with the GSB EAD Programme will be undertaken within OMV's Petroleum Exploration Permit (**PEP**) 50119.

A checkshot survey, which is a form of borehole seismic survey used to identify specific characteristics about geological features below the seafloor that have been intersected during drilling activities, may be undertaken in the event that hydrocarbon accumulations are discovered during the GSB EAD Programme (**GSB Checkshot Survey**). In the event that no hydrocarbon accumulations are discovered, no checkshot survey is likely to be required; however, that will not be known until the well has been drilled and appropriate formation evaluation has been undertaken. The objective of the GSB Checkshot Survey is to ascertain further information about the velocity characteristics of the strata penetrated by the wellbore, in order to accurately translate between sonic/density properties measured within the well and acoustic data from seismic surveys recorded in the vicinity of the well.

Under the Exclusive Economic Zone and Continental Shelf (Environmental Effects - Permitted Activities) Regulations (**Permitted Activities Regulations**), seismic operations in New Zealand's Exclusive Economic Zone (**EEZ**) must comply with the Department of Conservation's (**DOC**) 2013 Code for Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations (**Code of Conduct**). Under the Code of Conduct, a Marine Mammal Impact Assessment (**MMIA**) is required in order to describe the proposed seismic operations, provide a description of the baseline environment, identify any potential environmental effects from the seismic operations, and to specify any proposed mitigation measures to minimise environmental effects.

An Operational Area has been drawn around the Tāwhaki-1 well location in order to describe the marine environment and potential effects of the GSB Checkshot Survey. Supplementary MMIAs will be submitted if additional wells are required in the GSB EAD Programme, specific to the characteristics of those locations.

Where seismic activities are undertaken within an Area of Ecological Importance, Sound Transmission Loss Modelling (**STLM**) is also required; although the Operational Area for the GSB Checkshot Survey does not occur within an Area of Ecological Importance, STLM has been carried out to ensure the standard mitigation zones will provide adequate protection to marine mammals. An Environmental Risk Assessment (**ERA**) process has been utilised within this MMIA to assess the significance of any predicted adverse effects on biological, socio-economic, and cultural environments of relevance to the Operational Area. Stakeholder engagement has been carried out by OMV as a key part of the GSB Checkshot Survey and wider GSB EAD Programme.

Utilising data within DOC's stranding and sighting database, and knowledge of migration paths and habitat preferences of each species (obtained from published scientific literature), the following marine mammals are *likely* to be present within the Operational Area: bottlenose dolphin, dusky dolphin, false killer whale, Gray's beaked whale, killer whale, long-finned pilot whale, New Zealand sea lion, New Zealand fur seal, southern elephant seal, southern right whale, southern right whale dolphin, sperm whale, Shepherd's beaked whale and strap-toothed whale. Andrew's beaked whale, Antarctic minke whale, common dolphin, Cuvier's beaked whale, dwarf minke whale, Hector's beaked whale, Hector's dolphin, pygmy sperm whale, southern bottlenose whale, and spectacled porpoise are considered to have a *possible* presence within the Operational Area.

EXECUTIVE SUMMARY

OMV's proposed checkshot survey falls within the classification of a Level 1 marine seismic survey under the Code of Conduct due to the proposed source volume (i.e. > 427 in^3). Compliance with the Code of Conduct for a Level 1 marine seismic survey is the primary mitigation measure that OMV will employ during the GSB Checkshot Survey. The full protocol of operational procedures and control measures that will be followed during the GSB Checkshot Survey are detailed in the Marine Mammal Mitigation Plan (**MMMP**, **Appendix D**) which will be used as a working document during the checkshot survey. The following specific actions are particularly important with regard to operating in accordance with the Code of Conduct:

- Where available, two qualified Marine Mammal Observers (**MMO**) and two qualified Passive Acoustic Monitoring (**PAM**) Observers will be present for the duration of the GSB Checkshot Survey. In the event that two qualified MMOs or PAM Operators are unable to be engaged, the Code of Conduct provides for a qualified observer to act in a supervisor/mentor role to a trained observer;
- The MMOs will be present onboard the mobile offshore drilling unit (**MODU**) and the PAM Operators will be present onboard a support vessel to visually and acoustically detect for the presence of any marine mammals prior to the commencement of the checkshot surveys and for the duration of the survey. Due to the noise interference from the actively-operating MODU, PAM (**Appendix B**) will be deployed from the support vessel, which will circle the MODU within a radius of approximately 1 km;
- Seismic operations will be delayed if marine mammals are detected within the mitigation zones as defined in the Code of Conduct;
- The power of the acoustic source will be gradually increased through a 'soft start' procedure prior to any seismic operations commencing to ensure any undetected marine mammals have an opportunity to leave the mitigation zones before full operational power is reached; and
- The acoustic source will be shut down if a marine mammal enters the relevant defined mitigation zones.

STLM (**Appendix A**) has been used to verify the thresholds for the standard mitigation zones specified within the Code of Conduct. The short-range modelling prediction demonstrates that the maximum received Sound Exposure Level (**SEL**) will comply with the limits of 186 dB re 1µPa^2·s at 200 m, and 171 dB re 1µPa^2·s at 1.0 km and 1.5 km.

While the focus of this MMIA is on marine mammals, potential effects on other environmental and socio-economic receptors have also been considered.

Overall, the predicted effects of the GSB Checkshot Survey are considered to be sufficiently managed by the proposed mitigation measures, predominantly compliance with the Code of Conduct. Due to the small volume acoustic source that will be utilised during each survey, the potential for temporary threshold shift (TTS) to affect marine mammals will be restricted to within 123.5 m of the acoustic source, as demonstrated by STLM. The STLM results have confirmed that the proposed GSB Checkshot Survey is compliant with the requirements stipulated for SEL thresholds within the Code of Conduct.

CONTENTS

CONTENTS

CONTENTS

DOCUMENT REFERENCES

TABLES

FIGURES

CONTENTS

APPENDICES

ABBREVIATIONS AND DEFINITIONS

AIS	Automatic Identification System
AOI	Area of Interest
BOMEC	Benthic Optimised Marine Environment Classification
CGSB	Canterbury Great South Basin
CMA	Coastal Marine Area
Code of Conduct	2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations
COLREGS	International Regulations for the Prevention of Collisions at Sea 1972
dB	Decibels
DOC	Department of Conservation
DTIS	Deep Towed Imaging System
EAD	Exploration and Appraisal Drilling
EEZ	Exclusive Economic Zone

CONTENTS

EEZ Act	Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012
EPA	Environmental Protection Authority
ERA	Environmental Risk Assessment
FNZ	Fisheries New Zealand
GSB	Great South Basin
Hz	Hertz
MARPOL	International Convention for the Prevention of Pollution from Ships 1973 as Modified by the Protocol of 1978
MMIA	Marine Mammal Impact Assessment
MMMP	Marine Mammal Mitigation Plan
MMO	Marine Mammal Observer
MODU	Mobile Offshore Drilling Unit
NIWA	National Institute of Water and Atmospheric Research
NM	Nautical Mile
OMV	OMV GSB Limited
PAM	Passive Acoustic Monitoring
PEP	Petroleum Exploration Permit
Permitted Activities Regulations	Exclusive Economic Zone and Continental Shelf (Environmental Effects – Permitted Activities) Regulations 2013
Pk-SPL	Peak sound pressure level
Pk-Pk SPL	Peak-to-peak sound pressure level
SEL	Sound Exposure Level

1 Introduction

OMV GSB Limited (**OMV**) will be undertaking an Exploration and Appraisal Drilling (**EAD**) Programme within the Great South Basin (**GSB**); the GSB EAD Programme. The GSB EAD Programme is expected to commence in Q1 2020 with the drilling of the Tāwhaki-1 well. Drilling activities associated with the GSB EAD Programme will be undertaken within OMV's Petroleum Exploration Permit (**PEP**) 50119. Should Tāwhaki-1 be successful, additional exploration and appraisal wells may be drilled.

There are a number of regulatory approvals that OMV is required to have in place prior to commencing the GSB EAD Programme, split across various pieces of legislation. At the time of drafting this Marine Mammal Impact Assessment (**MMIA**), the GSB EAD Programme Marine Consent and Marine Discharge Consent Application has been lodged with the Environmental Protection Authority (**EPA**).

A checkshot survey may be undertaken if commercial quantities of hydrocarbons are discovered at Tāwhaki-1 (**GSB Checkshot Survey**). In the event that no hydrocarbon accumulations are discovered, no checkshot survey is likely to be required; however, that is not going to be known until the well has been drilled and appropriate formation evaluation has been undertaken. The objective of the GSB Checkshot Survey is to ascertain further information about the velocity characteristics of the strata penetrated by the wellbore, in order to accurately translate between sonic/density properties measured within the well and acoustic data from seismic surveys recorded in the vicinity of the well. The Tāwhaki-1 well is located in the GSB at a water depth of approximately 1,323 m. Planned well characteristics are provided in **Table 1** below. An Operational Area has been defined around the Tāwhaki-1 well location (**Figure 1**) and assessed within this MMIA. This Operational Area is the area where the acoustic source is able to be active based on the assessment of effects considered within this MMIA.

Table 1 Planned Well Characteristics for the Tāwhaki-1 well

Well	Water Depth (m bMSL)	Total Depth (m)	Last Casing Depth (m)	Length of Open Hole (m)
Tāwhaki-1	1,323	2,977	2,558	439

The Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (**EEZ Act**) came into force in 2013 and established the first comprehensive environmental consenting regime for activities in New Zealand's Exclusive Economic Zone (**EEZ**) and Continental Shelf. The Exclusive Economic Zone and Continental Shelf (Environmental Effects – Permitted Activities) Regulations 2013 (**Permitted Activities Regulations**) classify marine seismic surveys as a permitted activity.

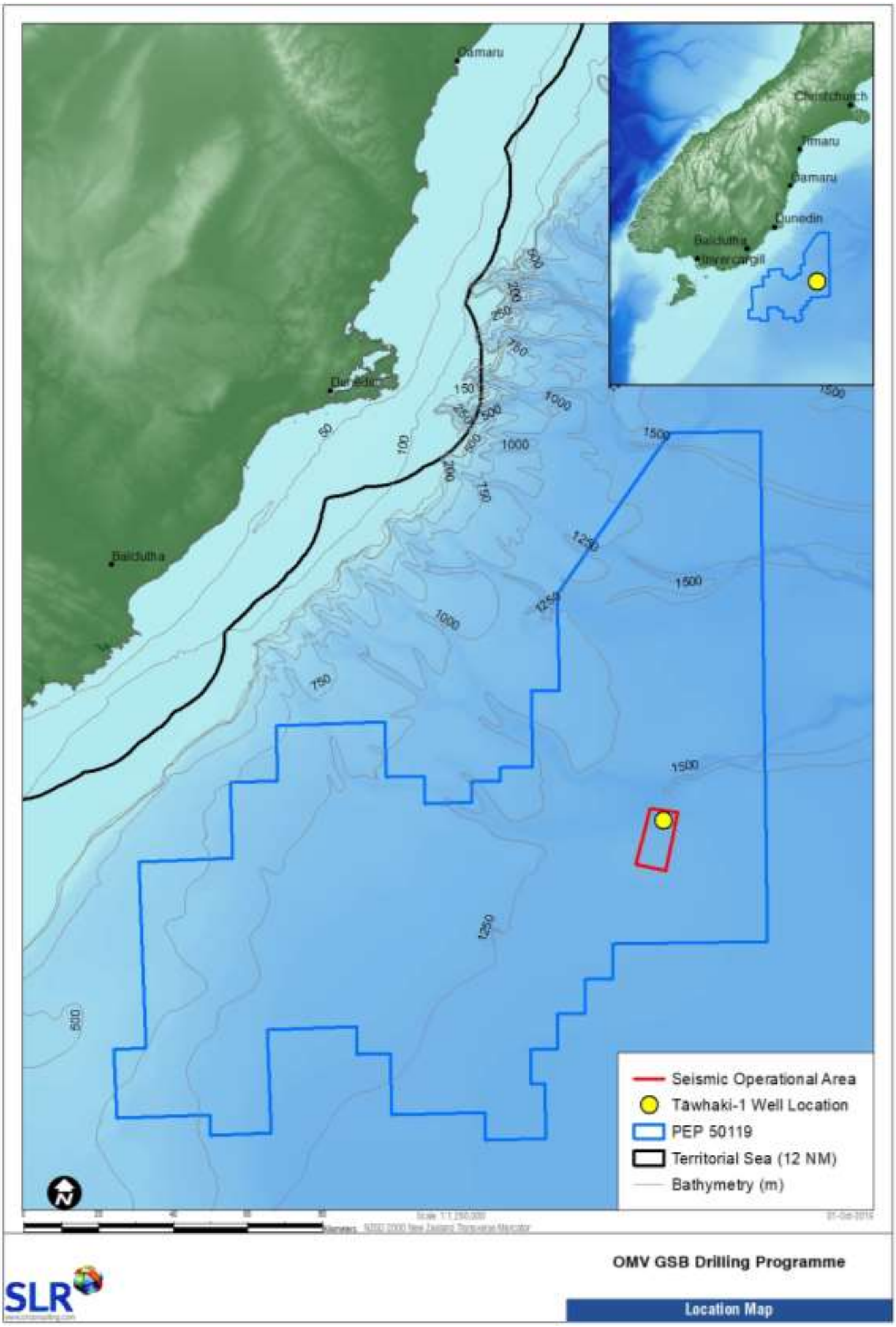
The Permitted Activities Regulations permit seismic surveys providing the operator undertaking the survey complies with the Department of Conservation (**DOC**) 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations (**Code of Conduct**) or obtains a marine consent from the EPA. The Code of Conduct is summarised in **Section 3.5**.

This MMIA is an integral component to ensure that OMV undertakes the GSB Checkshot Survey in adherence to the Permitted Activities Regulations and the Code of Conduct. The Code of Conduct requires Sound Transmission Loss Modelling (**STLM**) to be undertaken for any seismic surveys that will operate within an Area of Ecological Importance. STLM provides a prediction of the received Sound Exposure Levels (**SEL**) over a range of a few kilometres from the array sound location in order to assess whether the proposed survey complies with the Code of Conduct mitigation zones. Although the Operational Area does not lie within the Area of Ecological Importance, OMV has commissioned STLM to ensure the standard mitigation zones will provide adequate protection to marine mammals. As well as operating to the requirements of the Code of Conduct throughout the duration of the checkshot survey, OMV will operate in accordance with relevant New Zealand legislation, international conventions, and their internal environmental standards.

The GSB Checkshot Survey is classified as a 'Level 1' survey by the Code of Conduct (i.e. >427 in^3 acoustic source), and OMV will comply with all relevant requirements while conducting the survey. The Code of Conduct requirements for a Level 1 marine seismic survey are outlined in **Section 3.5**. The protocol that the Marine Mammal Observers (**MMO**) and Passive Acoustic Monitoring (**PAM**) Operators will follow during the GSB Checkshot Survey is outlined in the Marine Mammal Mitigation Plan (**MMMP**) which is included as **Appendix C**.

During the preparation of the MMIA for the GSB Checkshot Survey, an extensive review of literature and existing data on the environment surrounding the Operational Area has been undertaken. A description of the existing environment is provided throughout **Section 5**. Published scientific literature has been used within **Section 6** in order to provide an assessment of the potential effects of the GSB Checkshot Survey on the fauna described in **Section 5**. A full list of the references used throughout this MMIA is provided in **Section 8**.

Figure 1 Location of PEP 50119 and GSB Checkshot Survey Operational Area



2 Project Description

2.1 Marine Seismic Surveys – Overview

The principle behind any marine seismic survey is that an energy source (i.e. acoustic source) instantaneously releases compressed air (in the case of the GSB Checkshot Survey, bottled nitrogen (compressed) will be utilised) which generates a directionally focused acoustic wave at low frequency that can travel several kilometres through the earth's rocky crust. Portions of this acoustic wave are reflected by the underlying rock layers and the reflected energy is recorded by receivers (hydrophones) to determine the velocity of sound through the subsurface strata. Depths and spatial extent of the strata can be calibrated and mapped, based on the time difference of the energy being generated and subsequently recorded by the receivers.

2.1.1 Checkshot Surveys

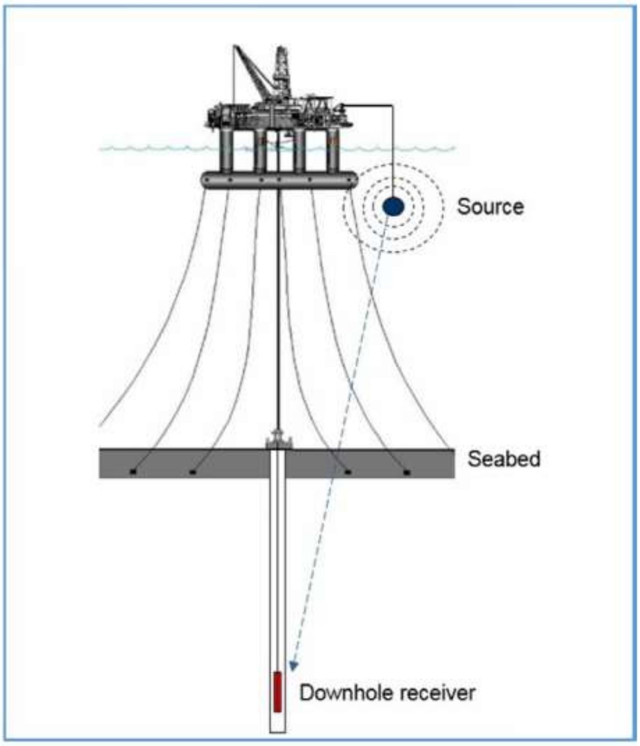
Checkshot surveys are a form of borehole seismic survey used to identify specific characteristics about geological features below the seafloor that have been intersected during drilling activities. The characteristics of the geological features are identified by the differing reflective properties of sound waves off the various subsurface rock strata.

During a survey the sound energy source (acoustic source array) is lowered from the MODU to approximately 5 m below the surface of the ocean, and when it is activated the acoustic source releases a sound wave generated by the release of compressed nitrogen (bottled) from the array. This pulse is focussed downwards through the water column and into the sub-surface beneath the MODU. At each point where different geological strata exist, different densities and velocity discontinuities cause a portion of the energy to be reflected/modified. The returned sound waves are recorded through a downhole receiver which is located within the recently completed well bore at known depths.

Typically, the acoustic source emits the first signal when the receiver is at the deepest point in the well, and then after the returned signal is received the receiver is raised a distance up the wellbore and the process is repeated. This continues until the receiver reaches a point within the subsurface where the signal received is unable to be accurately recorded. Signals recorded by the receiver are amplified and digitised to facilitate interpretation of the geological structure and strata through which the well has been drilled.

The checkshot survey data provides a velocity profile of the rock structure surrounding the well down to a depth just below the completed depth of the well. A schematic of a checkshot survey configuration is shown in **Figure 2**.

Figure 2 Schematic of an Operational Marine Checkshot Survey



2.1.2 Underwater Sound

Underwater sound has two primary measures:

- Amplitude (or relative loudness) expressed by the decibel (**dB**) system. This is a logarithmic scale that represents a ratio that must be expressed in relation to a reference value; and
- Frequency which is the number of acoustic pressure waves that pass by a reference point per unit of time, or cycles per second. This is measured in Hertz (**Hz**).

Sound levels in water are not the same as sound levels in air and confusion often arises when trying to compare the two. The reference level of the amplitude of a sound must always be specified. For sound in water the reference level is expressed as 'dB re 1µPa' – the amplitude of a sound wave's loudness with a pressure of 1 micro-pascal (**µPa**). In comparison, the reference level for sound in air is 'dB re 20 µPa'. The amplitude of a sound wave depends on the pressure of the wave as well as the density and sound speed of the medium through which the sound is travelling (e.g. air, water, etc.). As a result of environmental differences, 62 dB must be subtracted from any sound measurement underwater to make it equivalent to the same sound level in the air.

Although sound travels further in water than it does in air (due to water being denser), in both mediums the loudness of a sound diminishes as the sound wave radiates away from its source. In air, the sound level reduces by 10 dB as the distance doubles, while in water sound level reduces by 6 dB for each doubling of distance. Underwater sounds are also subject to additional attenuation as they interact with obstacles and barriers (e.g. water temperature gradients, currents, etc.). Furthermore, the loudness of a sound in water diminishes very quickly close to the source and more slowly at distance from the source.

The ocean is a naturally noisy environment. Natural sound inputs include wind, waves, marine life, underwater volcanoes and earthquakes. Man-made sounds such as shipping, fishing, marine construction, dredging, military activities and sonar. further add to the underwater noise profile. The sound levels produced during a seismic survey are comparable to several naturally occurring and man-made sources (**Table 2**).

Table 2 Sound Comparisons in Air and Water

Type of Sound	In Air (dB re 20µPa @ 1m)	In Water (dB re 1µPa @ 1m)
Threshold of Hearing	0 dB	62 dB
Whisper at 1 m	20 dB	82 dB
Normal conversation in restaurant	60 dB	122 dB
Ambient sea noise	-	100 dB
Blue whale	-	190 dB
Live rock music	110 dB	172 dB
Thunderclap or chainsaw	120 dB	182 dB
Large ship	-	200 dB
Earthquake	-	210 dB
Seismic array at 1 m	158 – 203 dB	220 – 265 dB
Colliding iceberg	-	220 dB
Bottlenose dolphin	-	225 dB
Sperm whale click	-	236 dB
Jet engine take-off at 1 m	180 dB	242 dB
Volcanic eruption	-	255 dB

Note: The sound levels provided above for a seismic array refers to that from a full seismic survey. The volume of the acoustic source that will be used for the GSB Checkshot Survey is considerably smaller than that used in a full seismic survey, the noise output during the GSB Checkshot Survey will be much less than that of a full-scale seismic survey.

2.1.3 The Acoustic Source

The acoustic source is lowered into the water from a crane on the MODU above and slightly to the side (approximately 49.5 m) of the drilled well. The source is comprised of two high-pressure chambers; an upper control chamber and a discharge chamber. High-pressure bottled nitrogen (compressed) on-board the MODU is continuously fed to each source in the array, forcing a piston downwards. The chambers then fill with high-pressure nitrogen while the piston remains in the closed position.

Each element is activated by sending an electrical pulse to a valve which opens, and the piston is forced upwards, allowing the high-pressure nitrogen in the lower chamber to discharge to the surrounding water. The discharged nitrogen forms a bubble, which oscillates according to the operating pressure, the depth of operation, the water temperature, and the discharge volume. Following this discharge, the piston is forced back down to its original position by the high-pressure nitrogen in the control chamber, allowing the sequence to be repeated. The compressors are capable of re-charging the acoustic source rapidly, enabling the source arrays to be fired again when required.

Acoustic arrays are designed so that they direct most of the sound energy vertically downwards, although there is some residual energy which dissipates horizontally into the surrounding water column. The amplitude of sound waves declines with lateral distance from the acoustic source, and the weakening of the signal with distance (attenuation) is frequency dependent, with stronger attenuation at higher frequencies. The decay of sound in the sea is dependent on the local conditions such as water temperature, water depth, seabed characteristics and depth at which the acoustic signal is generated.

Acoustic sources used by the oil and gas industry are designed to emit most of their energy at low frequencies, typically 20 – 50 Hz with declining energy at frequencies above 200 Hz (Popper *et al*., 2014). Total source levels range from ~222 – 264 dB re 1µPa-m_{p-p} (Richardson *et al*., 1995), with the proposed source having a peak sound pressure level (**Pk-SPL**) of 7.3 Bar (237.4 dB re 1µPa @ 1m) and peak-to-peak sound pressure level (**Pk-Pk SPL**) of 14.1 Bar (243 dB re 1µPa @ 1m).

The triple acoustic source cluster that will be used by OMV during the GSB Checkshot Survey is shown in **Figure 3** below.

Figure 3 Triple Acoustic Source Cluster Inside Standard Delta Deployment Frame

2.2 GSB Checkshot Survey

A Checkshot survey will be undertaken if, during the drilling of the Tāwhaki-1 exploration well, there are indications of potentially-commercial accumulations of hydrocarbons present. The acoustic source will consist of three 150 in^3 sub-sources, with an effective total volume of 450 in^3. The acoustic source will be deployed from a crane and positioned approximately 5 m below the sea surface, while a receiver will be lowered to the bottom of the well on a wireline. The acoustic source will have an operating pressure of approximately 2,000 psi.

The survey specifications for the GSB Checkshot Survey is provided in **Table 3**.

Table 3 GSB Checkshot Survey Specifications

Parameter	Specifications
Source type	Triple Source cluster array
Source volume	450 in^3
Maximum predicted output	14.1 Bar = 243 dB re 1µPa @ 1m (peak to peak)
Number of sub-arrays per source	3
Nominal operating pressure	2,000 psi firing pressure, 2,400 psi accumulator pressure
Source Frequency	10 Hz, approximately 90 seconds on average between shots
Source Depth	4.9 m

Marine mammal observations and PAM for the acoustic detections of marine mammals will be implemented during the GSB Checkshot Survey. These are discussed in more detail in **Section 3.5**. Due to the interfering noise that is emitted from the actively-operating MODU, the PAM system will be deployed from a support vessel for the acoustic detections of marine mammals, with the support vessel circling the MODU at a distance of approximately 1 km.

STLM was conducted based on the specific acoustic source volume and array configuration described in **Table 3**. The STLM is further discussed in **Section 6.2.2.1** and the full STLM results are attached as **Appendix A**.

A checkshot survey could take up to 12 hours to complete, depending on the particular well characteristics (i.e. depth) and required information. OMV has undertaken checkshot surveys during previous exploration drilling programmes in the Taranaki Basin, and these have ranged between 2.7 and 11.5 hours for completion, with the number of activated shots ranging from 89 - 332.

2.3 Navigational Safety

The GSB Checkshot Survey will occur following the completion of drilling operations at the Tāwhaki-1 exploration well (if required), during which time the MODU will have been in position for between 30 and 90 days. Other marine users will be aware of the presence of the MODU through a Notice to Mariners and coastal navigation warnings broadcast daily on maritime radio. A 500 m non-interference zone will exist around the MODU to exclude other marine users from the immediate vicinity. The MODU and support vessel will have Automatic Identification System (**AIS**) technology on-board, allowing the vessel to receive information about the positions of other vessels and to transmit information about its position to others. The MODU and support vessel will display the appropriate lights and day shapes while on location.

A MODU would not be present at the well location without all relevant regulatory approvals in being place (including marine consent and marine discharge consent) in accordance with the EEZ Act, for which an extensive engagement and notification process would already have been undertaken, including with other marine users.

2.4 Survey Design Considerations and Alternatives

The proposed acoustic source array configuration and the produced sound levels for the GSB Checkshot Survey were selected in order to provide sufficient power to fulfil the survey objective, whilst minimising excessive acoustic noise entering into the surrounding marine environments. A total source level of 450 in^3, comprising three individual 150 in^3 sources firing in unison in a cluster, has been chosen by OMV as a suitable power level to achieve the survey objectives.

Given there are many variables at play that will determine if and when a check shot survey is undertaken, it is possible that the GSB Checkshot Survey could occur in any season. As such, an assessment has been made for all the potential overlaps with whale migrations in and through the GSB area that could possibly be affected by increased underwater noise. As a result, the Environmental Risk Assessment (**ERA**) incorporated into this MMIA has considered any potential effects on the marine environment from the GSB Checkshot Survey throughout the year.

3 Legislative Framework

New Zealand Petroleum and Minerals administers the New Zealand Government's oil, gas, mineral and coal resources. These resources are often regarded as the Crown Mineral Estate. The role of New Zealand Petroleum and Minerals is to maximise New Zealand's gains from the development of mineral resources, in line with the Government's objectives for energy and economic growth.

The legislative framework that relates to the proposed GSB Checkshot Survey is described below.

3.1 Crown Minerals Act 1991

The Crown Minerals Act 1991 sets the broad legislative framework for the issuing of permits for prospecting, exploration and mining of Crown-owned minerals in New Zealand, which includes those minerals found on land and offshore to the boundary of the extended continental shelf.

The Crown Minerals Act 'regime' comprises the Crown Minerals Act 1991, two minerals programmes (one for petroleum and one for other Crown-owned minerals), and associated regulations. Together, these regulate the exploration and production of Crown-owned minerals (NZP&M, 2015).

The Petroleum Minerals Programme 2013 applies to all applications for permits for petroleum activities. It sets out the policies and procedures to be followed for the allocation of petroleum resources, while the requirements to be met by permit holders are defined in the regulations. The programme also defines specific requirements for engagement with iwi and hapū, including the matters that must be consulted on (such as all permit applications) and the engagement principles. Specific engagement that was undertaken by OMV in relation to the proposed GSB Checkshot Survey is detailed in **Section 4**.

3.2 Exclusive Economic Zone & Continental Shelf (Environmental Effects) Act 2012

The EEZ Act came into force in 2013 and established the first comprehensive environmental consenting regime for activities in New Zealand's EEZ and Continental Shelf. The purpose of the EEZ Act is to promote the sustainable management of the natural resources of the EEZ and continental shelf. Sustainable management involves managing the use, development and protection of natural resources in a way, or at a rate, that enables people to provide for their economic well-being while:

- Sustaining the potential of natural resources (excluding minerals) to meet the reasonably foreseeable needs of future generations;
- Safeguarding the life-supporting capacity of the environment; and
- Avoiding, remedying, or mitigating any adverse effects of activities on the environment.

The EEZ Act classifies activities within the EEZ and continental shelf as:

- **Permitted** – the activity can be undertaken provided the operator meets the conditions specified within the regulations. Seismic surveys fall within this classification and the conditions state that the person undertaking the activity must comply with the Code of Conduct;
- **Non-notified discretionary** – the activity can be undertaken if the applicant obtains a marine consent from the EPA;

- **Discretionary** – the activity may be undertaken if the applicant obtains a notified marine consent from the EPA; and
- **Prohibited** – the activity may not be undertaken.

While DOC administer the Code of Conduct, the EPA enforces the EEZ Permitted Activities regime, including monitoring for compliance with the seismic surveying Code of Conduct and may conduct audits of the MODU and survey equipment before, during or after the surveys. The EPA has the authority to take enforcement action in relation to any non-compliant activities during the GSB Checkshot Survey.

3.3 Marine Mammals Protection Act 1978

DOC administers and manages all Marine Mammal Sanctuaries in accordance with the Marine Mammals Protection Act 1978 (and associated general policy). Marine Mammal Sanctuaries are established to provide protection of marine mammals from harmful human impacts, particularly in sensitive areas such as breeding grounds, migratory routes and the habitats of threatened species. There are currently six gazetted Marine Mammal Sanctuaries along the coast of New Zealand. Additionally, one whale sanctuary and a fur seal sanctuary were established under the Kaikoura (Te Tai o Marokura) Marine Management Act 2014 (DOC, 2014) that have equivalent status to Marine Mammal Sanctuaries.

Restrictions can be placed on noise emitting surveys in Marine Mammal Sanctuaries to prevent or minimise disturbance to marine mammals. In order to conduct a seismic survey within a Marine Mammal Sanctuary, the Code of Conduct requires that an operator must notify the Director-General of DOC and submit a written Environmental Impact Assessment not less than three months before commencing the survey. The operator must also comply with any additional conditions that are imposed by DOC relating to operations within the sanctuary; in particular, Gazette Notices may place specific restrictions on seismic surveys within a sanctuary.

The closest Marine Mammal Sanctuary to the GSB Checkshot Survey Operational Area is the Catlins Coast Marine Mammal Sanctuary; which lies over 180 km inshore of the Operational Area. Due to the localised effects of the GSB Checkshot Survey, there will be no impacts to any Marine Mammal Sanctuaries.

3.4 International Regulations and Conventions

A number of international regulations and conventions will be adhered to during the GSB Checkshot Survey, for example the International Regulations for the Prevention of Collisions at Sea 1972 (**COLREGS**) and International Convention for the Prevention of Pollution from Ships 1973 (**MARPOL**). These have been covered in detail under the relevant marine consents for the wider GSB EAD Programme and are therefore not described further within this MMIA.

3.5 Code of Conduct

The Code of Conduct was developed by DOC in consultation with a range of stakeholders in marine seismic survey operations in New Zealand to manage the potential impacts of seismic operations on marine mammals. Throughout the development of the Code of Conduct, DOC worked with stakeholders who participated in various working and review groups and provided submissions and contributed to the review process. Stakeholders involved in the development of the Code of Conduct include observers, researchers, operators and regulators. Under the Permitted Activities Regulations, any operator proposing to undertake seismic surveys within the waters of the EEZ must comply with the requirements within the Code of Conduct.

The Code of Conduct aims to:

- Minimise disturbance to marine mammals from seismic survey activities;
- Minimise noise in the marine environment arising from seismic survey activities;
- Contribute to the body of scientific knowledge on the physical and behavioural impacts of seismic surveys on marine mammals through improved, standardised observations and reporting;
- Provide for the conduct of seismic surveys in New Zealand continental waters in an environmentally responsible and sustainable manner; and
- Build effective working relationships between government, industry and research stakeholders.

Under the Code of Conduct, three levels of seismic survey are defined based on the power level of the acoustic array:

- Level 1 surveys (>427 in^3 acoustic source) are typically large-scale geophysical investigations;
- Level 2 surveys (151 – 426 in^3 acoustic source) are lower scale seismic investigations often associated with scientific research; and
- Level 3 surveys (<150 in^3 acoustic source) include all small-scale, low-impact surveys.

The combined output of the source array to be utilised for the GSB Checkout Survey (i.e. 450 in^3) means this survey is classified as a Level 1 survey. The Code of Conduct requirements for a Level 1 seismic survey are provided below.

3.5.1 Notification

Under the Code of Conduct, an operator may not carry out a marine seismic survey unless they have notified the Director-General of Conservation in writing at least three months prior to the commencement of the survey.

OMV notified the Director-General of Conservation on 26 June 2019 of its intention to undertake a checkshot survey as part of the wider GSB EAD Programme.

3.5.2 Marine Mammal Impact Assessment

To comply with the Code of Conduct, an MMIA is required to:

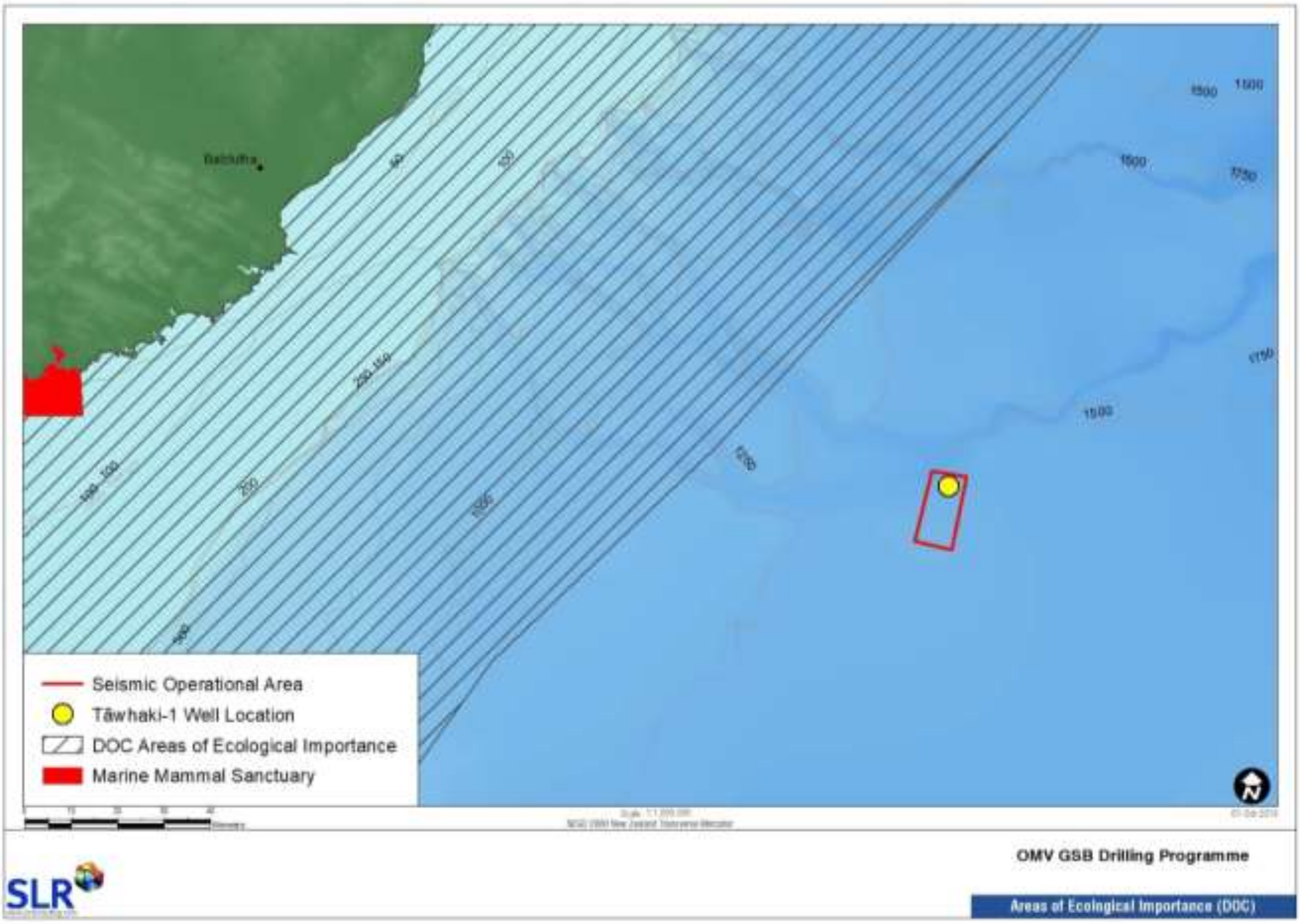
- Describe the activities related to the survey;
- Describe the state of the local environment in relation to marine species and habitats, with a particular focus on marine mammals;
- Identify the actual and potential effects of the activities on the environment and existing interests, including any conflicts with existing interests;
- Identify the significance (in terms of risk and consequence) of any potential negative impacts and define the criteria used in making each determination;
- Identify persons, organisations or tangata whenua with specific interests or expertise relevant to the potential impacts on the environment;
- Describe any engagement undertaken with persons described above, and specify those who have provided written submissions on the proposed activities;
- Include copies of any written submissions from the engagement process;
- Specify any possible alternative methods for undertaking the activities to avoid, remedy or mitigate any adverse effects;
- Specify the measures that the operator intends to take to avoid, remedy or mitigate the adverse effects identified;
- Specify a monitoring and reporting plan; and
- Specify means of coordinating research opportunities, plans and activities relating to reducing and evaluating environment effects.

3.5.3 Areas of Ecological Importance

Any seismic survey operation within an Area of Ecological Importance requires more comprehensive planning and consideration, including additional mitigation measures to be developed and implemented through the MMIA process.

The extent of the Areas of Ecological Importance around New Zealand was determined from DOC's database of marine mammal sightings and strandings, fisheries-related data maintained by the Ministry for Primary Industries, and the National Aquatic Biodiversity Information System. Where data was incomplete or absent, technical experts have helped refine the Area of Ecological Importance maps. The GSB Checkshot Survey will occur outside of the Areas of Ecological Importance (**Figure 4**).

Figure 4 Relationship between the Operational Area and Areas of Ecological Importance



The Code of Conduct requires STLM to be undertaken for any seismic survey that will operate within an Area of Ecological Importance. Although the Operational Area is outside of the Areas of Ecological Importance, out of best operator practice OMV has commissioned STLM. STLM is used to validate the suitability of the mitigation zones by accounting for the specific configuration of the acoustic array and the local environmental conditions (i.e. bathymetry, substrate, water temperature and underlying geology) within the modelled area. The model results indicate whether or not the mitigation zones outlined in the Code of Conduct are sufficient to protect marine mammals from physiological impacts during the seismic survey in accordance with the following thresholds:

- Temporary loss of hearing ability may occur if marine mammals are subject to SELs greater than 171 dB re 1μPa^2.s. Temporary hearing loss is referred to as a 'Temporary Threshold Shift' and is discussed further in **Section 6.2.2.2.1**); and
- Permanent loss of hearing ability and other physiological injury may occur if marine mammals are subject to SELs greater than 186 dB re 1μPa^2.s. Permanent hearing loss is referred to as a 'Permanent Threshold Shift' and is discussed further in **Section 6.2.2.2.1**).

If the modelling predicts exceedances of these thresholds, then consideration must be given to either extending the radius of the mitigation zones or limiting acoustic source power accordingly. Results from the STLM undertaken for the GSB Checkshot Survey are discussed in **Section 6.2.2.1**.

3.5.4 Observer Requirements

All Level 1 seismic surveys require the use of MMOs in conjunction with PAM. MMOs visually detect marine mammals during daylight hours while the PAM system acoustically detects marine mammal vocalisations with hydrophones throughout the duration of the GSB Checkshot Survey and is overseen by PAM Operators. MMOs and PAM Operators must be qualified according to the criteria outlined in the Code of Conduct.

To undertake a Level 1 seismic survey in compliance with the Code of Conduct, the minimum qualified observer requirements are:

- There will be at least two trained and qualified MMOs on-board at all times;
- There will be at least two trained and qualified PAM Operators on-board at all times to provide 24-hour coverage;
- The roles of MMOs and PAM Operators are strictly limited to the detection and collection of marine mammal sighting data, and the instruction of crew on the Code of Conduct and the crew's requirements when a marine mammal is detected within mitigation zones (including pre-start, soft start and operating at full acquisition capacity requirements);
- At all times when the acoustic source is in the water, at least one qualified MMO (during daylight hours) and at least one qualified PAM Operator will maintain 'watch' for marine mammals; and
- The maximum on-duty shift for an MMO or PAM Operator must not exceed 12 hours per day.

Note that in the event that qualified MMO and PAM Operator personnel are unable to be engaged for the GSB Checkshot Survey, the Code of Conduct provides for a qualified MMO or PAM Operator to act as a supervisor/mentor to a trained MMO or PAM Operator. Therefore, one qualified observer and one trained observed may be engaged in each observation role (i.e. MMO or PAM Operator); however, at least one of the engaged MMOs will be qualified as there are no provisions under the Code of Conduct for a suitable trained MMO to undertake the same role as a qualified MMO. Given the unknowns around the duration and timing of the GSB EAD Programme and associated checkshot survey, details of the observers engaged for the GSB Checkshot Survey are not known as part of this MMIA process. Prior to the commencement of the GSB Checkshot Survey, the names, qualifications, and experience of each observer will be provided to DOC and the EPA for approval/acceptance.

If observers (i.e. MMOs or PAM Operators) consider that there are higher than expected numbers of marine mammals encountered during seismic survey operations, they are required to immediately notify the Director-General of Conservation. If this occurred, adaptive management procedures will be agreed following a discussion between DOC and OMV. In the event that the Director-General determines additional measures are necessary, the MMO/PAM team in conjunction with OMV would then immediately implement any adaptive management actions without delay.

Due to the limited detection range of current PAM technology for ultra-high frequency cetaceans (i.e. Hector's/Māui's dolphin, dwarf sperm whale, and spectacled porpoise), any such detection will require an immediate shutdown of an active source or will delay the start of operations, regardless of signal strength or whether distance or bearing from the acoustic source has been determined. It is not necessary to determine whether the marine mammal is within a mitigation zone. However, shutdown of an activated source will not be required if visual observations by a MMO confirm the acoustic detection was of a species falling into the category of 'Other Marine Mammals' (i.e. not a Species of Concern).

If the PAM system malfunctions or becomes damaged, seismic operations may continue for 20 minutes without PAM while the PAM Operator diagnoses the problem. If it is found that the PAM system needs to be repaired, seismic operations may continue for an additional two hours without PAM as long as the following conditions are met:

- It is during daylight hours and the sea state is less than or equal to Beaufort 4;
- No marine mammals were detected solely by PAM in the relevant mitigation zones in the previous two hours;
- Two MMOs maintain watch at all times during seismic operations when PAM is not operational;
- DOC is notified via email as soon as practicable, stating time and location in which seismic operations began without an active PAM system; and
- Seismic operations with an active source, but without an active PAM system, do not exceed a cumulative total of four hours in any 24-hour period.

OMV has contracted Blue Planet Marine to provide the required MMOs and PAM Operators for any checkshot survey that may be conducted in relation to the Tāwhaki-1 exploration well. Blue Planet Marine personnel and their equipment will be located onboard the MODU, and on the support vessel where the PAM system will be deployed. The MMOs and PAM Operators will be qualified and trained in accordance with the Code of Conduct and will be in close contact with each other, even though they are on different vessels.

MMO observations can only be made during daylight hours whereas PAM can be operational on a 24-hour basis. Details of the PAM specifications are provided in **Appendix B**.

3.5.5 Operational and Reporting Requirements

MMOs and PAM Operators are required under the Code of Conduct to record and report all marine mammal sightings during the survey. All raw datasheets must be submitted directly to DOC by the qualified observers at the earliest opportunity, but no longer than 14 days after the completion of each deployment. A written final trip report must also be provided to DOC at the earliest opportunity, but no later than 60 days after the completion of the project.

The operational duties of MMOs and PAM Operators during seismic operations are outlined in **Table 4**.

Table 4 Operational Duties of MMOs and PAM Operators

Operational Duties	
MMO Duties	**PAM Operator Duties**
Provide effective briefings to crew members, and establish clear lines of communication and procedures for on-board operations	Provide effective briefings to crew members, and establish clear lines of communication and procedures for on-board operations
Continually scan the water surface in all directions around the acoustic source for presence of marine mammals, using a combination of naked eye and high-quality binoculars from optimum vantage points for unimpaired visual observations	Deploy, retrieve, test and optimise hydrophone arrays

Determine distance/bearing and plot positions of marine mammals whenever possible during sightings using GPS, sextant, reticule binoculars, compass, measuring sticks, angle boards or another appropriate tool	When on duty, concentrate on continually listening to received signals and/or monitor PAM display screens in order to detect vocalising cetaceans, except when required to attend to PAM equipment
Record/report all marine mammal sightings, including species, group size, behaviour/activity, presence of calves, distance and direction of travel (if discernible)	Use appropriate sample analysis and filtering techniques
Record sighting conditions (Beaufort Sea state, swell height, visibility, fog/rain and glare) at the beginning and end of the observation period, and when there is a significant change in weather condition	Record and report all cetacean detections, including - if discernible - identification of species or cetacean group, position, distance and bearing from vessel and acoustic source. Record the type and nature of sound, and the time and duration it was heard.
Implement appropriate mitigation actions (delayed starts and shut downs)	Implement appropriate mitigation actions (delayed starts and shut downs)
Record acoustic source power output while in operation, and any mitigation measure taken	Record general environmental conditions, acoustic source power output while in operation, and any mitigation measures taken.
Communicate with DOC to clarify any uncertainty or ambiguity in application of the Code of Conduct	Communicate with DOC to clarify any uncertainty or ambiguity in application of the Code of Conduct
Immediately report to DOC and the EPA any instances of non-compliance with the Code of Conduct	Immediately report to DOC and the EPA any instances of non-compliance with the Code of Conduct

3.5.6 Pre-start Observations

During a Level 1 survey, the acoustic source can only be activated if it is within the specified Operational Area and adheres to the following protocol:

- The acoustic source cannot be activated during daylight hours unless:
    - At least one qualified MMO has made continuous visual observations around the source for the presence of marine mammals, from the bridge (or preferably even higher vantage point) using both binoculars and the naked eye, and no marine mammals have been observed in the respective mitigation zones for at least 30 minutes, and no fur seals have been observed in the relevant mitigation zones for at least 10 minutes; and
    - Passive acoustic monitoring for the presence of marine mammals has been carried out by a qualified PAM Operator for at least 30 minutes before activation and no vocalising cetaceans have been detected in the respective mitigation zones.
- The acoustic source cannot be activated during night-time hours or poor sighting conditions (visibility of 1.5 km or less or in a sea state greater than or equal to Beaufort 4) unless:
    - Passive acoustic monitoring for the presence of marine mammals has been carried out by a qualified PAM Operator for at least 30 minutes before activation; and
    - The qualified observer has not detected any vocalising cetaceans in the relevant mitigation zones.

The Code of Conduct provides additional observation requirements for surveys starting up at a 'new location'. For the GSB Checkshot Survey the acoustic source will be deployed from the stationary MODU and will therefore remain in one location over the entire survey. However, initial activation of the acoustic source for the checkshot survey meets the definition of a new location, therefore the following additional requirements for start-up at night or in poor sightings conditions will be applied:

- MMOs will have undertaken observations within 20 NM of the planned start-up position for at least the last two hours of good sighting conditions preceding proposed operations, and no marine mammals have been detected; or
- Where there have been less than two hours of good sighting conditions preceding proposed operations (within 20 NM of the planned start-up position), the source may be activated if:
  - PAM monitoring has been conducted for two hours immediately preceding proposed operations;
  - Two MMOs have conducted visual monitoring in the two hours immediately preceding proposed operations;
  - No Species of Concern have been sighted during visual monitoring or detected during acoustic monitoring in the relevant mitigation zones in the two hours immediately preceding proposed operations;
  - No fur seals have been sighted during visual monitoring in the relevant mitigation zone in the 10 minutes immediately preceding proposed operations; and
  - No other marine mammals have been sighted during visual monitoring or detected during acoustic monitoring in the relevant mitigation zones in the 30 minutes immediately preceding proposed operations.

3.5.7 Soft Starts

A soft start consists of gradually increasing the source's power, starting with the lowest capacity acoustic source, over a period of at least 20 minutes and no more than 40 minutes. The operational source capacity is not to be exceeded during the soft start period.

The acoustic source will not be activated at any time except by soft start, unless the source is being reactivated after a single break in firing (not in response to a marine mammal observation within a mitigation zone) of less than 10 minutes immediately following normal operations at full power, and the qualified observers have not detected marine mammals in the relevant mitigation zones. Activation of the acoustic source at least once within sequential 10-minute periods shall be regarded as continuous operation.

3.5.8 Delayed Starts and Shutdowns

The following Code of Conduct requirements for delayed starts and shutdowns will be followed. Stricter mitigation measures have been implemented for marine mammals classified as a 'Species of Concern' (i.e. all whales and most dolphins in New Zealand) under Schedule 2 of the Code of Conduct. Species of Concern are identified in **Table 10**, with the full list provided as **Appendix C**. Marine mammals not considered a 'Species of Concern' fall under the category of 'Other Marine Mammal'.

3.5.8.1 Species of Concern with Calves within a Mitigation Zone of 1.5 km

If, during pre-start observations or while the acoustic source is activated (including during soft starts), a qualified observer detects at least one Species of Concern with a calf within 1.5 km of the source, start-up will be delayed, or the source will be shut down and not reactivated until:

- A qualified observer confirms the group has moved to a point that is more than 1.5 km from the source; or
- Despite continuous observation, 30 minutes has elapsed since the last detection of the group within 1.5 km of the source, and the mitigation zone remains clear.

3.5.8.2 Species of Concern within a Mitigation Zone of 1 km

If during pre-start observations or while the acoustic source is activated (including during soft starts), a qualified observer detects a Species of Concern within 1 km of the source, start-up will be delayed, or the source will be shut down and not reactivated until:

- A qualified observer confirms the Species of Concern has moved to a point that is more than 1 km from the source; or
- Despite continuous observation, 30 minutes has elapsed since the last detection of a Species of Concern within 1 km of the source, and the mitigation zone remains clear.

3.5.8.3 Other Marine Mammals within a Mitigation Zone of 200 m

If during pre-start observations prior to initiation of the acoustic source soft start procedures, a qualified observer detects a marine mammal other than a Species of Concern within 200 m of the source, start-up will be delayed until:

- A qualified observer confirms the marine mammal has moved to a point that is more than 200 m from the source; or
- Despite continuous observation, 10 minutes has elapsed since the last detection of a New Zealand fur seal within 200 m of the source and 30 minutes has elapsed since the last detection of any other marine mammal within 200 m of the source, and the mitigation zone remains clear.

Once all marine mammals that were detected within the relevant mitigation zones have been observed to move beyond the respective mitigation zones, there will be no further delays to the initiation of soft start procedures.

4 Stakeholder Engagement

The GSB Checkshot Survey that may be acquired at the Tāwhaki-1 exploration well forms a component of the GSB EAD Programme and as such engagement regarding this survey has been undertaken as part of the wider GSB EAD Programme.

Based on the confined spatial extent of effects from the GSB Checkshot Survey, as confirmed by the STLM (**Appendix A**), the engagement process has been limited and targeted towards certain key groups. **Table 5** provides a list of the groups that have been engaged with, advised, or a request to meet has been made by OMV regarding the wider GSB EAD Programme.

OMV has not received any feedback or concerns regarding the GSB Checkshot Survey throughout the extensive consultation process with iwi and stakeholders.

Table 5 Stakeholders and Iwi Groups OMV has Engaged with

Regulators and Department of Conservation	
EPA	Maritime New Zealand
DOC – National Office	DOC – Southern region, Queenstown Office
DOC – Otago Office	
Iwi and Papatipu Rūnanga	
Ngāti Tahu	Te Rūnanga Awarua
Te Rūnanga o Ōtakou	Kāti Huirapa Rūnaka ki Puketeraki
Te Rūnanga o Moeraki	
Fisheries	
Deepwater Group	Te Ohu Kaimoana
Ngāi Tahu Seafood	Fisheries Inshore New Zealand
Seafood New Zealand	
Shipping	
New Zealand Shipping Federation	
Territorial Authorities and Regional Councils	
Southland District Council	Environment Southland
Otago Regional Council	

5 Description of Existing Environment

5.1 Physical Environment

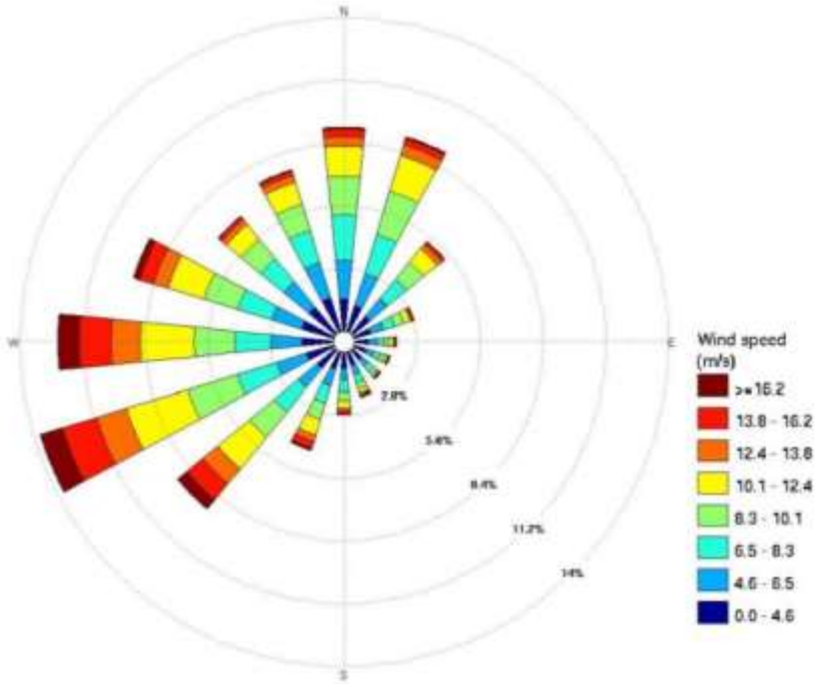
5.1.1 Meteorology

The climate of New Zealand varies from warm sub-tropical in the upper north to cool temperate in the lower south (NIWA, 2019). There are three key features which determine New Zealand's climate: the prevailing winds, the oceans, and the mountain ranges. Within the Operational Area, the winds and oceans are the two main features controlling the climate. Due to the latitude at which New Zealand sits, strong winds from the west, known as the roaring forties and furious fifties, buffet the country and dominate the circulation of atmosphere (Te Ara, 2019). Low-pressure systems develop within these westerly winds as they head towards New Zealand, bringing rain and stormy weather conditions as they pass across, or south of the country.

The Operational Area is located off the coast of the 'Southern New Zealand' zone. Most of the climate within this zone is characterised by cool coastal breezes with an absence of shelter from unsettled weather moving over the sea from the south and southwest (NIWA, 2019a).

In a desktop analysis of metocean conditions at the Tāwhaki-1 well location (MOS, 2017), near-surface wind conditions were extracted at hourly intervals from a 37 year hindcast analysis from 1979 to 2015. A summary of the monthly and annual wind statistics for the modelled location within the Operational Area is provided in **Table 6**. The annual wind rose in **Figure 5** shows the predominance of wind blowing from the north, west and southwest octants (MOS, 2017).

Figure 5 Annual Wind Rose at Tāwhaki-1



Source: MOS, 2017.

Note: Sectors indicate the direction from which the winds blow.

Table 6 Summary of Monthly and Annual Wind Speed Statistics at Tāwhaki-1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Min (m/s)	0.01	0.04	0.07	0.02	0.03	0.05	0.08	0.05	0.11	0.07	0.09	0.04	0.01
Max (m/s)	27.00	28.44	29.73	23.97	24.93	24.77	24.47	23.98	24.29	25.07	25.87	24.78	29.73
Mean (m/s)	8.02	7.87	8.30	8.59	9.15	9.16	8.66	8.68	8.89	8.63	8.40	7.84	8.52
Main direction	N, SW, W	N, SW, W	N, SW, W	N, SW, W, NW	N, SW, W, NW	SW, W	N, SW, W, NW	N, SW, W	N, SW, W, NW	N, SW, W, NW	N, SW, W	N, SW, W	N, SW, W

Source: MOS, 2017

5.1.2 Currents and Waves

New Zealand's coastal current regime is dominated by three components: wind-driven flows, low-frequency flows and tidal currents. The net current flow is a combination of all these components and is often further influenced by the local bathymetry.

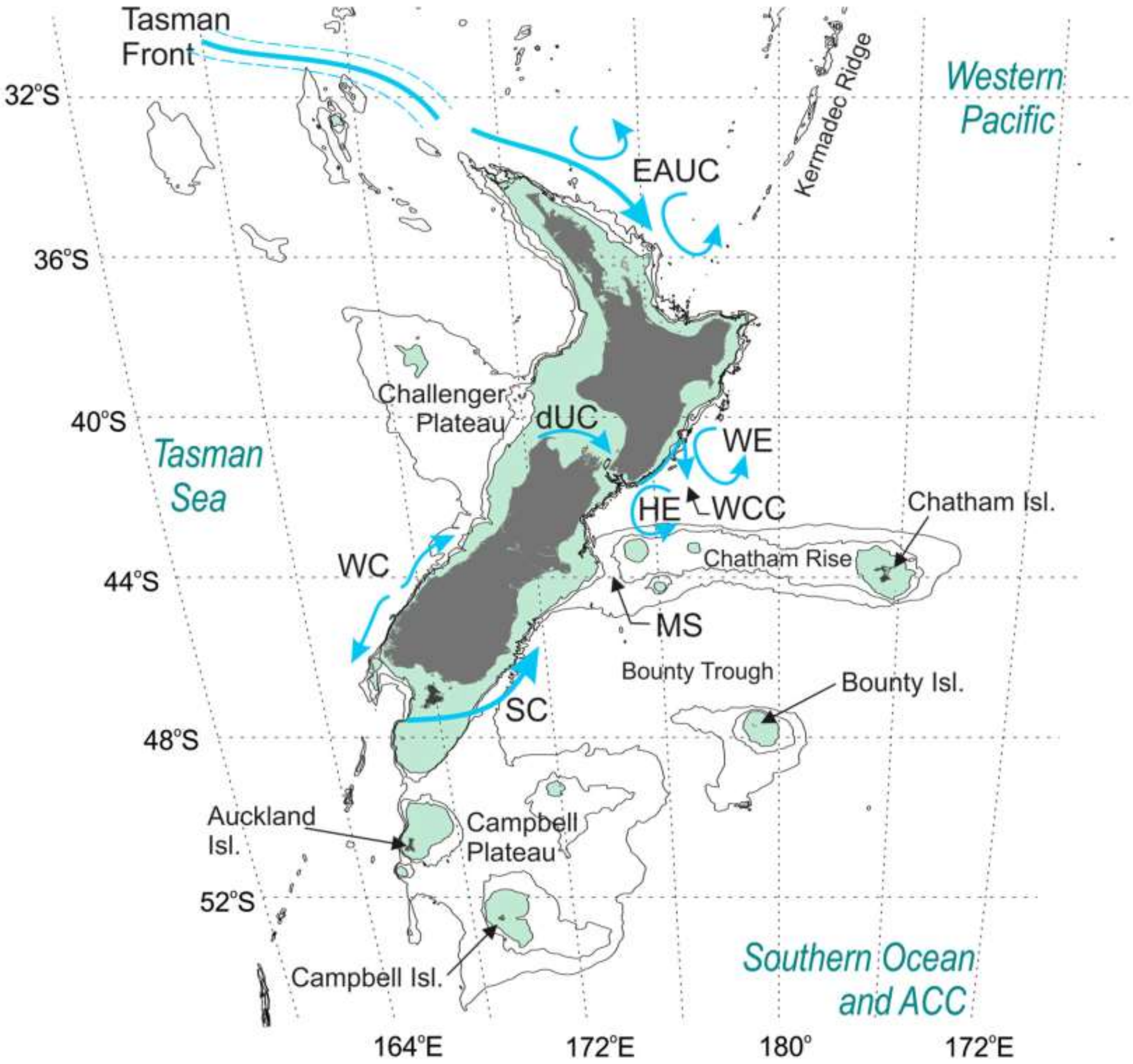
New Zealand lies in the pathway of eastward-flowing currents driven by winds that blow across the South Pacific Ocean (Brodie, 1960; Te Ara, 2019a). As a result, New Zealand is exposed to the southern branch of the South Pacific sub-tropical gyre driven by the southeast trade winds to the north and the westerly flowing roaring forties to the south (Gorman *et al.*, 2005; Te Ara, 2019a).

The main ocean currents around New Zealand are illustrated in **Figure 6**. Inshore of the Operational Area the current flow is known as the Southland Current, which flows north-eastwards along the Otago coast at speeds of up to 0.25 m/s and has been observed up to 130 km from shore (Te Ara, 2019a; Heath, 1985). This pronounced north-easterly flow is the dominant current within the Operational Area.

Hydrodynamic conditions at the Tāwhaki-1 well location was derived from a 36-year (1980 – 2015) New Zealand hindcast, with current meter data from around New Zealand used to validate the model. Typical monthly maximum current speeds are in the range of 0.50 – 1 m/s, with an annual mean non-tidal surface current speed of 0.18 m/s. Currents predominantly move to the north – north-northeast sectors within the whole water column (MOS, 2017).

The directional wave spectra were defined at the Tāwhaki-1 well location based on a 37-year (1979 – 2015) high-resolution wave hindcast. At this location, the mean annual significant wave height was 3.17 m, with the 1st and 99th percentile exceedance levels being 1.55 m and 6.98 m (MOS, 2017). The largest significant wave height at the modelled location was 11.70 m. The predominant wave direction throughout the year was from the southwest quarter.

Figure 6 Ocean Circulation around the New Zealand Coastline



Note: Costal currents, plateaus and features shown including the Tasman Front, East Auckland Current (EAUC), Wairarapa Coastal Current (WCC) and Eddy (WE), Westland Current (WC), Southland Current (SC), Hikurangi Eddy (HE), Mernoo Saddle (MS), and D'Urville Current (dUC). Regions less than 250 m water depth are shaded and the 500 and 1,000 m isobaths are shown.

Source: Stevens *et al,* 2019.

5.1.3 Thermoclines and Sea Surface Temperature

Sea surface temperatures in New Zealand waters show a north to south gradient with warmer waters found in the north, cooling towards the south (Te Ara, 2019b).

Monthly and annual sea temperature statistics at the Tāwhaki-1 well location at 10 m, 500 m and 1,000 m below the sea surface (**Table 7**) are taken from a 36-year (1980 – 2015) hindcast data set. Overall, water temperatures vary throughout the water column, with warmest temperatures experienced towards the sea surface, cooling with increasing depth (MOS, 2017).

Table 7 Annual and Monthly Sea Temperatures within the Operational Area at 10 m, 500 m, and 1,000 m Below Sea Surface

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
10 m below sea surface													
Min (°C)	10.62	11.62	10.18	9.62	8.68	7.52	7.54	7.19	7.05	7.66	8.32	9.01	7.07
Max (°C)	16.69	16.25	15.89	14.33	12.49	11.08	10.23	9.71	9.79	10.77	12.58	14.83	16.69
Mean (°C)	13.18	13.73	13.08	11.76	10.58	9.49	8.68	8.28	8.35	8.94	10.20	11.77	10.66
500 m below sea surface													
Min (°C)	5.26	5.20	5.18	5.10	5.10	5.05	4.98	5.07	4.88	5.03	5.23	5.26	4.88
Max (°C)	7.82	7.57	7.33	8.09	7.75	7.76	7.77	7.60	8.20	7.77	7.77	8.24	8.24
Mean (°C)	6.58	6.47	6.37	6.41	6.40	6.36	6.33	6.51	6.62	6.50	6.48	6.53	6.46
1,000 m below sea surface													
Min (°C)	3.41	3.20	3.31	3.34	3.35	3.29	3.31	3.30	3.39	3.45	3.49	3.38	3.20
Max (°C)	5.48	5.51	5.67	5.68	5.57	5.68	5.70	5.78	5.78	5.63	5.52	5.52	5.78
Mean (°C)	4.38	4.36	4.35	4.37	4.32	4.32	4.36	4.43	4.45	4.43	4.73	4.39	4.38

Source: MOS, 2017

During spring and summer, thermal stratification of the water column can develop as a result of solar heating in the upper water column. The profile of the thermocline varies with surrounding environmental conditions; for example, storm conditions can cause significant vertical mixing and breakdown of the thermal structure, and tides and currents can either enhance or damage the structure of the thermocline. As a result, a well-defined thermocline is not always present (ASR, 2004).

Surface water temperature was recorded continuously (at 30-minute intervals) throughout the Tāwhaki-1 Pre-drill Survey voyage. Surface water temperatures ranged between 13 and 14°C with a distinct thermocline down to 8°C at 100 m water depth. Between the water depths of 100 and approximately 500 m, water temperatures were relatively stable in the 7-8 °C range before steadily dropping with depth to reach 2.8 - 3.1 °C at the lowest point of the casts near the seabed.

5.1.4 Ambient Noise

Hildebrand (2009) defines ambient noise in the ocean as the sound field against which signals must be detected. In the marine environment, ambient noise is generated by numerous sources, including:

- Biological – marine organisms (e.g. cetacean vocalisations, echolocations, drumming of the swim bladder by fish, snapping shrimp feeding behaviours);
- Physical – meteorological, oceanographic processes and natural seismic events (e.g. breaking waves, rain, lighting strikes, earthquakes); and
- Anthropogenic – shipping traffic, marine construction, seismic surveys, drilling.

Water depth and seabed reflectivity influences the levels of ambient noise present in the marine environment, where ambient noise levels increase with seabed reflectivity and decrease with water depth (Dahl *et al.*, 2007). As a result, deeper offshore waters, which generally have mud substrates, will have a lower ambient noise level than the shallower seabed closer to the shoreline, which generally has sandy substrates.

There have been no measurements of ambient noise in the Operational Area or wider GSB; however, due to the substantial water depths present within the Operational Area and the distance offshore, ambient noise sources will likely be limited to natural sources, with infrequent additions from passing fishing vessels. The GSB Checkshot Survey and associated activities (e.g. vessel machinery, etc.) are expected to provide the main source of anthropogenic noises in the Operational Area.

5.1.5 Geology, Bathymetry and Seabed Substrate

5.1.5.1 Geology

New Zealand is surrounded by a flat, gently sloping zone known as the continental shelf. The shelf extends from the coast out to a water depth of approximately 200 m. Beyond this shelf, the gradient of the seabed steepens and passes into the continental slope, which descends relatively rapidly from the edge of the shelf down to depths greater than 4,000 m. At the slope's foot, the seaward gradient typically flattens out into an ocean basin which is constituted of a wide, undulating, but relatively flat zone lying at 4,000 to 5,000 m depth, and which covers most of the central parts of the major oceans (Te Ara, 2019c).

The surface of the continental shelf is predominantly flat although diversified by local banks and reefs, whereas the slope is more irregular, being cut in many areas by large marine valleys known as submarine canyons. These tend to occur in slope areas of relatively steep gradient and generally run from the edge of the continental shelf to the foot of the continental slope.

There are numerous sedimentary basins around New Zealand (**Figure 7**) that have known or potential hydrocarbons present, both onshore and offshore underlying the continental shelf. Hydrocarbon discoveries have been made in the Taranaki, East Coast, Canterbury, and Great South basins (NZP&M, 2014), but the only commercial hydrocarbon fields discovered to date have been in the Taranaki Basin.

The Canterbury-Great South Basin (**CGSB**) comprises the Great South and the Canterbury Basin (**Figure 7**), which are geologically contiguous and indistinguishable. The CGSB is an extensional basin associated with Cretaceous rifting and break-up of the Gondwana supercontinent. Prior to extension, the CGSB was located on the active eastern margin of Gondwana where arc-related terranes were accreted from the late Palaeozoic through Jurassic, as reflected in the complex basement configuration of New Zealand. Subsequent Mid-Cretaceous extension led to the development of NE-SW rift basins characterized by en-echelon half-graben systems that evolved from isolated to connected depocentres as extension progressed. Fourteen offshore wells have been drilled in the CGSB to date, most encountered hydrocarbon shows of oil and gas and four sub-commercial discoveries of gas/condensate were made. However, the main exploration efforts in the CGSB occurred in the 1970s and was primarily on sparse 2D seismic data.

Recent regional seismic mapping reveals that the CGSB has three dominant structural trends, a NW-SE trend associated with pre-rift terrane accretion and SW-NE and WSW-ENE trends associated with rift extension. Syn- and post-rift coals and coaly mudstones constitute the main source rocks within the basin and these are contemporaneous with known source rocks for giant oil and gas fields within the Late Cretaceous Gippsland Basin (Australia) and Taranaki Basin. The Gippsland Basin was part of the same rift system as the CGSB, and the opening of the Taranaki Basin commenced at the end of the rifting within the CGSB. Source rock samples from these analogous basins show similar quality as samples from the CGSB. The main reservoirs within the CGSB in the area of PEP 50119 are transgressive sands directly overlying pre-rift highs, receiving hydrocarbon charge generated from syn-rift coal measures surrounding the basement highs. Pre-rift lithologies as well as depositional environments are the main controlling factor on reservoir quality. Late Cretaceous marine transgressive shales act as top seals for these sands. Gas-escape features in the overburden of nearby leads support the interpretation of a working petroleum system in PEP 50119.

Figure 7 New Zealand Sedimentary Basins

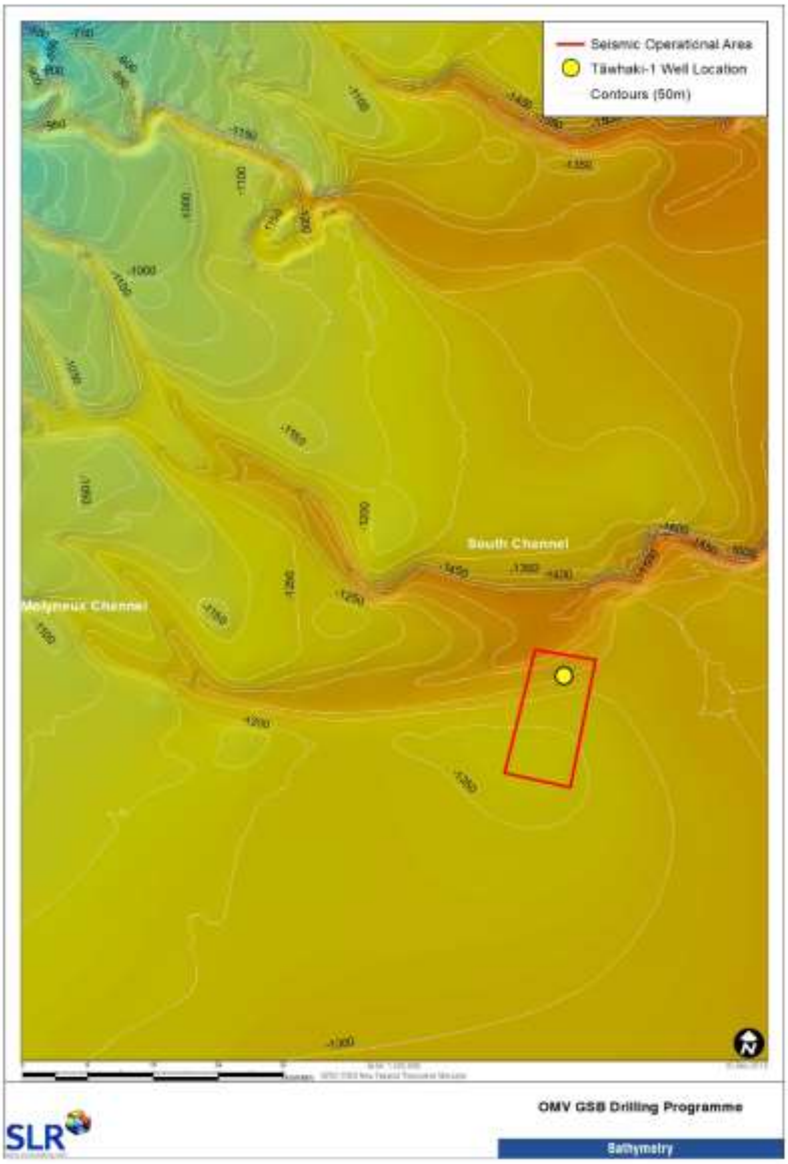
Source: NZP&M, 2014

5.1.5.2 Bathymetry

The continental shelf extends for approximately 20 Nautical Miles (**NM**) off the coast of south Otago. Beyond this, a series of submarine canyons known as the Otago Fan Complex incise the continental slope to the northwest of the Operational Area. Bathymetric contours within the Operational Area show water depths predominantly around 1,200 – 1,300 m (**Figure 8**).

Submarine canyons along the Otago Fan Complex feed into a series of tributaries that form the western edge of the Bounty Trough. The Operational Area is located near two of these tributaries – the Molyneux and South, Channels (as can be seen in **Figure 8**). These tributaries are entrenched at around 250 m relative to the surrounding seafloor.

Figure 8 Bathymetry of the Operational Area



Source: contours derived using NIWA New Zealand Bathymetric Grid (2016) (250 m resolution).

5.1.5.3 Seabed Substrate

Seabed imagery collected during the Tāwhaki-1 Pre-drill Survey revealed the seabed surrounding the Tāwhaki-1 well location is dominated by muddy sediments. These muddy sediments represented the main proportion of sediments at most of the sample sites, with the exception of a number of sites to the northwest and northeast of Tāwhaki-1. Sediments at these sites appeared to contain coarser materials such as boulders, gravel, and barnacle plates, and are associated with the canyons transecting the wider vicinity of the Operational Area.

Grain-size analysis of multi-core sediment samples collected during the Tāwhaki-1 Pre-drill Survey showed a seabed dominated by higher proportions of mud than sand at most sites resulting a substrate considered to be composed mainly of 'very coarse silt'. Higher proportions of sand than mud occur in areas surrounding the channels, with these substrates described mainly as 'coarse silt', or 'fine sand'.

5.2 Biological Environment

5.2.1 New Zealand Marine Environment Classification

The New Zealand Marine Environment Classification covers New Zealand's CMA and EEZ, providing a spatial framework for structured and systematic management. Geographic domains are divided into classes with similar environmental and biological characters (Snelder *et al.*, 2005). Classes are characterised by factors such as depth, solar radiation, sea-surface temperatures, waves, tidal current, sediment type, seabed slope and curvature.

According to this classification, the Operational Area lies within Class 47 (**Figure 9**). This classification is useful in providing a general understanding of what marine species could be present within the Operational Area, specifically when data is limited.

Class 47 is an oceanic, shelf and sub-tropical front environment that occurs extensively in deep waters (mean = 2998 m) over a latitudinal range from around 37 – 47°S. Average chlorophyll-α concentration is moderately low. Characteristic fish species include smooth oreo, Baxter's lantern dogfish, the rattail *Macrourus carinatus*, Johnson's cod and orange roughy.

The MEC is generic in that it classifies patterns for both the pelagic and benthic elements of the marine ecosystem. A more specifically tailored classification was developed by Leathwick *et al.* (2012) that was designed to assess the impacts of bottom trawling on benthic organisms: the Benthic Optimised Marine Environment Classification (**BOMEC**). The BOMEC can also be used to assess the potential impacts from other human activities at the sea floor on demersal fish communities and is possibly more relevant than the Marine Environment Classification (Leathwick *et al.*, 2012).

According to the BOMEC, the Operational Area lies primarily within 'Class N' waters (**Figure 10**), which are defined as the second deepest waters described within the BOMEC (averaging 1,400 m), occurring over a wide latitudinal range, with low sea surface temperature gradients and tidal currents, and fine sediments (Leathwick *et al.*, 2012).

Figure 9 New Zealand Marine Environmental Classification around the Operational Area

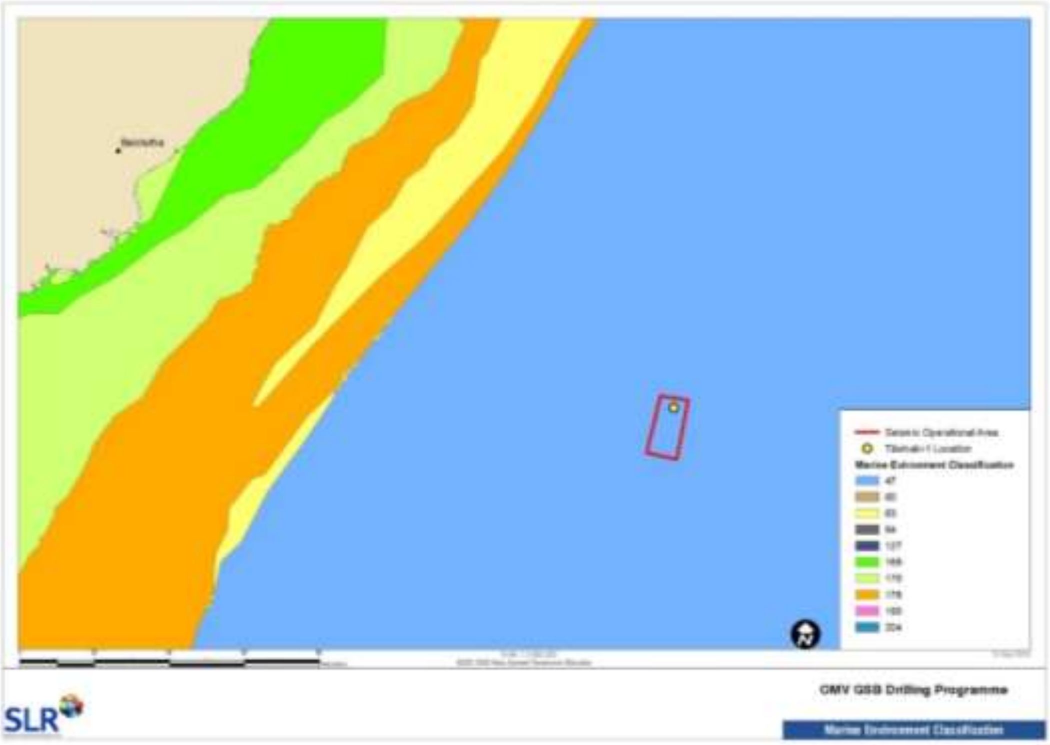
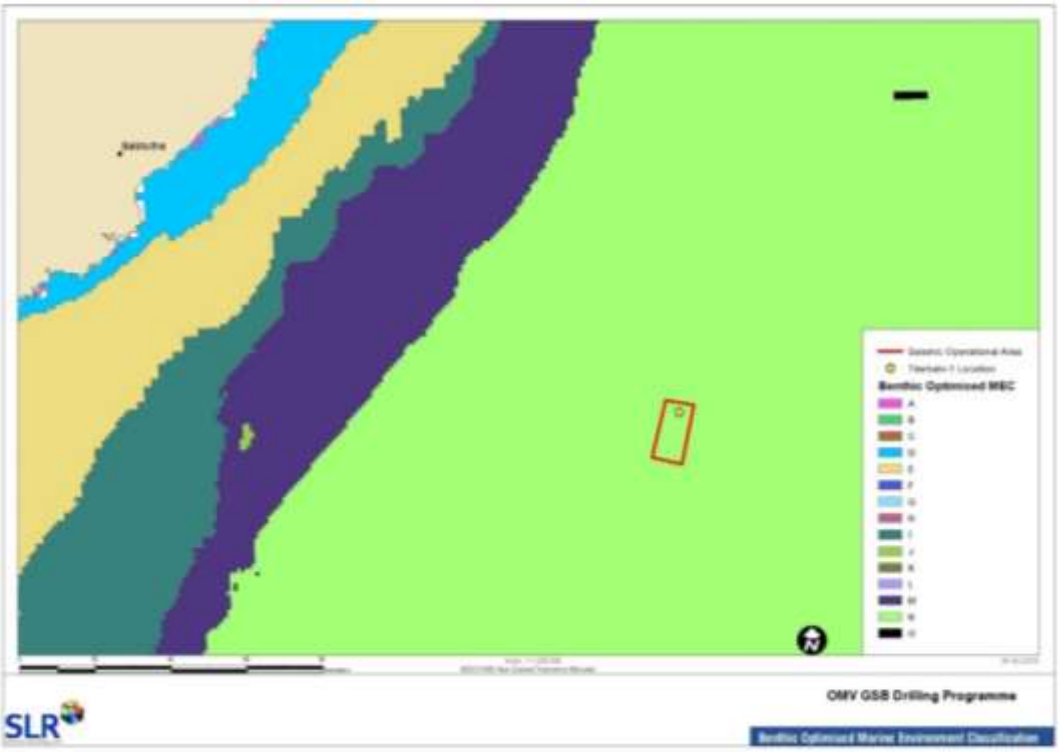


Figure 10 Benthic Optimised Marine Environment Classification around the Operational Area



5.2.2 Plankton

'Plankton' is the collective term for drifting organisms that inhabit the pelagic zone (water column) of the world's oceans. Plankton fulfils the primary-producer role in the ocean and forms the basis of the marine food web. Plankton travel with the ocean currents and although some plankton can move vertically within the water column, their horizontal distribution is primarily determined by surrounding currents. There are four broad functional planktonic groups (Nybakken & Bertness, 2005):

- Viroplankton – viral organisms in the size range of 0.02 – 0.2 µm that cannot survive without infecting a host;
- Bacterioplankton – bacteria that are free-floating within the plankton and usually of a size range from 0.2 – 2.0 µm;
- Phytoplankton – free-floating organisms capable of photosynthesis (includes diatoms and dinoflagellates); and
- Zooplankton – free-floating animals (includes copepods, jellyfish and larval stages of larger animals (meroplankton)).

The productivity of the ocean is the result of many factors. These include ocean currents, climate and bathymetry which cause upwelling and create nutrient-rich waters. Such conditions are ideal for the growth of plankton and plankton-consuming animals (MacKenzie, 2014).

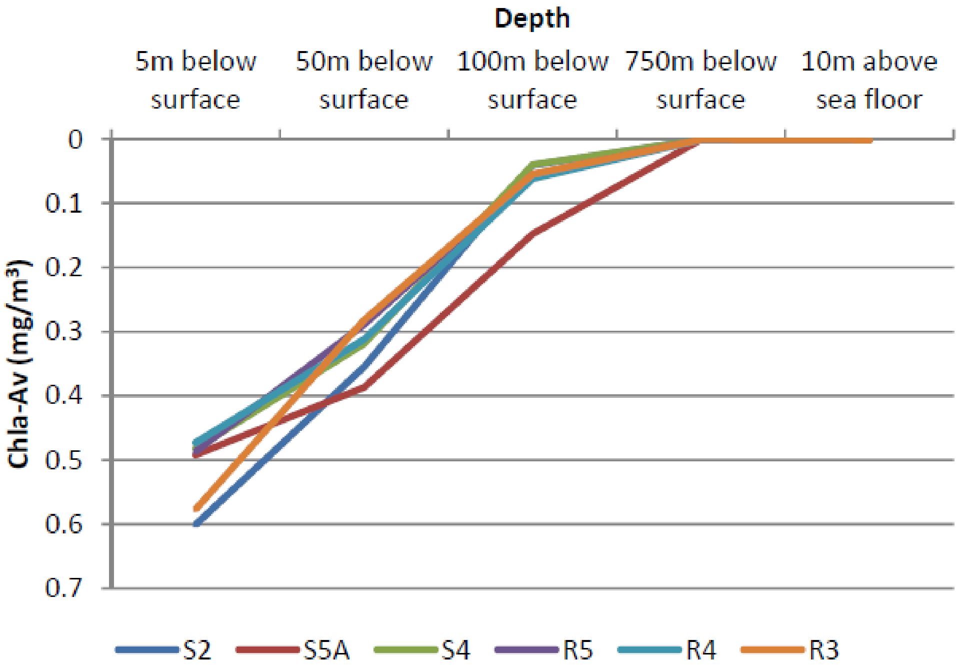
Further information on the phytoplankton and zooplankton that may be present throughout the Operational Area is provided in the sub-sections below.

5.2.2.1 Phytoplankton

Phytoplankton forms the base of the marine food chain and uses solar energy to fix atmospheric carbon dioxide into particulate organic carbon (Murphy *et al*., 2001). The South Island lies adjacent to the Subtropical Convergence, which separates sub-tropical water in the north from sub-Antarctic water in the south and brings strong physical and nutrient gradients that influence phytoplankton growth (Vincent *et al,* 1991).

Chlorophyll-α concentration is used as a proxy for near-surface phytoplankton abundance (Murphy *et al*., 2001; Pinkerton *et al*., 2006). Chlorophyll-α levels were measured at a number of stations throughout the GSB in the vicinity of the Operational Area as part of the baseline assessment. During the 2013 TAN1303 voyage, chlorophyll-α concentration across all sampled sites ranged from 0.001 to 0.601 mg/m^3, with a mean concentration of 0.1824 mg/m^3. Unsurprisingly, chlorophyll-α concentration decreased with depth across all sampling sites (**Figure 11**). During the Tāwhaki-1 Pre-drill Survey fluorescence data from CTD casts gave an indication of phytoplankton concentration within the water column and showed that phytoplankton levels peaked in surface waters down to approximately 20 m water depth (2.5-4.2 µg/L) before decreasing rapidly with depth down to around 0.5 µg/L at 60-70 m water depth, and then slowly decreasing to near zero by 100 m water depth. It is worth noting that as these surveys were carried out in the same month of the year on both occasions (March 2013 and 2019) they do not provide any indication of seasonality and should be interpreted with caution when trying to analyse results.

Figure 11 Average Chlorophyll-α Concentration with Depth across NIWA GSB Sample Stations



Source: 2013 EBS

5.2.2.2 Zooplankton

Zooplankton play an important role in phytoplankton grazing and nutrient recycling (Boyd & Smith, 1983), and provide a food source for animals higher up in the food chain. While no zooplankton surveys have been carried out specifically within the Operational Area, the following information provides an indication of the zooplankton communities present in the wider vicinity.

Jillet (1976) provides one of the only analyses of the zooplankton present off the Otago Peninsula; approximately 40 km from the Otago Peninsula. Zooplankton communities were comprised of sub-Antarctic species reaching their northern limit, and sub-Tropical species reaching their southern limit. Sub-Antarctic species were less abundant from late summer through to early winter. The oceanic zooplankton recorded included various copepods, amphipods, euphausiids, heteropods (swimming marine snails), and tunicates/salps. Although the Operational Area lies to the south-east of the Otago Peninsula and over 46 km from the coastline, the zooplankton communities present are likely to be similar to those described in Jillet (1976) for oceanic communities.

Pakhomov and McQuaid (1996) recorded zooplankton communities on a return voyage from the southeast coast of the South Island down to the Ross Sea. Immediately to the south of New Zealand and north of the sub-Antarctic Front, zooplankton species composition varied between each leg of the voyage. During the south-bound leg of the voyage, abundance and biomass was low, with communities dominated by the chaetognaths (predatory marine worms) *Eukrohnia hamate* and *Sagitta gazellae*. On the north-bound leg, zooplankton communities were dominated by high densities of the salp *Salpa thompsoni* along the shelf region; however, if salps are excluded from the analysis, composition was similar between both legs of the voyage (Pakhomov & McQuaid, 1996).

Stomach analyses of oceanic foraging seabirds can also provide indications of the potential zooplankton communities in the vicinity of the Operational Area. Sooty shearwaters are an important species around the southern coast of the South Island and forage in offshore waters, with their at-sea abundance correlating with high abundances of zooplankton (Pakhomov & McQuaid, 1996). Regurgitated samples taken from chicks at Taiaroa Head and Nugget Point indicate the presence of euphausiid krill (mostly *Nyctiphanes australis*), amphipods (*Themisto medusarum* and *Hyperia medusarum*) and salps (*Pyrosoma atlanticum*) in oceanic waters off the south-east coast of the South Island (Cruz *et al*., 2001).

5.2.3 Invertebrates

Data collected during the 2019 Tāwhaki-1 Pre-drill benthic survey have been used to describe the benthic infauna and epifauna communities present within the Operational Area and the wider vicinity around the Tāwhaki-1 well location.

Multi-core samples revealed polychaetes as the most numerous taxonomic group, with relatively high abundances of discrete foraminiferas (potentially pelagic in origin) also present. Other taxonomic groups recorded in the multi-core samples included Cnidaria (anemones, Scyphozoa, and 'unknown'), Crustacea (Amphipoda, Isopoda, Tanaidacea, Copepoda, Cumacea, Ostracoda, and 'unkown'), Echinodermata (Asteroidea, Ophiuroidea, Holothuroidea, Echinoidea, and 'unknown'), Hydrozoa, Acari, Paripulida, Gromiida, Mollusca (Aplacophora, Solenogastres, Bivalvia, Gastropoda, Scaphopoda), Bryozoa, Pycnogonida, Porifera, Sipunculida, Nematoda, Nemertea, and Platyhelminthes.

High-resolution seabed imagery was used to specifically cover three broad habitats (broad slope basin, channel sites, and seamount features) within the Operational Area and surrounding area. The soft muddy sediments of the broad slope basin were dominated by ophiuroids, Porifera, Actinaria (anemones), echinoids, gastropods, holothurians, terebellid worms, large agglutinated foraminifera, bryozoans and scaphopods. Channel sites included areas of hard substrate relatively barren of encrusting fauna, while sponges and gorgonians encrusted other areas of hard substrate. The closest channel feature is 8.5 km north of the Tāwhaki-1 well location. Sponges, sea pens and echinoderms dominated the muddy/sandy sediments of the channel floor, with carnivorous sponges observed at some channel floor sites. The hard substrate seamounts were often colonised by gorgonians, barnacles, sponges, stylasterid hydrocorals, rock pens and other encrusting fauna, although areas of smooth bedrock were also present and were relatively barren.

The seamount features, which are located approximately 18 km from the Tāwhaki-1 well location, supported a number of coral groups including gorgonians and Stylasteridae (hydrocorals). High abundances of gorgonians were observed on seamount features and at some channel sites, many of which were small yellow gorgonians (*Thouarella* sp., family Primnoidae); however, large habitat-forming gorgonians were also observed (e.g. bubblegum (family Paragorgiidae) and bamboo (family Isididae) corals). Golden corals (*Radicipes* spp.) were occasionally observed at hard and soft sediment sites. Scleractinia (in the form of branching stony corals and cup corals) were observed during the survey. Cup corals were observed in their highest abundances to the south of the channel in close proximity to the Tāwhaki-1 well location. Observed cup corals were identified as within the genera Stephanocyanthus.

Previous deep-water sampling that has occurred in areas around New Zealand (as reviewed in Consalvey *et al.*, 2006) found black corals in areas well to the north and east of the Operational Area. However, the number and nature of samples was insufficient to provide a full picture of the occurrence of cold-water corals in general. Modelling to predict the occurrence of gorgonians, hydrocorals, black corals and stony corals in New Zealand waters, suggested a generally high occurrence of gorgonians and stony corals within the GSB and a low occurrence of black corals (Baird *et al.*, 2013), in line with the known occurrences of these taxa (Consalvey *et al.*, 2006).

5.2.3.1 Sensitive Environments

Schedule 6 of the Exclusive Economic Zone and Continental Shelf (Environmental Effects – Permitted Activities) Regulations 2013 describes 13 sensitive biogenic environments. The Ministry for the Environment (in consultation with NIWA) defined a number of marine biogenic and geological environments as 'sensitive' in order to provide guidance for operators planning to conduct activities within the EEZ (MacDiarmid *et al*., 2013).

The 'sensitivity' of an environment is defined as the tolerance of a species or habitat to damage from an external factor combined with the time taken for its subsequent recovery from damage sustained as a result of the external factor. The rarity of a particular habitat was also taken into account when considering its tolerance; an external factor is more likely to damage a higher proportion of a population or habitat as rarity increases, therefore a rare habitat has a lower tolerance rating (MacDiarmid *et al.*, 2013).

Based on the results of the Tāwhaki-1 Pre-drill Survey, three sensitive environments (based on the Schedule 6 criteria) were identified as being present within, or in the vicinity of the Operational Area; stony coral thickets or reefs, xenophyophores, and brachiopods. These three sensitive environments are described in further detail below.

5.2.3.1.1 Stony Coral Thickets or Reefs

Coldwater corals include the Scleractinia (stony corals), Octocorallia (soft corals), Antipatharia (black corals), and Stylasteridae (hydrocorals). Stony corals provide the most complex habitats and can form 3D reefs or thickets (Roberts *et al.*, 2006). They are fragile, sessile, slow-growing, long-lived and have limited larval dispersal and a restricted distribution (Consalvey *et al.*, 2006). The distribution of stony corals is determined by the presence of favourable conditions such as high nutrient and food supply, currents or mixing to deliver food and nutrients, and low sedimentation rates (Roberts *et al.*, 2006). There are five main habitat-forming species of stony coral in New Zealand waters, all of which (with the exclusion of *Oculina virgosa* which is only found along the Kermadec Ridge) are found in water 800 – 1,000 m deep and are typically associated with seamounts (Tracey *et al.*, 2011).

Stony corals were observed during the Tāwhaki-1 Pre-drill Survey as live branching and intact dead colonies. A branching coral (probably *Madrepora* sp. or *Enallopasmmia* sp.) was observed at sites R9, R10, and R25 on the sides of seamount features. Based on these findings, stony coral thickets are present in the required densities to be considered a sensitive environment under the Schedule 6 criteria. The closest identified stony coral thicket was 18.9 km from the Tāwhaki-1 well location.

5.2.3.1.2 Xenophyophores

Xenophyophores are large single-celled protozoans that live on the seabed and form an external test of mineral grains, sponge spicule fragments and organic debris (Hayward *et al.*, 2012), and as a result are often mistakenly identified as broken and decaying parts of other animals (Tendal, 1975). Seven species of xenophyophore have been recorded in New Zealand including three endemic species (MacDiarmid *et al.*, 2013). They are particularly abundant below areas of high surface productivity (Hayward *et al.*, 2012). Sampling locations in New Zealand include the eastern, northern, and western continental slopes and on the Chatham Rise in depths of 500 – 1,300 m (Tendal & Lewis, 1978; Hayward *et al.*, 2012).

Xenophyophores are a type of foraminifera. They are among the most abundant shelled organism in many marine environments and can be found in all marine environments, in either planktonic or benthic life stages, although, most live a benthic life cycle.

The Tāwhaki-1 Pre-drill Survey confirmed the presence of xenophyophores as a sensitive environment based on the Schedule 6 criteria. The closest location of this sensitive environment to the Tāwhaki-1 well location was 2 km, with other locations identified out to 57 km from the Tāwhaki-1 well location.

5.2.3.1.3 Brachiopods

Brachiopods are small bilaterally symmetrical filter feeders that superficially resemble bivalve molluscs and range in size from 5 – 50 mm long (Lee & Smith, 2007; Tracey *et al.*, 2011). They typically anchor to hard substrates such as rocks, gravel, or shell debris by a muscular stalk.

Brachiopods occur throughout New Zealand at all depths in areas of significant water movement that are free of fine sediment (Lee & Smith, 2007). While brachiopods have been found at all depths, the majority occur in water depths less than 500 m, with known or abundant brachiopod assemblages occurring on parts of the Chatham Rise, often associated with coral thickets (MacDiarmid *et al.*, 2013). The presence of both live and dead brachiopods increases habitat complexity (MacDiarmid *et al.*, 2013).

Based on observations during the Tāwhaki-1 Pre-drill Survey brachiopods are associated with hard substrate features such as those present on the seamount and channel features, to the north of the Operational Area.

5.2.4 Fish

Fish populations within, and near, the Operational Area are represented by various demersal and pelagic species, most of which are widely distributed throughout New Zealand's deep offshore waters. A large proportion (~30%) of New Zealand's fish are categorised as 'widespread', in that they occur across all three major oceans or in the Pacific and Atlantic oceans; however, there is also a large proportion that are classified as endemic (approximately 22% of described species) (Roberts *et al.*, 2015).

The fish species potentially present within and in the vicinity of the Operational Area are listed in **Table 8**. This information was collated from the Ministry for Primary Industries' fish guides (McMillan *et al.*, 2011a; 2011b; 2011c), a Fisheries New Zealand (**FNZ**) analysis of commercial fishing within the Operational Area (FNZ, 2019; 2019a), more than 35 years of commercial trawl surveys (Anderson *et al.,* 1998; Bagley *et al.,* 2000, Hurst *et al.,* 2000a, 2000b; O'Driscoll *et al.,* 2003), and an analysis of commercial fishing effort in the vicinity of the Operational Area (Gibbs, 2018). The number of fish species described within New Zealand's EEZ is 1,262 (Roberts *et al*., 2015); therefore, **Table 8** is not intended to provide an exhaustive list of all fish species potentially present within the Operational Area, but lists the main species based on published literature. **Table 8** includes fish with the potential to be present in the Operational Area (i.e. water depths of 700 m or greater).

Deep Towed Imaging System (**DTIS**) footage collected during the Tāwhaki-1 Pre-drill Survey captured images of various species of rattail, sharks and eels, with deep-sea skate and ghost sharks also observed. Fish were observed across all DTIS transects, with bony fishes being the most commonly observed in all transects. Eels were also observed in most of the DTIS transects, although at lower abundances compared to bony fish. Cartilaginous fish (i.e. sharks and rays/skates) were not particularly common throughout the surveyed area but were observed across several transects

DOC aims to update the New Zealand Threat Classification status for all of New Zealand's species over a 5-year cycle for each group; however, the threat status of marine fish has not been updated since the 2005 cycle (Hitchmough *et al.*, 2007), the exception to this are New Zealand chondrichthyans (chimaeras, sharks and rays) (Duffy *et al*., 2018). There were no marine fish identified within the 2005 cycle as threatened (i.e. nationally critical, nationally endangered or nationally vulnerable (Hitchmough *et al*., 2007). All chondrichthyan species potentially present within the Operational Area are classified as either 'Not Threatened' or 'Data Deficient', with the exception of great white sharks ('Nationally Endangered') and basking sharks ('Nationally Vulnerable') (Duffy *et al*., 2018).

Long-finned (*Anguila dieffenbachia*) and short-finned (*A. australis schmidtii*) eels occur in freshwater river systems along the South Island's east coast. When sexually mature, adult eels move from freshwater systems to the marine environment and undertake large migrations north of New Zealand for spawning. Juveniles, known as glass eels, return to freshwater systems following marine migrations. Due to their known presence in lower South Island freshwater systems, and lack of information on their marine distribution during spawning migrations, the presence of long-finned and short-finned eels within the Operational Area cannot be ruled out, although adults will only be present in marine waters during migrations between February and April.

Areas utilised by fish for spawning and pupping (the birth of live young) may be disproportionately important to fish populations; any disruption to spawning or pupping activity may result in a reduction in recruitment (Morrison *et al.*, 2014); i.e. reduced number of juveniles surviving. Spawning activities range from single pairs to small localised groups of spawning fish or even large spawning aggregations. Large aggregations may involve large-scale migrations (i.e. transient aggregations) or short-distance migrations of local fish (i.e. resident aggregations) (Morrison *et al.*, 2014).

Knowledge of spawning and pupping areas of New Zealand's fishes is typically limited; detailed information on spawning activity is only well known for a few commercially important species. Data on the presence of spawning and pupping locations usually relies on reported catch of spent or ripe-running females from research trawls (Hurst *et al.*, 2000b); however, a lack of catch records of fish in spawning condition is not sufficient evidence to conclude that no spawning occurs within an area. Species potentially spawning/pupping in the vicinity of the Operational Area were identified based on the findings of O'Driscoll *et al*. (2003), with black oreo the only species identified as potentially spawning in the vicinity of the Operational Area. Spawning black oreo have been recorded off the southeast coast of the South Island, with fish in spawning condition observed between September and February (O'Driscoll *et al*., 2003).

Table 8 Fish Species Potentially Present Within the Operational Area

Species – Common name		
Arrow squid [1]	Javelinfish [1,2]	Ridge scaled rattail [1,2]
Banded bellowsfish [1,2]	Johnson's cod [1,2]	Robust cardinalfish [2]
Banded rattail [1,2]	Kaiyomaru rattail [1,2]	Rough skate [1]
Basking shark [3]	Lanternfish (*Myctophidae* spp.) [1]	Rudderfish [1,2]

Basketwork eel [1,2]	Leafscale gulper shark [1,2]	Sandfish [2]
Baxter's dogfish [1,2]	Lighthouse fish [1,2]	Scaly dragonfish (*Stomias* spp.) [2]
Bigeye cardinalfish [1,2]	Ling [1,2]	School shark [2]
Black dragonfish (*Idiacanthus* spp.) [1,2]	Long barbel rattail [1]	Sea perch (*Helicolenus* spp.)[1,2]
Black javelinfish [1,2]	Longnose deepsea skate [2]	Seal shark [1,2]
Black oreo [1,2]	Longnose spookfish [1,2]	Serrulate rattail [1,2]
Blackspot rattail [2]	Longnose velvet dogfish [1,2]	Shovelnose dogfish [1,2]
Bluenose [2]	Lookdown dory [1,2]	Silver warehou [1,2]
Blobfish [1,2]	Lucifer dogfish [2]	Silverside [1,2]
Blue shark [1,2]	*Lyconus* spp.[2]	Sleeper ray (*Typhlonarke* spp.)
Blue warehou [1]	Mahia rattail [1,2]	Small banded rattail[2]
Bollons's rattail [1,2]	Mako shark [1,2]	Small-headed cod [1,2]
Brown chimaera [2]	Moonfish [2]	Smallscaled brown slickhead [1,2]
Catshark (*Apristurus* spp.) [1,2]	Murray's rattail [2]	Smooth deepsea skate [1,2]
Codheaded rattail [2]	Notable rattail [1,2]	Smooth oreo [1,2]
Cookie-cutter shark [2]	Oblique banded rattail [2]	Smooth skate [1,2]
Common roughy [1]	Oliver's rattail [1,2]	Southern bluefin tuna [1,2]
Dawson's catshark[2]	Orange roughy [1,2]	Southern blue whiting [1,2]
Dark ghost shark [1]	Owston's dogfish [2]	Southern boarfish [2]
Dark toadfish [1]	Pacific spookfish [1,2]	Spineback [1,2]
Dealfish [2]	Pale ghost shark [1,2]	Spiny dogfish [1,2]
Deepsea flathead [2]	Pale toadfish [1,2]	Swollenhead conger [1, 2]
Electric ray [1]	Plunket's shark [2]	Thresher shark [2]
Finless flounder [1,2]	Pointynose blue ghost shark [2]	Tubeshoulder [2]
Four-rayed rattail [1,2]	Porbeagle shark [1,2]	Violet cod [1,2]
Gemfish [1]	Prickly deepsea skate [1,2]	Violet squid [1]
Giant stargazer [1,2]	Prickly dogfish [1,2]	Viperfish [1,2]
Hairy conger [1,2]	Ragfish [2]	Warty squid [1]
Hake [1,2]	Ray's bream [1,2]	White pointer shark (great white) [2]
Hoki [1,2]	Red cod [1]	White rattail [1,2]
Humpback rattail [2]	Ribaldo [1,2]	White warehou [1]

1 Trawl surveys (Anderson *et al.*, 1998; Bagley *et al.*, 2000; Hurst *et al.*, 2000a, 2000b; O'Driscoll *et al.*, 2003)
2 McMillan *et al.,* 2011a, 2011b, 2011c
3 Francis, 2017

5.2.4.1 Freshwater Eels

Within New Zealand waters there are two main species of freshwater eel: the endemic long-finned eel (*Anguila dieffenbachii*) and the short-finned eel (*A. australis schmidtii*). Under the New Zealand Threat Classification System long-finned eels are classified as 'Declining' and short-finned eels as 'Not Threatened' (Dunn *et al*., 2018). Both species are commercially harvested and managed under New Zealand's Quota Management System (Jellyman, 2012).

Although considered a freshwater species, long- and short-finned eels have a catadromous life history and carry out oceanic spawning at great distances from their typical freshwater habitat (Jellyman, 2012). On account of their breeding migration into marine waters, both species of eel are considered to be seasonally significant components in both inshore and offshore marine waters around New Zealand. Little is known of the marine component of their life cycle; however, three distinct migrations have been observed in New Zealand:

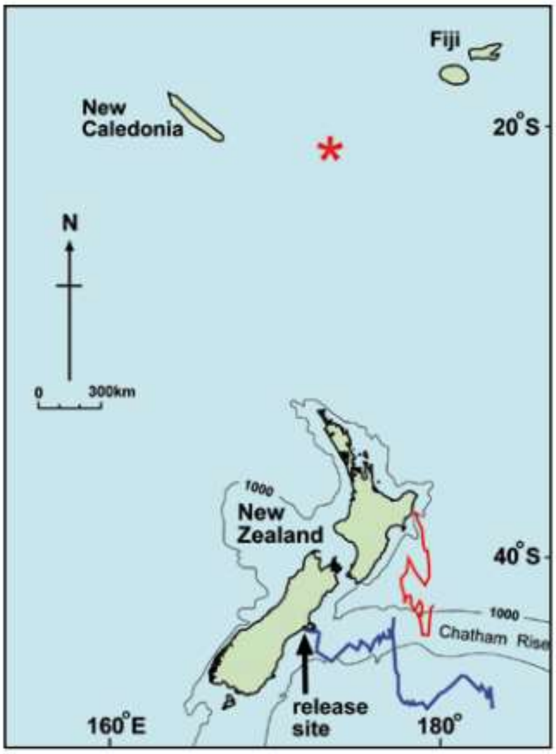
- Elvers (juvenile two-year-old eels) move from the marine environment into freshwater habitats from October to December. These young eels move at night during the dark phases of the moon (Boubée *et al*., 2001), during which time they find suitable cover and feeding grounds in the lower reaches of streams. Here they remain for the next four to five years (Cairns, 1950). Research has shown that these movements can be triggered by high levels of rainfall (Boubée *et al*., 2001);
- Following the influx of the elvers, the four- to five-year-old eels begin an upstream migration. This migration occurs annually in January (Cairns, 1950); and
- The third migration involves the movement of sexually mature adult eels (known to Māori as tuna heke or tuna whakaheke) to spawning grounds. This migration occurs in February and March, with the majority of eels having migrated by April, and follows a distinct pattern. Mature females begin by moving to brackish waters where they join the mature males. First to enter the sea are short-finned males followed by short-finned females. Long-finned eels show a similar pattern whereby the males migrate before the females, with this migration occurring after that of the short-finned eels (Cairns, 1950; Todd, 1981). It has been suggested that the movement of sexually mature adult eels is influenced by the lunar cycle (Todd, 1981). Adult eels move to the sub-tropical Pacific Ocean and although the exact location and migration route for spawning is not definitively known (as eel spawning has never been observed – see below), deep ocean trenches (DOC, 2019) near Fiji and New Caledonia are thought to be important spawning grounds (NIWA, 2019b). Short-finned and long-finned eels are semelparous; that is they breed only once at the end of their life (DOC, 2019), resulting in no southern migration of adults returning to New Zealand.

A fourth, unobserved migration occurs involving the leptocephalus young (transparent leaf-shaped eel larvae). Leptocephalii reach New Zealand waters by drifting on ocean currents. Once reaching New Zealand coastal waters they morph into eel-shaped 'glass eels' and move into river mouths and estuaries (Te Ara, 2019d), where they are generally sedentary during their first year in fresh water (Jellyman, 1977). Following a year spent in river mouths and estuaries the glass eels commence their freshwater life-cycle as elvers (see first point).

There is limited scientific information available regarding specific migration routes of New Zealand's eels. Attempts to track four long-finned eels leaving Te Waihora/Lake Ellesmere using GPS trackers began in May 2000 (Jellyman, 2006); however, these experiments only yielded limited results (**Figure 12**). Three of the tagged eels moved east along the Chatham Rise. The fourth eel's tag did not transmit until three weeks into the tagging experiment. Upon the start of transmission, the fourth eel was located in Hawke's Bay, but made a southerly change in direction and travelled south along the Chatham Rise. The tagged eels moved significant vertical distances in the water column and swam at speeds ranging from 26 to 31 km per day (Jellyman, 2006). A second tracking study of eels tagged in Te Waihora began in May 2001, with ten tagged eels released. Only three tags returned significant information. As with the eels tracked in 2000, those tagged in 2001 carried out regular daily vertical movements within the water column, with two eels frequently swimming to depths of 800 m or more. A tag was retrieved 160 km northeast of New Caledonia, providing the first evidence that spawning grounds for long-finned eels is in the tropics. Although the location of long-finned eel spawning grounds remain unknown (Jellyman, 2006), a general overview of migration pathways is understood and shown in **Figure 13**. Due to the size of the GPS tags, only large female long-finned eels have been able to be tracked (Jellyman, 2006).

Long-finned and short-finned eels both occur in freshwater river systems along the South Island's east coast, with a commercial fishery also occurring along the lower South Island's east coast. Due to their known presence in lower South Island freshwater systems, and the above-mentioned lack of information on marine distribution, the presence of long-finned and short-finned eels within the Operational Area cannot be ruled out; however, given the southern and offshore location of the Operational Area and the lack of any major river systems to the south of the Operation Area, this is unlikely.

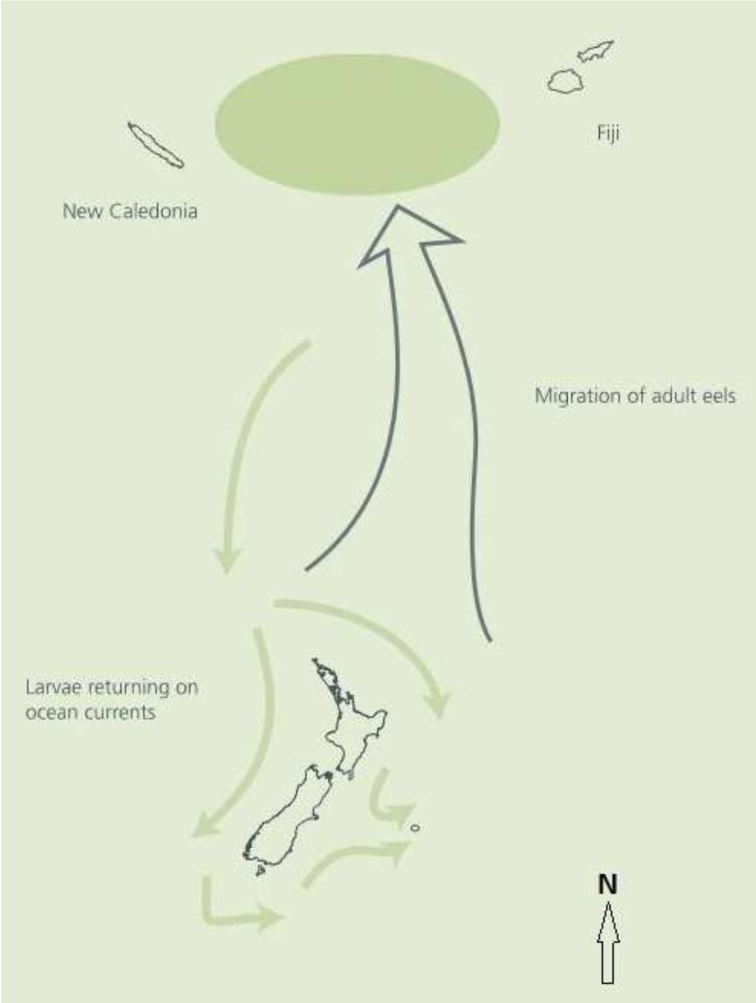
Figure 12 GPS Tracks from Tagged Long-finned Eels



Source: Jellyman, 2006.

Key: The blue and red lines mark the tracks of two eels which were released in May 2000 at Te Waihora, Canterbury (transmission from the eel marked by the red line only commenced 3 weeks after release). The star marks the location of a transmission from an eel in 2001, 161 days after release.

Figure 13 Long-finned Eel Migration Paths



Source: PCE, 2013

5.2.4.2 Protected Species

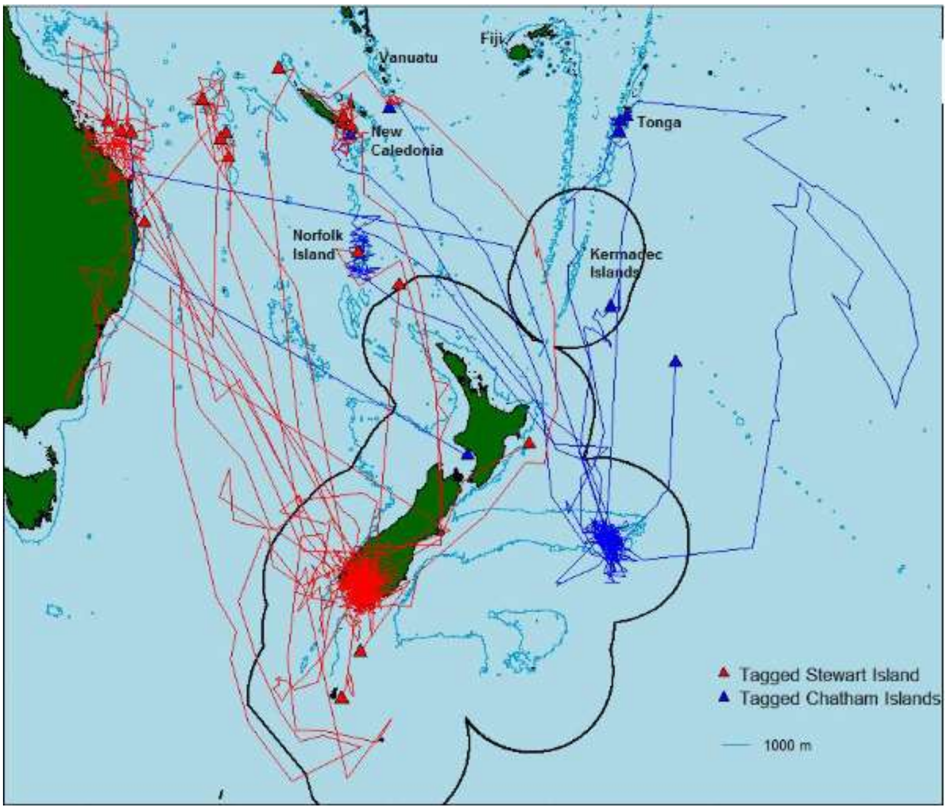
Nine fish species are listed as protected under Schedule 7A of the Wildlife Act 1953; basking shark, deep-water nurse shark, great white shark, manta ray, oceanic white-tip shark, spiny-tailed devil ray, spotted black grouper, giant grouper, and whale shark. In addition to the protection offered under the Wildlife Act 1953, great white sharks, basking sharks and oceanic white-tip sharks are also protected under the Fisheries Act 1996. Of these protected species, great white sharks and basking sharks have the greatest potential to occur in the Operational Area.

White sharks are classified under the New Zealand Threat Classification System as 'Nationally Endangered' (Duffy *et al*., 2018). They occur widely in New Zealand waters, from the subtropical Kermadec Islands to the subantarctic Campbell Island (Francis *et al.,* 2015). Little is known of the habitat use of white sharks in New Zealand waters; however, juveniles and adults are known to occur in shallow coastal waters where they feed largely on fish (DOC, 2019a). Sub-adults and adults also utilise waters of the open ocean and around offshore islands and banks, and once they reach approximately 3 m in length, they begin to also feed on marine mammals (DOC, 2019a). Subadult and adult white sharks tend to aggregate near seal colonies; major aggregation sites are known only in southern New Zealand and the Chatham Islands and these coincide with major New Zealand fur seal breeding rookeries and bachelor 'haulout' areas (Francis *et al.,* 2015).

Results from NIWA and DOC's 10-year shark tagging and tracking project showed that white shark migrations occur from March to September, with individuals moving from aggregation sites at Stewart Island and the Chatham Islands to the tropical and sub-tropical Pacific where they spent at least 5 – 7 months before returning, usually to their original tagging location (Duffy *et al.*, 2012) (**Figure 14**). During northern journeys, New Zealand white sharks travelled up to 150 km per day, averaging about 100 km per day. The sharks spent two-thirds of their time at the surface, and the other third making repeated deep dives 200 – 800 m; the deepest dive was recorded at 1,246 m (NIWA, 2019c).

The tracking data showed that the sharks travelled in a remarkably straight line. Individuals from the Stewart Island population generally headed northwest of New Zealand, whereas the Chatham Islands sharks generally headed north (**Figure 14**). There has been no documented direct movement of white sharks between the Chatham Islands and the east coast of the South Island (Duffy *et al*., 2012; Francis *et al*., 2015). Tagging tracks suggest that most white sharks departing from Stewart Island head rapidly into the open ocean rather than swimming northward along the mainland coasts. Outside of migration periods, tagging has shown that white sharks remain over the continental shelf and rarely swim deeper than 100 m (Bonfil *et al.*, 2010). Data from the tagging project showed that white sharks spent 95.6% of their time in water shallower than 50 m and, when near aggregation sites, rarely ventured deeper than 100 m (Francis *et al*., 2012). The water depth in the Operational Area (1,200 – 1,300 m) is well beyond the preferred depth of white sharks.

Figure 14 South-west Pacific Ocean showing Tracks of White Sharks Tagged at Stewart Island and Chatham Islands with Pop-up Tags



Source: https://www.niwa.co.nz/coasts-and-oceans/research-projects/white-sharks

Note: tracks over land are due to the time between the shark surfacing and receiving GPS satellite reception, where it has subsequently moved significant distances, and sometimes around areas of the coast, as such, the tracks appear to be over land, but it is just the most direct line between the two locations received by the satellites.

NIWA/DOC deployed electronic 'pinger' tags on white sharks at north-eastern Stewart Island, around the Titi Islands, as this location was where major New Zealand fur seal breeding colonies occur and attract seasonal aggregations of white sharks. Loggers were deployed around northern Stewart Island, Ruapuke Island and Foveaux Strait and the results showed that white sharks occurred almost continuously from late summer to early winter, with abundances peaking in autumn (March − June) (Francis *et al*., 2015). They spent around 4 − 5 months in the region and the rest of the year outside New Zealand on their tropical migrations. The abundance of white sharks was greatest in the Titi Islands although sharks displayed preferences for different islands (Francis *et al*., 2015).

Basking sharks in New Zealand waters are typically caught as by-catch near or beyond the edge of the continental shelf (Francis & Duffy, 2002). They often inhabit water depths greater than 600 m, where they may remain for months (Francis, 2017). There are three core 'fishery regions' that account for most basking shark by-catch incidents: the east coast South Island around Banks Peninsula, west coast South Island from approximately Anatori south to Hokitika, and Southland – the Auckland Islands, suggesting a predominantly southern distribution in New Zealand waters (Francis, 2017). By-catch rates of basking sharks off the South Island were greatest in water depths 200 – 400 m, with moderate catch rates also occurring in trawls over water depths of 800 m (Francis, 2017). Sightings of groups of live basking sharks within a few kilometres of the coastline during spring and summer suggest an increase in inshore abundance during warmer months (Francis & Duffy, 2002); however, the use of coastal waters represents only part of the habitat requirements of basking sharks (Francis, 2017). A lack of genetic separation between basking sharks at the scale of ocean basins suggests that this species carries out large-scale movements within ocean basins, and possibly between basins (Francis, 2017). Basking sharks are considered 'Nationally Vulnerable' under the New Zealand Threat Classification System (Duffy *et al*., 2018).

5.2.5 Cephalopods

Octopuses mainly live on the seafloor and are one of the top reef predators, feeding on crustaceans, shellfish and small fish (Te Ara, 2019e). Cephalopods are a favourite prey to a number of species including pilot whales which feed mainly on arrow squid and common octopus (Beatson *et al.*, 2007).

Various squids and octopuses were observed in DTIS imagery collected during the Tāwhaki-1 Pre-drill Survey. Cephalopods were observed across the majority of the DTIS transects; octopuses were the most commonly observed although squid were also observed across some transects. Observed cephalopods included Dumbo octopus (*Grimpoteuthis* sp.) and squid.

The New Zealand squid fishery appears amongst the top five fisheries in New Zealand and focusses on targeting the two species of arrow squid; Gould's arrow squid (*Nototodarus gouldi*) and Sloan's arrow squid (*N. sloanii*) (FNZ, 2019b). Waters directly within the Operational Area are not important areas for the New Zealand squid fishery which is largely targeted by deepwater trawlers in the southern and sub-Antarctic fishing grounds (Deepwater Group, 2019), located to the south and southeast of the Operational Area. Within that area *N. sloanii* is the primary species (Smith *et al.*, 1987) and given their presence is in high numbers in these fishing grounds it is possible for smaller numbers of these squid to be present within the Operational Area.

5.2.6 Marine Reptiles

While up to eight species of marine reptiles have been found to exist in New Zealand's waters they tend to be characteristically found in the warmer, temperate waters along New Zealand's northern and north-eastern coastlines, typically in the summer months (DOC, 2019b, 2019c). As such, it would be unlikely that any of these marine reptile species will be present within the Operational Area.

However, in 2019 a leatherback turtle was found beached in Akaroa, Canterbury (Chumko, 2019), to the north of the Operational Area. Leatherback turtles have also been encountered as far south as Fiordland on the West Coast of the South Island, where they would likely have followed the remnants of the warmer currents which flow eastward across the Tasman Sea and then split to head south down the West Coast. Along the southeast coast of the South Island the last of this warmer current is pushed close to the coast by colder currents from the South (e.g. Southland Current) and the Operational Area is well out into these colder currents making it less preferable habitat for marine reptiles. So, while remotely possible, it would be very rare to encounter marine reptiles such as Leatherback turtles in the Operational Area and any such sighting would be a first in this area.

5.2.7 Cetaceans

Both toothed whales (suborder Odontoceti) and baleen whales (suborder Mysticeti) are well represented in New Zealand waters (Baker *et al*., 2019). The majority of baleen whales are oceanic and undertake large seasonal migrations between high latitude summer feeding grounds and winter mating and calving areas in warmer, low latitude waters (DOC, 2007). Toothed whales do not carry out large migrations; instead most species tend to remain resident to an area (Berkenbusch *et al*., 2013). The sections below summarise those cetacean species which could be present within the Operational Area.

5.2.7.1 Cetacean Species that Could be Present

As ecological research on cetaceans is notoriously difficult (largely due to their large home ranges and extended periods of time spent submerged), knowledge of cetacean distribution is typically amassed over long temporal periods using a combination of data collection techniques (e.g. stranding data, opportunistic sightings, systematic survey data and published literature). For this reason, it is important to assess multiple data sources when considering cetacean distribution in any one location. This approach has been used to predict which cetacean species may be present within the Operational Area. Data sources for this assessment included:

- Sightings data from within the Marine Mammal Area of Interest (**AOI**):
  - From previous seismic surveys (obtained from the DOC marine mammals sightings database representing sightings from 1969 – May 2019);
  - From opportunistic sightings (obtained from the DOC marine mammals sightings database);
- Stranding data from the coastline in proximity to the Marine Mammal AOI (Oamaru to Waipapa Point) (obtained from the DOC marine mammals stranding database representing strandings from 1862 – June 2019); and
- Knowledge of migration paths and habitat preferences of each species which overlap with or are in close proximity to the Marine Mammal AOI (obtained from published literature).

However, despite these data sources representing the best possible information, it is important to exercise some caution when interpreting these results as:

1. Gaps in sighting data do no necessarily indicate an absence of cetaceans, but typically reflect a lack of observation effort;
2. Although stranding data gives a broad indication of species occurrence, dead animals can wash ashore well away from where they died due to ocean currents and weather patterns; and that prior to death, sick or diseased animals may be outside their normal distributional range;
3. Each point depicted in **Figure 15** and **Figure 16** represents a sighting entry within the DOC database. Each entry can be either an individual sighting, or a group of any number of marine mammals (e.g. a pod of dolphins). Therefore, each point does not represent the actual number of marine mammals; instead the figures provide an indication of the distribution of marine mammals; and
4. A large number of sightings were recorded in the database without identification to species level. For example, many were recorded simply as ‘unidentified baleen’. These records were not included in the analysis for this MMIA.

Previous assessments of marine mammal distribution within the GSB note that the area is used by many marine mammal species with extensive home ranges. For this reason it was considered that basing the marine mammal analysis on the small Operational Area (as shown in **Figure 1**) alone would be inappropriate as it would most certainly lead to an under-estimate of the species that could potentially be present at the well locations. On this basis a much more extensive 'Marine Mammal AOI' was used to describe marine mammal species potentially affected by the GSB Checkshot Survey as shown in **Figure 15**. This approach ensures that all species that may occasionally be present at these locations also be identified and their possible presence in the vicinity of the GSB Checkshot Survey can be assessed in context of their wider habitat use. This large AOI is based on the area used within the Marine Consent and Marine Discharge Consent application for the GSB EAD Programme to determine marine mammal presence.

Figure 15 provides a summary of all sightings (including all dolphins and whales) from the DOC Marine Mammal Sightings Database in the vicinity of the Marine Mammal AOI, while **Figure 16** provides a summary of the DOC stranding records along the coastline inshore of the Marine Mammal AOI. Stranding events were considered relevant to the Marine Mammal AOI if they occurred along the coastline from Oamaru to Waipapa Point. Sighting records were considered if they occurred in the Marine Mammal AOI or within the surrounding waters as represented by a 15 NM buffer around the Marine Mammal AOI.

The number of sightings or stranding events for each species is provided in **Table 10**. The criteria used to assess the likelihood of a species being present in the Operational Area are presented in **Table 9**.

Table 9 Criteria Used to Assess the Likelihood of Cetacean Species Being Present in the Operational Area

Likely	Species that are represented in the DOC sightings and/or stranding record from the Marine Mammal AOI and which are not classified as 'Vagrant' in the New Zealand Threat Classification System (Baker *et al.*, 2019) and for which a reasonable number of sightings or strandings are reported for the AOI.
Occasional Visitor	Species that are represented in the DOC sightings and/or stranding record from the Marine Mammal AOI but are listed as 'Migrant' in the New Zealand Threat Classification System (Baker *et al.*, 2019) or for which few sightings or strandings are reported for the AOI. Note that this criterion does not preclude some 'Migrant' species from being assessed as being 'likely' to occur in the Operational Areas.
Rare Visitor	Species that are present in the DOC sightings and/or stranding record from the Marine Mammal AOI, or reportedly occur in the Marine Mammal AOI, or whose known range is directly adjacent to the Marine Mammal AOI but are listed as 'Vagrant' in the New Zealand Threat Classification System (Baker *et al.*, 2019).
Unlikely	Those species not represented in the DOC sightings and/or stranding record from the Marine Mammal AOI.

Note: Where only very small numbers of sightings or stranding's present in the DOC Stranding's and Sighting Databases, likelihood determination has been adjusted to take any additional information into consideration.

Figure 15 Cetacean Sightings in the Vicinity of the Operational Area

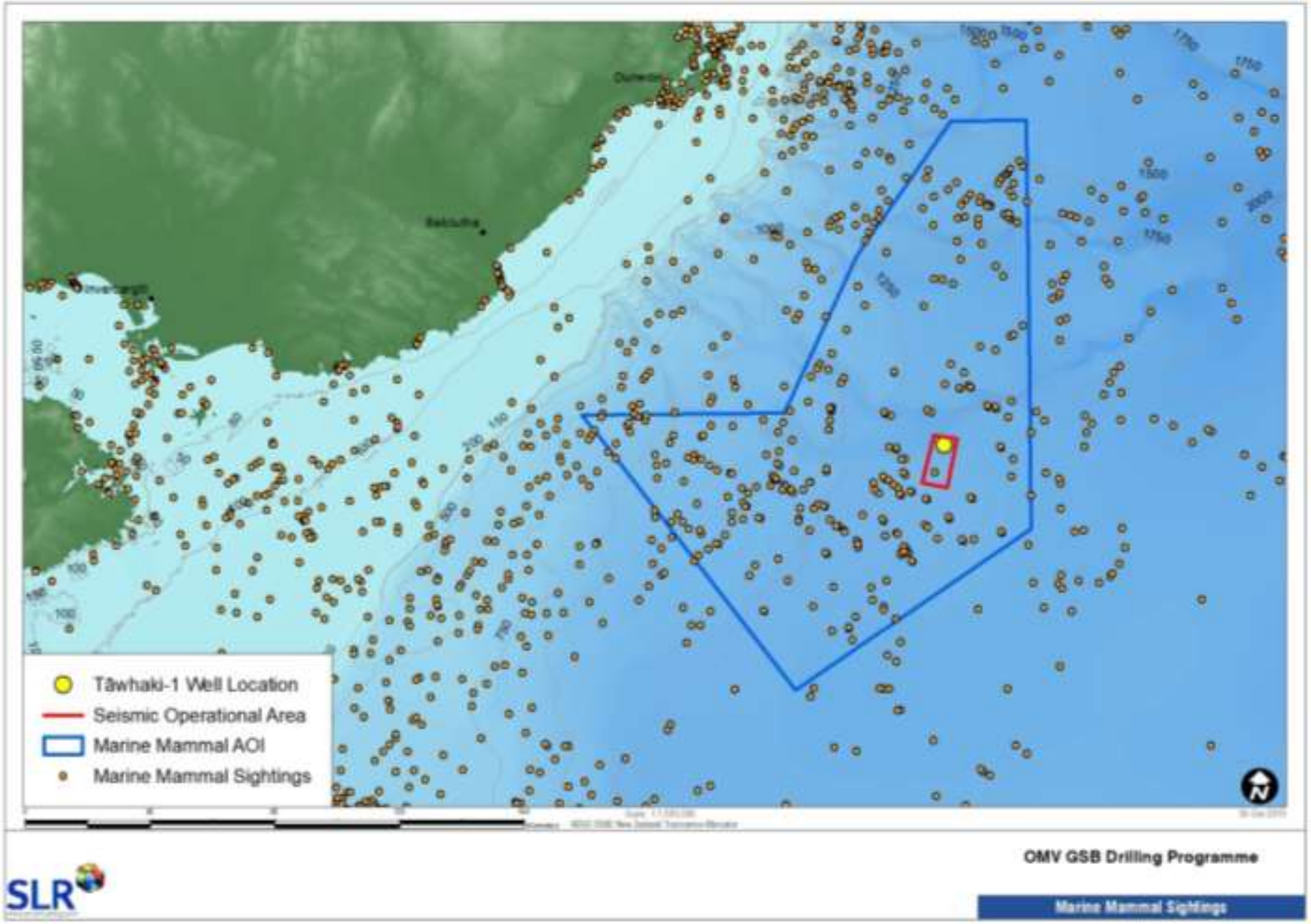


Figure 16 Cetacean Stranding Events Inshore of the Operational Area

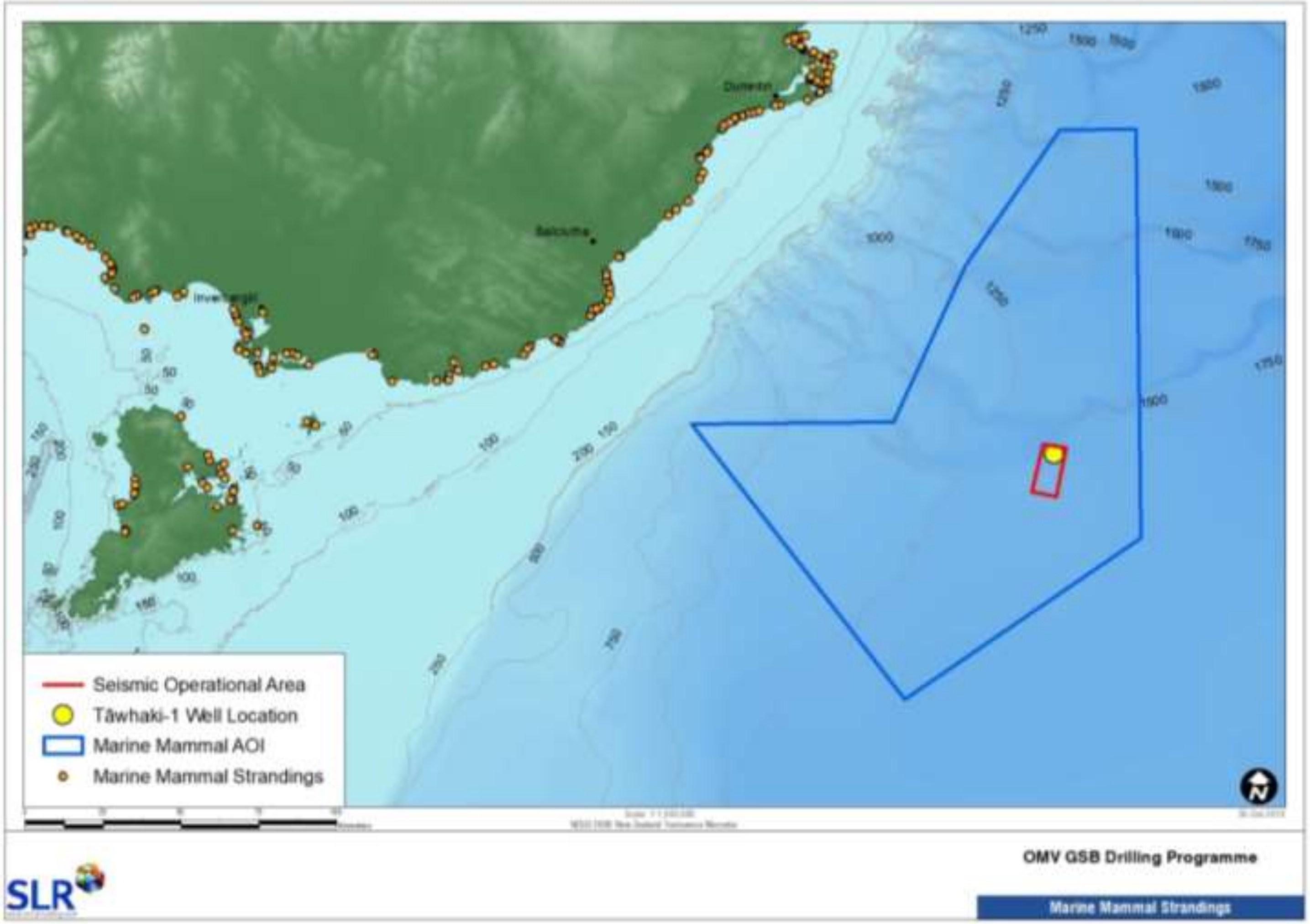


Table 10 Likelihood of Occurrence of Marine Mammals in the Operational Area

Common Name	Scientific Name	New Zealand Conservation Status (Baker *et al.*, 2019)	Qualifier [1]	International Union for Conservation of Nature (IUCN) Conservation Status www.redlist.org	DOC Stranding database (No. of events near Marine Mammal AOI[2])	DOC Sightings database (No. of reports within Marine Mammal AOI)	DOC Sightings database (No. of reports in surrounding waters [2])	Likely presence in the Operational Area
Andrew's beaked whale	*Mesoplodon bowdoini*	Data deficient	S?O	Data deficient	✓ (2)	×	×	**Occasional Visitor**
Antarctic blue whale	*Balaenoptera musculus intermedia*	Data deficient	TO	Endangered	×	×[4]	×[4]	**Occasional Visitor**
Antarctic fur seal	*Arctocephalus gazella*	Vagrant	SO	Least Concern	×	×	×	Unlikely
Antarctic minke whale	*Balaenoptera bonaerensis*	Data deficient	DP, SO	Near threatened	✓ (3)	×	✓ (1)[5]	**Occasional Visitor**
Arnoux's beaked whale	*Berardius arnuxii*	Data deficient	S?O	Data deficient	✓ (1)	×	×	**Occasional Visitor**
Blainville's/Dense beaked whale	*Mesoplodon densirostris*	Data deficient	S?O	Data deficient	×	×	×	Unlikely
Bottlenose dolphin	*Tursiops truncatus*	Nationally endangered	De, PF, SO, Sp	Least concern	✓ (14)	✓ (1)	×	**Likely**
Bryde's whale	*Balaenoptera edeni*	Nationally critical	CD, DP, SO	Least concern	×	×	✓ (2)	Unlikely[3 6]
Common dolphin	*Delphinus delphis*	Not threatened	DP,SO	Least concern	×	×	✓ (1)	**Occasional Visitor**
Crab eater seal	*Lobodon carcinophaga*	Vagrant	SO	Least concern	×	×	×	Unlikely
Cuvier's beaked whale	*Ziphius cavirostris*	Data deficient	SO	Least concern	✓ (6)	×	×	**Likely**
Dusky dolphin	*Lagenorhynchus obscurus*	Not threatened	S?O	Data deficient	✓ (22)	✓ (2)	✓ (2)	**Likely**
Dwarf minke whale	*Balaenoptera acutorostrata*	Data deficient	DP, SO	Least concern	✓ (4)	×	× [5]	**Occasional Visitor**
Dwarf sperm whale	*Kogia sima*	Data deficient	S?O	Data deficient	×	×	×	Unlikely
False killer whale	*Pseudorca crassidens*	Naturally uncommon	DP, T?O	Data deficient	✓ (2)	×	✓ (1)	**Likely**
Fin whale	*Balaenoptera physalus*	Data deficient	TO	Endangered	✓ (2)	✓ (1)	×	**Occasional Visitor**
Fraser’s dolphin	*Lagenodelphis hosei*	Data deficient	SO	Least concern	×	×	×	Unlikely
Gingko-toothed whale	*Mesoplodon ginkgodens*	Data deficient	S?O	Data deficient	×	×	×	Unlikely
Gray's beaked whale	*Mesoplodon grayi*	Not threatened	S?O	Data deficient	✓ (13)	×	×	**Likely**
Hector's beaked whale	*Mesoplodon hectori*	Data deficient	S?O	Data deficient	✓ (1)	×	×	**Occasional Visitor**
Hector's dolphin	*Cephalorhynchus hectori hectori*	Nationally vulnerable	CD, DP, PF	Endangered	✓ (25)	×	×	**Occasional Visitor[3]**
Hourglass dolphin	*Lagenorhynchus cruciger*	Data deficient	SO	Least concern	×	×	×	Unlikely
Humpback whale	*Megaptera novaeangliae*	Migrant	SO	Least concern	✓ (1)	×	✓ (1)	**Occasional Visitor**
Killer whale	*Orcinus orca*	Nationally critical	DP, S?O	Data deficient	✓ (4)	×	×	**Likely**
Leopard seal	*Hydrurga leptonyx*	Naturally Uncommon	De, SO	Least concern	✓ (2)	×	×	**Likely**
Lesser/pygmy beaked whale	*Mesoplodon peruvianus*	Data deficient	S?O	Data deficient	×	×	×	Unlikely
Long-finned pilot whale	*Globicephala melas*	Not threatened	DP, S?O	Data deficient	✓ (18)	✓ (31)	✓ (14)	**Likely**
Maui’s dolphin	*Cephalorhynchus hectori maui*	Nationally critical	CD	Not assessed	×	×	×	Unlikely
Melon-headed whale	*Peponocephala electra*	Vagrant	SO	Least concern	×	×	×	Unlikely
New Zealand sea lion	*Phocarctos hookeri*	Nationally Vulnerable	CD, RR	Endangered	✓ (16)	×	×	**Likely**
New Zealand fur seal	*Arctocephalus forsteri*	Not threatened	Inc, SO	Least Concern	✓ (2)	✓ (55)	✓ (120)	**Likely**
Pantropical spotted dolphin	*Stenella attenuata*	Vagrant	SO	Least concern	×	×	×	Unlikely
Pygmy blue whale	*Balaenoptera musculus brevicauda*	Data deficient	S?O	Not assessed	×	✓ (5) [4]	✓ (2)[4]	**Occasional Visitor[3]**
Pygmy killer whale	*Feresa attenuata*	Vagrant	DP, S?O	Data deficient	×	×	×	Unlikely
Pygmy right whale	*Caperea marginata*	Data deficient	S?O	Data deficient	×	×	×	Unlikely
Pygmy sperm whale	*Kogia breviceps*	Data deficient	DP, S?O	Data deficient	✓ (5)	×	×	**Likely**
Risso's dolphin	*Grampus griseus*	Data deficient	SO	Least concern	×	×	×	Unlikely
Ross seal	*Ommatophoca rossi*	Vagrant	SO	Least concern	×	×	×	Unlikely
Rough-toothed dolphin	*Steno bredanensis*	Data deficient	SO	Least concern	×	×	×	Unlikely
Sei whale	*Balaenoptera borealis*	Data deficient	TO	Endangered	×	×	✓ (2)	**Occasional Visitor**

Common Name	Scientific Name	New Zealand Conservation Status (Baker *et al.*, 2019)	Qualifier [1]	International Union for Conservation of Nature (IUCN) Conservation Status www.redlist.org	DOC Stranding database (No. of events near Marine Mammal AOI[2])	DOC Sightings database (No. of reports within Marine Mammal AOI)	DOC Sightings database (No. of reports in surrounding waters [2,])	Likely presence in the Operational Area
Shepherd's beaked whale	*Tasmacetus shepherdi*	Data deficient	SO	Data deficient	✓ (2)	×	×	**Likely**
Short-finned pilot whale	*Globicephala macrorhynchus*	Data deficient	S?O	Data deficient	✓ (1)	×	×	**Occasional Visitor**
Southern bottlenose whale	*Hyperoodon planifrons*	Data deficient	SO	Least concern	×	×	✓ (1)	**Occasional Visitor**
Southern elephant seal	*Mirounga leonina*	Nationally critical	RR, SO	Least concern	×	✓ (1)	×	**Likely**
Southern right whale	*Eubalaena australis*	Recovering	OL, RR, SO	Least concern	×	×	✓ (8)	**Likely[3]**
Southern right whale dolphin	*Lissodelphis peronii*	Data deficient	DP,S?O	Data deficient	✓ (1)	✓ (4)	✓ (1)	**Likely**
Spade-toothed whale	*Mesoplodon traversii*	Data deficient	S?O	Data deficient	×	×	×	Unlikely
Spectacled porpoise	*Phocoena dioptrica*	Data deficient	S?O	Data deficient	✓ (1)	×	✓ (2)	**Occasional Visitor**
Sperm whale	*Physeter macrocephalus*	Data deficient	DP, TO	Vulnerable	✓ (8)	✓ (9)	✓ (5)	**Likely[3]**
Strap-toothed whale	*Mesoplodon layardii*	Data deficient	S?O	Data deficient	✓ (14)	×	×	**Likely[3]**
Striped dolphin	*Stenella coeruleoalba*	Data deficient	SO	Least concern	×	×	×	Unlikely
Subantarctic fur seal	*Arctocephalus tropicalis*	Vagrant	SO	Least concern	×	×	×	Unlikely
True's beaked whale	*Mesoplodon mirus*	Data deficient	S?O	Data deficient	×	×	×	Unlikely
Weddell seal	*Leptonychotes weddelli*	Vagrant	SO	Least concern	×	×	×	Unlikely

1 Qualifiers to the New Zealand Threat Classification System are as follows: Secure Overseas (SO), Uncertain whether the taxon is secure overseas (S?O), Threatened Overseas (TO), Data Poor (DP), Conservation Dependent (CD), Sparse (Sp), Range Restricted (RR), Increasing (Inc), One Location (OL), Designated (De), Population Fragmentation (PF)

2 Stranding data from the Otago and Southland regions, specifically from Oamaru to Waipapa Point. Sighting data included this coastline, and all waters out to, and surrounding the Operational Area.

3 Likelihood determination has been adjusted to take into consideration the relatively high number of stranding events for this species, or other distributional knowledge

4 The number of sightings of blue whales is difficult to interpret as the DOC Sighting Database records most sightings as *Balaenoptera musculus* (i.e. without subspecies identification). Based on the recent findings of Torres *et al*. (2013), it is likely that the majority of sightings are of *Balaenoptera musculus brevicauda* (pygmy blue whales).

5 The number of sightings of minke whales is difficult to interpret as the DOC Sightings Database records a number of sightings as *Balaenoptera acutorostrata* (i.e. do not differentiate between Antarctic and dwarf minke). These sightings have been interpreted and recorded in the table above as Antarctic minke whales, although both species have been discussed below.

6 Bryde's whales are mainly found in the waters of the North Island, and the latitudinal range extends from 40°N to 40°S (Reikkola, 2013).

5.2.7.2 Baleen Whales (suborder Mysticeti)

5.2.7.2.1 Southern right whale (*Eubalaena australis*)

Southern right whales exhibit a seasonal distribution, spending summer months feeding in latitudes between 40 and 50 °S (Oshumi & Kasamatsu, 1986) before moving north in late autumn to coastal breeding grounds (Braham & Rice, 1984). This species feeds on dense euphausiid (krill) and copepod aggregations (Tormosov *et al.*, 1998; Rowantree *et al*., 2008) in the upper 100 m of the water column (Braham & Rice, 1984).

Southern right whales originally occupied bays and inlets around mainland New Zealand during their winter breeding season (Bannister, 1986; Dawbin, 1986); however, commercial whaling reduced numbers around New Zealand to near extinction. No southern right whales were seen around mainland New Zealand between 1928 and 1963 following the cessation of commercial operations (Gaskin, 1963). Capture-recapture data (photo-identification and genetics) now suggests that the New Zealand population is recovering (Carroll *et al*., 2015) and although Port Ross in the subantarctic Auckland Islands supports the densest New Zealand breeding aggregation (Rayment *et al*., 2012), recent evidence suggests a gradual recolonisation of breeding range around mainland New Zealand (Patenaude, 2003; Carroll *et al*., 2014; Carroll et al., 2015).

Southern right whales produce low-frequency social sounds including stereotyped upcalls used as contact calls and other tonal sounds for mate attraction (Parks & Tyack, 2005). Such vocalisations range in frequency from 50 – 600 Hz (Parks *et al*., 2007; 2011) at sound levels from 172 – 187 dB re 1 µPa @1 m (as referenced in Erbe, 2002).

While no strandings of this species are reported inshore of the Operational Area, five sightings have occurred inside the Marine Mammal AOI and 59 sightings have occurred in the surrounding waters. Sightings of this species are relatively common inshore of the Marine Mammal AOI during winter months. Based on this, it is ***likely*** that southern right whales will be present in the Operational Area.

5.2.7.2.2 Minke whales (*Balaenoptera acutorostrata* and *B. bonaerensis*)

Antarctic minke whales (*B. bonaerensis*) and dwarf minke whales (*B. acutorostrata*) both occur in New Zealand waters. The distribution of the Antarctic minke is restricted to the southern hemisphere where it is very abundant in Antarctic waters in summer. This species is seen at lower latitudes in other seasons, although outside of the summer months their distribution is less well-known (Reilly *et al*., 2008). Dwarf minke occur over most latitudes in both hemispheres. In the southern hemisphere, they too feed in Antarctic waters in summer, with a broader latitudinal distribution in other seasons (Reilly *et al*., 2008).

The DOC sighting and stranding data indicates that the distribution of minke whales extends around mainland New Zealand and throughout New Zealand's sub-Antarctic waters. There were 60 reported sightings of minke whales (both species) in New Zealand's EEZ between 1970 and 2013, the majority of which were in spring (38%). This timing aligns well with the southern migration towards Antarctic feeding grounds (Berkenbusch *et al.*, 2013). Minke whales feed on planktonic crustaceans and small schooling fish (e.g. anchovy and herring); with fish comprising a higher proportion of their diet compared to other baleen whales.

Recordings of a population of dwarf minke whales off Australia's Great Barrier Reef revealed complex vocalisations that span a wide frequency range (50 Hz – 9.4 kHz) and are composed of distinct repeated units. Broadband source levels for the recorded vocalisations were calculated to be 150 – 165 dB re 1 µPa @ 1 m (Gedamke *et al*., 2001).

Three Antarctic minke whales and four dwarf minke whales have stranded on the coastline inshore of the Operational Area. While no minke whale sightings have been reported inside the Marine Mammal AOI, two sightings have occurred in the surrounding waters. Based on the stranding data and the low level of sightings nearby. minke whales may be **occasional visitors** to the Operational Area.

5.2.7.2.3 Sei whale (*Balaenoptera borealis*)

Sei whales tend to prefer warmer waters (8 - 18 °C) than other baleen whales (Mizroch *et al*., 1984; Horwood, 2009). Sei whales from the South Pacific migrate to sub-Antarctic feeding grounds during late summer, spending the remainder of the year in sub-tropical waters (Miyashita *et al*., 1995). They usually occur in deep offshore waters beyond the continental slope (Horwood, 2009) where they surface feed on krill, copepods, and small fish (Baker, 1999).

Sei whale vocalisations have been recorded as low-frequency down-sweep calls that sweep from 82 to 34 Hz over 1.4 seconds, most often produced as a single call but occasionally as pairs or triplicates (Baumgartner *et al*., 2008). McDonald (2006) also recorded broadband sounds described as 'growls' or 'wooshes'. The maximum source level of tonal calls recorded by McDonald (2006) was 156 ± 3.6 dB re 1 µPa @ 1 m.

While no strandings of this species are reported inshore of the Operational Area, and no sightings have been reported from inside the Marine Mammal AOI, seven sightings have occurred in the surrounding waters. Based on the low level of sightings in surrounding waters, sei whales are considered to be ***occasional visitors*** to the Operational Area. Berkenbusch *et al.* (2013) indicates that sightings of this species around New Zealand may be more common during summer and autumn months.

5.2.7.2.4 Fin whale (*Balaenoptera physalus)*

Fin whales migrate to high latitudes (between 50–65°S) to feed in summer (Miyashita *et al.,* 1995), and return to warmer waters at lower latitudes in winter to breed. They are not commonly observed in New Zealand coastal waters (Dawson, 1985). Their diet is variable but is dominated by krill in the southern hemisphere (Miyashita *et al*., 1995; Shirihai & Jarrett, 2006).

Fin whale communication vocalisations have been described as short (<1 second) down-swept tones, between 28 and 15 Hz at source levels of 189 ± 4 dB re 1 µPa @1 m (Širović *et al*., 2007).

Two fin whale strandings have been reported from the coastline inshore of the Operational Area, and one sighting has been reported inside the Marine Mammal AOI. In addition, four sightings of this species have occurred in the surrounding waters. Based on the stranding data and the low levels of sightings, it is considered that fin whales will be ***occasional visitors*** to the Operational Area.

5.2.7.2.5 Blue whales (*Balaenoptera musculus*)

There are two subspecies of blue whale known within New Zealand waters: pygmy blue whale (*B. musculus brevicauda*) and Antarctic blue whale (*B. musculus intermedia*). These two subspecies are difficult to distinguish, hence stranding and sighting data has not consistently differentiated between the two. Blue whales are present around most of New Zealand including the east coast of the South Island (Berkenbusch *et al.,* 2013). Most sightings in the vicinity of the Operational Area have occurred in summer; however, blue whales have been sighted in New Zealand waters in all seasons (Berkenbusch *et al.,* 2013).

Krill make up the majority of the diet of blue whales which they capture via lunge feeding at the surface or to depths of 100 m. Feeding bouts typically last 10 – 20 minutes, although blue whales are capable of carrying out dives to depths of up to 500 m that last for as long as 50 minutes (Todd, 2014). Large aggregations of prey are particularly important to the maintenance and distribution of these whales (DOC, 2007).

Blue whales vocalise at a low frequency (average of 0.01 – 0.110 kHz) (McDonald *et al.*, 2001; Miller *et al.*, 2014), meaning that their calls travel hundreds of kilometres underwater. Vocalisations of pygmy blue whales have been characterised as songs of either two or three repeating tonal sounds with harmonics (Gavrilov *et al.,* 2011). The most intense tonal sounds were recorded to have a source level of 179 ±2 dB re 1 µPa @ 1 m. Weaker short-duration calls of impulsive down-swept sounds were estimated to have source levels of 168 – 179 dB re 1 µPa @ 1 m (Gavrilov *et al.,* 2011).

While no strandings of blue whales are reported inshore of the Operational Area, five sightings have occurred inside the Marine Mammal AOI and two sightings have occurred in the surrounding waters. Based on the low level of sightings, blue whales are considered to be ***occasional visitors*** to the Operational Area.

5.2.7.2.6 Humpback whale (*Megaptera novaeangliae*)

Humpback whales are distributed throughout the North Atlantic, North Pacific, and Southern Hemisphere (Gibbs & Childerhouse, 2000) and undertake the longest migration of any mammal (Jackson *et al.*, 2014), feeding in the circumpolar waters of the Antarctic in summer and migrating to breeding grounds in sub-tropical or tropical waters in winter (Dawbin, 1956). Migrating whales typically use continental shelf waters (Jefferson *et al* 2008) and can approach closely to shore when passing headlands or moving through confined waters (e.g. Gibbs *et al*., 2017).

Humpback whale migration routes along New Zealand's coast were first described by Dawbin (1956) and later by Gibbs and Childerhouse (2000). When migrating north the majority of whales move up the South Island's east coast towards Cook Strait. Here, the migration route splits with most whales passing through Cook Strait and up the North Island's west coast, with some individuals continuing north along the North Island's east coast (Gibbs & Childerhouse, 2000). The northward migration occurs from late May to early August (Dawbin, 1956). While the breeding grounds of the whales migrating past New Zealand have not been clearly identified, a number of studies have linked New Zealand humpbacks to breeding grounds in New Caledonia, Fiji and Tonga (Gibbs *et al*., 2017).

Southern migrating humpbacks pass along the west coast of the North and South Islands where they aggregate near the southwest corner of the South Island before moving further south. A small number of southern migrating whales pass the east coast of the North Island to East Cape where they depart offshore (Gibbs & Childerhouse, 2000). Recent satellite tagging of southern-migrating whales has revealed that those that travel along the east of New Zealand typically congregate at the Kermadec Islands before proceeding south to two recently discovered Southern Ocean feeding areas (Riekkola *et al*., 2019). Southern migrations occur from mid-September to early December (Dawbin, 1956).

Both male and female humpbacks produce communication calls, but only males emit the long, loud, and complex 'songs' associated with breeding activities. Dunlop *et al*. (2007) recorded social vocalisations of migrating east Australian humpbacks and recorded frequencies ranging from <30 Hz to 2.5 kHz over 34 different vocalisation types. The source level of singing humpbacks ranges from 123 – 183 dB re 1 µPa @ 1 m (Dunlop *et al.,* 2013). Surface-generated social sounds (e.g. breaches, pectoral slaps, and tail slaps) are also generated by humpback whales and are thought to have a communicative function (Dunlop *et al.,* 2010). Surface-generated sounds have been reported to be in the range of 133 – 171 dB re 1 µPa @1 m (Dunlop *et al.,* 2013).

One humpback whale stranding has been reported from the coastline inshore of the Operational Area. While no sightings have been reported inside the Marine Mammal AOI, 48 have occurred in the surrounding waters. Based on the stranding data and the moderate levels of sightings nearby, it is ***possible*** that humpback whales will be occasional visitors within the Operational Area, particularly during northern migrations (late May – early August).

5.2.7.3 Toothed Whales (suborder Odontoceti)

5.2.7.3.1 Sperm whale (*Physeter macrocephalus*)

Sperm whales have a wide geographical and latitudinal distribution but are predominantly found in deep waters (> 1,000 m) in the open ocean over the continental slope (Berkenbusch *et al.,* 2013). They forage primarily for squid (Evans & Hindell, 2004) at depths of up to 600 m (Whitehead, 2009). Smaller volumes of various species of fish also contribute to the diet of sperm whales (Gaskin & Cawthorn, 1967).

Systematic surveys of sperm whale distribution in New Zealand are limited to the Kaikoura region, which is home to a small number of resident male sperm whales that feed in nearby submarine canyons (Arnold, 2004). While sperm whales do not carry out large scale migrations, smaller movements occur, with males and females in the Southern Hemisphere moving southward from the equator in winter month (April – September), returning north in summer (October – March) (Berzin, 1971).

Sperm whales rely on echolocation to locate prey and navigate, with foraging clicks allowing the whales to determine the direction and distance of prey (Ocean Research Group, 2015). Clicks are also produced as a means of communication, to identify members of a group and to coordinate foraging activities (Andre & Kamminga, 2000). Sperm whale clicks have been reported to be multi-pulsed and broadband, ranging in frequency from 0.2 – 32 kHz (Backus & Schevill, 1966). Clicks from foraging male sperm whales have been recorded with source levels up to 236 dB re 1 µPa @ 1 m (Madsen *et al.,* 2002; Møhl *et al.,* 2003).

Eight sperm whale strandings have been reported from the coastline inshore of the Operational Area, and nine sightings have been reported inside the Marine Mammal AOI. Based on the stranding data and the moderate levels of sightings, it is ***likely*** that sperm whales will be present within the Operational Area.

5.2.7.3.2 Pygmy sperm whales (*Kogia breviceps*)

Pygmy sperm whales are seldom seen at sea on account of their low profile in the water and lack of a visible blow; for this reason, little information is available on this species. They are, however, known to be a deep-water species (Taylor *et al.,* 2012). Prey items of pygmy sperm whales include cephalopods, deep-sea fish and crustaceans (Shirihai & Jarrett, 2006; Jefferson *et al.,* 2008).

Although sounds associated with echolocation, such as clicks, buzzes, and grating sounds have been recorded, this species is not thought to be highly vocal (Ross, 2006). Data collected from live stranded animals has indicated that pygmy sperm whales emit click trains between 60 and 200 kHz (Marten, 2000).

Although no live sightings have been recorded within, or in the vicinity of the Marine Mammal AOI, five stranding events involving pygmy sperm whales have been reported along the coast inshore of the Operational Area. Based on the stranding data, pygmy sperm whales could be ***occasional visitors*** within the Operational Area.

5.2.7.3.3 Beaked whales (Family Ziphiidae)

Thirteen species of beaked whales have been reported in New Zealand (Baker *et al*., 2016); however, their elusive behaviour at sea means that very little is known about their distributions (Baker, 1999). The majority of knowledge comes from stranded individuals; however, recent expeditions off the Otago coast made live sightings of Shepherd's beaked whales in waters of the Taiaroa and Saunders Canyons (Donnelly et al., 2018). **Table 11** outlines those species that have stranded inshore of the Operational Area or have been observed at sea in the vicinity and provides a brief account of the ecology of each species. In general, beaked whales are deep divers and feed predominately on deep-water squid and fish species (Berkenbusch *et al*., 2013). From the assessment provided in **Table 11**, the following conclusions can be drawn for the GSB Checkshot Survey:

- Four species are ***likely*** to be present - Gray's beaked whale, Cuvier's beaked whale, strap-toothed whale and Shepherd's beaked whale;
- Four species could be an ***occasional visitor*** – Andrew's beaked whale, Hector's beaked whale, southern bottlenose whale, and Arnoux's beaked whale; and
- Five species are ***unlikely*** to occur - Blainville's/Dense beaked whale, ginkgo-toothed whale, lesser/pygmy beaked whale, True's beaked whale, and Spade-toothed whale.

Table 11 Ecology of Beaked Whales that are of Relevance to the Operational Area

Species	No. of stranding events inshore of Operational Area	Ecology
Gray's beaked whale *(Mesoplodon grayi)*	13	A Southern hemisphere species with a circumpolar distribution south of 30°. Many sightings are from Antarctic and sub-Antarctic waters. Many stranding records are from coastline of New Zealand implying they may be fairly common here. Occurs in deep waters beyond the shelf edge (Taylor *et al*., 2008).
Strap-toothed whale *(Mesoplodon layardii)*	14	Occur between 35-60°S in cold temperate waters. Stranding seasonality suggest this species may migrate. Prefer deep waters beyond the shelf edge. Probably not as rare as other *Mesoplodon* sp. (Taylor *et al*., 2008a). Feeds on squid (Sekiguchi *et al*., 1996).
Cuvier's beaked whale *(Ziphius cavirostris)*	6	Thought to have the largest range of any beaked whale; found in deep waters (> 200 m) of all oceans in both hemispheres. Thought to prefer steep bathymetry near the continental slope in water depths greater than 1,000 m. Feed mostly on squid and dive up to 40 minutes. Global abundance is likely to be well over 100,000 (Taylor *et al*., 2008b). Genetic studies suggest little movement of individuals between ocean basins (Dalebout *et al*., 2005).
Shepherd's beaked whale *(Tasmacetus shepherdi)*	2	A circumpolar distribution in cold temperate waters is presumed. All stranding events have occurred south of 30°S, the majority from New Zealand. Thought to be relatively rare. Occur in deep water usually well offshore. Diet contains fish, squid and crabs (Taylor *et al*., 2008d). Note that this species has recently been seen in waters of the Taiaroa and Saunders Canyons in coastal Otago (Donnelly et al., 2018).
Andrew's beaked whale *(Mesoplodon bowdoini)*	2	Found between 32°S and 55°S in the southern hemisphere. Presumed to inhabit deep, offshore waters (Pitman, 2002). Based on the global stranding record, New Zealand might represent an area of concentration (Taylor *et al*., 2008c).

Species	No. of stranding events inshore of Operational Area	Ecology
Hector's beaked whale (*Mesoplodon hectori*)	1	A southern hemisphere species found south of the Tropic of Capricorn. Majority of records are from New Zealand waters. Unlike most beaked whales, it is thought that this species may behave inquisitively around boats. Despite this behaviour there has only been one confirmed live sighting, suggesting Hector's beaked whales are naturally rare. Feeds primarily on deepwater squid off the continental shelf (WDC, 2019).
Arnoux's beaked whale *(Berardius arnuxii)*	1	Circumpolar distribution in deep, cold temperate and sub-polar waters. Considered to be naturally rare throughout its range; however, higher densities may occur seasonally in Cook Strait (Taylor *et al*., 2008e). New Zealand has the highest number of stranding recorded for this species (Jefferson *et al*., 1993).
Southern bottlenose whale (*Hyperoodon planifrons*)	0 strandings, but 1x sighting in Marine Mammal AOI	Circumpolar distribution in the southern hemisphere, south of about 30°S (Jefferson *et al.,* 1993). However, most sightings are from about 57°S to 70°S (Taylor *et al*., 2008f). Knowledge of the biology of this species is scarce, but they are thought to be a deep-diving species foraging primarily on squid (Baker, 1999).

5.2.7.3.4 Hector's dolphin (*Cephalorhynchus hectori hectori* and *C. hectori maui*)

There are two sub-species of Hector's dolphin: the South Island Hector's dolphin (*C. hectori hectori*) and the Māui's dolphin (*C. hectori maui*). Māui's dolphins are restricted to the west coast of the North Island (Slooten *et al*., 2005), hence are irrelevant to the Operational Area and this MMIA.

South Island Hector's dolphins are present around the South Island and their abundance has significantly declined in the past 40 years, largely on account of high levels of by-catch in coastal fisheries (Currey *et al*., 2012). Of relevance to the Operational Area is the East Coast South Island Hector's dolphin population, which extends from Farewell Spit to Nugget Point and is estimated to consist of 8,968 individuals (Mackenzie & Clement, 2016). Animals belonging to this population shift their distribution on a seasonal basis, with dolphin abundances being higher south of Banks Peninsula in winter, while during other seasons dolphin abundance is greater to the north. While Hector's dolphins are generally regarded as a coastal species occurring within the 100 m isobaths (Slooten *et al.,* 2006), almost half of the East Coast South Island population in summer and three-quarters in winter occur beyond 4 NM from the coast with some sightings occurring on or near the 20 NM boundary (Mackenzie & Clement, 2014). The Operational Area lies well outside the core coastal distribution of this species. Hector's dolphins feed on a range of fish species including red cod, ahuru, arrow squid, sprat, sole, and stargazer (Miller *et al*., 2013).

Although no live sightings of Hector's dolphins have been recorded within the Marine Mammal AOI, 70 sightings have been reported in inshore coastal waters, and 25 stranding events have been documented along the coastline of interest (Oamaru to Waipapa Point). Based on this information Hector's dolphins may be ***occasional visitors*** to the Operational Area; however, the offshore nature of the Operational Area serves to reduce the likelihood of encountering this threatened species.

5.2.7.3.5 Common dolphin (*Delphinus delphis*)

Common dolphins are abundant and widespread throughout tropical and temperate oceans of the Atlantic and Pacific Ocean and occur in waters encompassing all regions of New Zealand (Berkenbusch *et al*., 2013). Their occurrence is restricted by seasonal fluctuations in sea surface temperature (Webb, 1973); common dolphins are generally observed in coastal waters during spring and summer, moving further offshore in autumn (Stockin *et al.*, 2008). Total abundance of the New Zealand population is unknown (Berkenbusch *et al*., 2013) although based on the frequency of sightings it is likely that numbers are substantial. Common dolphins are highly social and often form large groups consisting of thousands of individuals (Stockin, 2008). The diet of common dolphins in New Zealand primarily consists of jack mackerel, anchovy, and arrow squid (Meynier *et al*., 2008).

Common dolphins are highly vocal animals, and use a variety of vocalisations including whistles, echolocation click-trains, burst pulse calls (Richardson *et al.,* 1995; Soldevilla *et al,* 2008), and other non-whistle pulsed sounds referred to as barks, yelps, or squeals (Ridgway, 1983). Petrella *et al*. (2012) determined the whistle characteristics of common dolphins in the Hauraki Gulf, New Zealand, indicating that the average frequency and length of whistles are 10 – 14 kHz and 0.27 seconds, respectively.

Although no live sightings of common dolphins have been recorded within the Marine Mammal AOI and no stranding events have been reported along the nearby coastline, 21 sightings of this species have occurred in waters inshore of the Operational Area. Based on this information, common dolphins may be ***occasional visitors*** to the Operational Area; however, their distribution is typically in shallower coastal waters.

5.2.7.3.6 Pilot whales (*Globicephala macrorhynchus* and *G. melas*)

There are two species of pilot whale: long-finned pilot whale (*Globicephala melas*) and short-finned pilot whale (*G. macrorhynchus*). Both species are present in New Zealand waters although the short-finned pilot whale is less frequently encountered here as it prefers warmer sub-tropical habitat (Berkenbusch *et al*., 2013). Pilot whales are highly social, often travelling in large groups of over 100 individuals (DOC, 2019d). Pilot whale sightings occur in New Zealand waters during all seasons (Berkenbusch *et al*., 2013). These whales commonly strand on New Zealand coasts, with the stranding rate peaking in spring and summer (O'Callaghan *et al*., 2001). Pilot whales feed predominantly on cephalopods (Olson, 2009).

Pilot whales are known to be highly vocal when socialising at the surface (Jensen *et al.,* 2011), with vocalisations ranging from simple whistles while resting at the surface to complex whistles and pulses sounds during active behaviours (Weilgart & Whitehead, 1990). Calls of deep-diving pilot whales have been recorded with median peak frequencies of 3.9 kHz (Jensen *et al.,* 2011).

No live sightings of short-finned pilot whales have been made in or around the Operational Area and only one stranding event has been documented for this species inshore of the Operational Area. Given the preference of short-finned pilot whales for warmer sub-tropical waters this relative lack of sightings is not surprising. Based on this information this species is considered an ***occasional visitor*** to the Operational Area.

Long-finned pilot whales on the other hand are more frequently encountered, with 36 sightings reported from within the Marine Mammal AOI and 35 sightings in surrounding waters. Eighteen strandings of long-finned pilot whales have been documented inshore of the Operational Area. Based on this information, long-finned pilot whales are ***likely*** to occur in the Operational Area.

In addition, moderate numbers of sightings that were not identified to species level have also been made (41 within the Operational Area and 25 in surrounding waters). Given the bias towards long-finned pilot whales in both the sighting and stranding records, long-finned pilot whales are the more likely of the two species to be present during the GSB Checkshot Survey.

5.2.7.3.7 Dusky dolphin (*Lagenorhynchus obscurus*)

Dusky dolphins are a Southern Hemisphere species present year-round in New Zealand waters (Berkenbusch *et al*., 2013). They occur in waters above the continental slope and shelf in water depths less than 2,000 m, usually in the cooler waters of the South Island and lower North Island, spending more time in offshore waters during winter months (Wűrsig *et al*., 2007). Little is known about dusky dolphin movements, but photo-identification data confirms that individuals travel up to 1,000 km between locations around the South Island (Wűrsig *et al*., 2007). Their diet is varied; southern anchovy are targeted in shallow surface waters, while mid-water and benthic prey such as squid, hake and lanternfish are also targeted (Hammond *et al*., 2008a).

Three sightings of dusky dolphins have been made in the Marine Mammal AOI and 73 sighting records exist for the surrounding waters. In addition, 22 stranding events have been documented for this species inshore of the Operational Area. Dusky dolphins are commonly seen in coastal waters inshore of the Operational Area. This species is ***likely*** to be present in the Operational Area, particularly if the survey was to be carried out in winter months.

5.2.7.3.8 Southern right-whale dolphin (*Lissodelphis peronii*)

Southern right whale dolphins are thought to be circumpolar and common throughout their range (Lipsky, 2002). They are predominantly oceanic, preferring deep, offshore waters (Lipsky, 2002) where they feed on a variety of fish and squid (Jefferson *et al,* 2008). Although there have been few sightings of southern right-whale dolphins in New Zealand waters, large groups (500 – 1,000) have been reported with the majority of sightings occurring off Otago and further south (Berkenbusch *et al.,* 2013).

No information is available on the acoustic repertoire of this species; however, it presumably uses echolocation to navigate and locate food as with other odontocetes.

One southern right whale dolphin stranding has been reported from the coastline inshore of the Operational Area and five sightings have been reported inside the Marine Mammal AOI and five in surrounding waters. Based on this information, it is ***likely*** that southern right whale dolphins utilise habitat within the Operational Area.

5.2.7.3.9 Killer whale (*Orcinus orca*)

Killer whales are distributed throughout all marine regions from the equator to polar waters (Reeves *et al*., 2017). Small groups are typical around New Zealand where they travel an average of 100 – 150 km per day (Visser, 2000). Killer whales form social groups ranging from larger temporary aggregations of over 20 individuals (Ford, 2009) to small, stable family units (Berkenbusch *et al*., 2013). Their diet differs between family groups, which typically specialise on one of the following prey types: sharks, rays, fin-fish, and cetaceans (Visser, 2000).

Echolocation characteristics vary between groups of whales and are thought to reflect the target prey species of a particular group (Barrett-Lennard *et al*., 1996). Whistles have an average dominant frequency of 8.3 kHz (Thomsen *et al*., 2001) and variations of these whistles (often referred to as dialects) have been documented between pods (Deecke *et al*., 2000).

Four killer whale strandings have been reported from the coastline inshore of the Operational Area. While no sightings have been reported inside the Marine Mammal AOI, 16 have occurred in the surrounding waters. Based on the stranding data and the moderate levels of sightings nearby, it is ***likely*** that killer whales will occur within the Operational Area.

5.2.7.3.10 False killer whale (*Pseudorca crassidens*)

This species is widespread in tropical and warm temperate waters (Baird, 2009). They are mostly found in deep, offshore waters but also occasionally over the continental shelf (Berkenbusch *et al*., 2013). False killer whales feed on cephalopods, fish, and other cetaceans (Baird, 2009).

False killer whales are extremely vocal with a diverse repertoire consisting of click trains, burst-pulse sounds, and whistles. Peak frequencies of false killer whale sounds recorded from captive animals ranged from 3 to 22 kHz (Murray *et al*., 1998).

Two false killer whale strandings have been reported from the coastline inshore of the Operational Area, and while no sightings have been reported inside the Marine Mammal AOI, three have occurred in the surrounding waters. Based on the stranding data and the sightings nearby, it is ***likely*** that false killer whales utilise habitat within the Operational Area.

5.2.7.3.11 Bottlenose dolphin (*Tursiops truncatus*)

Bottlenose dolphins occur globally in cold temperate and tropical seas, with New Zealand representing the southernmost extent of their range (DOC, 2019e). They occur in shallow coastal regions, including inshore waters, estuaries and lagoons (Berkenbusch *et al*., 2013), and although considered a coastal species, their distribution does extend to some offshore areas around oceanic islands (Jefferson *et al*., 2008). In addition to the inshore populations is an 'oceanic ecotype' (Baker *et al*., 2010) found around the New Zealand coast with a more offshore distribution (Zaeschmar *et al*., 2013). Bottlenose dolphins have a varied diet consisting of a variety of fish and squid, including benthic and pelagic species (Wells & Scott, 2009).

Common bottlenose dolphins produce 'clicks' which are used for echolocation purposes (0.8 – 24 kHz) and 'whistles' which are used as a form of communication (40 – 130 kHz).

Fourteen bottlenose dolphin strandings have been reported from the coastline inshore of the Operational Area. While only one sighting has been reported inside the Marine Mammal AOI, eight have occurred in the surrounding waters. Based on the stranding data and the low levels of sightings nearby, it is ***likely*** that bottlenose dolphins will occur within the Operational Area.

5.2.7.3.12 Spectacled porpoise (*Phocoena dioptrica*)

Spectacled porpoises occur only in cold temperate waters (Hammond *et al*., 2008b), with their distribution thought to be restricted to the circumpolar sub-Antarctic (Baker, 1999; Goodall, 2002).

Two live sightings of spectacled porpoises have been made within the Marine Mammal AOI, although there are no additional sightings reported for the surrounding waters. In addition, one stranding event has been reported inshore of the Operational Area. Based on this information, spectacled porpoises could utilise habitat within the Operational Area as ***occasional visitors***.

5.2.8 Pinnipeds

The New Zealand fur seal, New Zealand sea lion, southern elephant seal and leopard seal are the pinniped species that may occur in the Operational Area.

5.2.8.1 New Zealand fur seal (*Arctocephalus forsteri*)

The New Zealand fur seal is native to both New Zealand and Australia. Within New Zealand this species is widespread around rocky coastlines on the mainland and offshore islands.

New Zealand fur seals forage on a range of species, with the relative importance of each prey item varying by season. Arrow squid are important prey items in summer and autumn, lanternfish are taken year-round, barracouta and jack mackerel are major contributors to the summer diet, while pink cod, ahuru, and octopus are important winter prey species (Harcourt *et al*., 2002). In general, the diet of New Zealand fur seals shifts from a squid-dominated diet in summer and autumn, to mixed fish-dominated in winter (Harcourt *et al*., 2002).

New Zealand fur seals are among the deepest and longest diving species of fur seal (Mattlin *et al*., 1998); maximum female dives last for approximately 9 minutes to depths of 312 m, while dives carried out by males can last for approximately 15 minutes to depths greater than 380 m (Page *et al*., 2005). Foraging habitats vary with season and sex although inshore and deeper offshore foraging habitat is used throughout the year (Harcourt *et al*., 2002). Females tend to forage over continental shelf waters, with males using deeper continental shelf breaks and pelagic waters (Page *et al*., 2005). Foraging trips often last for a number of days (Page *et al*., 2005) and GPS tagged animals have shown females to forage up to 78 km from breeding colonies (Harcourt *et al*., 1995), foraging further offshore in winter (Harcourt *et al*., 2002).

The breeding season for New Zealand fur seals occurs from mid-November to mid-January, with peak pupping in mid-December (Crawley & Wilson, 1976). Pups are suckled for approximately 10 months during which females alternate between foraging at sea and returning ashore to feed their pups (Boren, 2005). Numerous breeding colonies occur across the Otago region where they are spread over 200 km of coastline from Moeraki in North Otago to Cosgrove Island, the Catlins (Lalas & Bradshaw, 2001). From pup production data at these colonies, the Otago population size for this species is estimated to be 20,000 to 30,000 animals (Lalas, 2008). Monthly distribution of New Zealand fur seal activity is summarised in **Table 12**.

The DOC sighting database lists 55 New Zealand fur seal sightings from within the Marine Mammal AOI, and 120 sightings in the surrounding waters. New Zealand fur seals were observed during the Tāwhaki-1 Pre-drill Survey. Based on the abundance of sightings in and around the Operational Area, New Zealand fur seals will ***likely*** be present in the Operational Area, both foraging and resting between foraging bouts.

Table 12 Monthly Distribution of New Zealand Fur Seal Activity

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Breeding males												
Breeding females												
Pups												
Non-breeders (including yearlings)												
Key:	At breeding colony			At breeding colony and at-sea foraging and suckling			At sea			Dispersed at sea, at haulouts, or breeding colony periphery		

Source: Re-drawn from Baird, 2011.

5.2.8.2 New Zealand sea lion (*Phocarctos hookeri*)

The endemic New Zealand sea lion is one of the world's rarest pinnipeds. New Zealand sea lions have undergone a dramatic range reduction; historically this species ranged along the entire New Zealand coast down to the New Zealand sub-Antarctic Islands (Childerhouse & Gales, 1998). The present-day breeding range is largely restricted to the Auckland Islands and Campbell Island, although recolonization of mainland New Zealand and Stewart Island is occurring (Childerhouse & Gales, 1998). The first live birth of a New Zealand sea lion pup on the Otago coast occurred in the 1993/4 breeding season (McConkey *et al.,* 2002) representing the beginning of a slow re-establishment of breeding on the mainland, with 2% of all sea lion pups now born at Stewart Island and on the Otago and Catlins coasts (DOC, 2017). Breeding occurs over summer, with pupping beginning in early December and ending by mid-January. Following the end of the breeding season, males disperse to the extremes of their range (Robertson *et al*., 2006), while females spend the next year alternating between foraging trips and time on land to suckle their pups (DOC, 2019f).

Female New Zealand sea lions are the deepest and longest-diving of all the otariids (eared seals), spending approximately 53% of their time at sea submerged (Chilvers *et al.,* 2006). Females are capable of diving to depths close to 180 m (Chilvers *et al.,* 2006). Individual sea lions have distinct dive profiles and are either benthic divers that consistently dive to the seabed, or more pelagic feeders with varied dive depths in deeper waters (Chilvers *et al.,* 2006). In the Auckland Islands, New Zealand sea lions typically forage along the continental shelf and shelf edge (Chilvers *et al*., 2005) where their diet consists of a variety of benthic and pelagic species, including hoki, opalfish, rattails, octopus and squid (Meynier *et al.,* 2010). Female sea lions are resident at Otago Peninsula; they typically forage close to the coast and show high levels of foraging site fidelity (Auge *et al.*, 2014) with barracouta and jack mackerel contributing the greatest biomass to their diets (Auge *et al*., 2011). Thirteen female New Zealand sea lions were satellite tagged on Otago Peninsula from 2008 to 2010, of these individuals, the maximum distance from shore during foraging trips was 9.7 +/- 5.7 km and the maximum water depth recorded for any tagged female was 111.8 +/- 281 m (Auge *et al*., 2014); primary foraging habitat was characterised by shallow rocky reefs and bryozoan thickets (Auge *et al*., 2011). The results of this tagging study suggest that foraging areas for female New Zealand sea lions off Otago are constrained to the east by the edge of the continental shelf (Auge *et al*., 2014). Based on the tagging data for females, and the fact that the Operational Area lies beyond the edge of the continental shelf in water depths of 750 – 1700 m, it is unlikely that female New Zealand sea lions would routinely forage in the Operational Area.

No information is available with regard to the foraging range of male New Zealand sea lions from Otago. However, adult males are known to make seasonal movements between breeding colonies at the Auckland Islands and the Otago Peninsula (Robertson *et al.,* 2006). The conservation status of this species commands a conservative assessment; therefore male New Zealand sea lions could be ***occasional visitors*** and forage in parts of the Operational Area or transit the Operational Area during breeding migrations. However, no sightings of New Zealand sea lions have been made within the Marine Mammal AOI.

5.2.8.3 Southern elephant seal (*Mirounga leonina*)

Southern elephant seals are resident on New Zealand's sub-Antarctic islands, with populations concentrated on the Antipodes Islands and Campbell Island (DOC, 2019g). Southern elephant seals occasionally visit the New Zealand mainland. Between 1965 and the early 1990s, breeding frequently occurred along the Otago coastline between Oamaru and Nugget Point (Harcourt, 2001); however, breeding activity has not been recorded in Otago for many years.

Elephant seals spend the majority of their lives at sea (McIntyre *et al.,* 2010), although it is not uncommon for southern elephant seals to moult on mainland New Zealand beaches, where they remain ashore for a number of weeks until the moult is complete. Due to their large size, haul-out areas around mainland New Zealand are usually characterised by sand or gravel beaches (DOC, 2019g).

Elephant seals are the deepest-diving of all pinnipeds and more or less dive continuously while at sea, spending on average approximately 78% of their lives diving at sea, 7% at the sea surface, and 15% hauled out on land (McIntyre *et al*., 2010). Mean dive depth for southern elephant seals is 400 m (Harcourt, 2001; McIntrye *et al*., 2010), although dives deeper than 1,000 m are regularly undertaken (Harcourt, 2001). Adult males undertake deeper dives than females and have occasionally been recorded performing dives to the seabed in excess of 2,000 m (McIntrye *et al*., 2010). The diet of elephant seals comprises squid and fish. Foraging for fish (Moridae and Notothenidae) largely occurs in winter months over the Antarctic continental shelf (Bradshaw *et al*., 2003; Hindell *et al*., 2003), while pelagic squid dominate the diet in more northerly foraging ranges during other seasons (Bradshaw *et al*., 2003).

One sighting of a southern elephant seal has been made within the Marine Mammal AOI; hence, elephant seals are considered ***likely*** to be present in the Operational Area.

5.2.8.4 Leopard seal (*Hydrurga leptonyx*)

Throughout the austral spring and summer, leopard seals are typically found around the Antarctic pack ice; however, come autumn and winter they disperse northwards away from Antarctic waters towards the Southern Ocean where they are occasionally observed along New Zealand's coastline. Leopard seals are opportunistic hunters, feeding on any readily available prey including krill, penguins, birds, fish, seals and cephalopods (DOC, 2019h).

Leopard seals were classified under the New Zealand Threat Classification System as 'Vagrant'; however, based on the increasing number of sightings made around the New Zealand coast, it has been suggested that at least some leopard seals reside around the New Zealand coast for months at a time (LeopardSeals, 2019), resulting in a change of threat status to 'Naturally Uncommon' (Baker *et al*., 2019). While no sightings of leopard seals have been made from within the Marine Mammal AOI or surrounding waters, two strandings have been reported and live sightings are not uncommon on Otago beaches. Leopard seals are therefore considered ***likely*** to be present within the Operational Area.

5.2.9 Seabirds

'Seabirds' covers those that spend some part of their life cycle feeding over open marine water; this is compared to 'waders' that feed in the intertidal zone (Taylor, 2000). Approximately 60% of New Zealand's seabirds regularly forage more than 50 km from shore, while the remaining feed over inshore waters and are only occasionally sighted away from land (Taylor, 2000). The seabirds potentially present within the Operational Area include albatross, skua, fulmars, petrels, prions, shearwaters, terns, and penguins.

Knowledge of the at-sea distribution of New Zealand's seabird species is limited and generally restricted to targeted studies and observations from commercial fishing vessels (Richard *et al.,* 2011). Since 2004, independent fisheries observers working off commercial fishing vessels have been making regular counts of the number of seabirds surrounding fishing vessels. This data is coordinated by DOC and groomed by Dragonfly Science (Richard *et al.*, 2011), and suggests that mollymawks (*Thalassarche* sp.) would be the most abundant seabird group within the Operational Area (**Figure 17**). However, **Figure 17** must be interpreted with some caution due to the nature of the observations; counts were made while on-board actively fishing vessels therefore sightings will favour those species that are known to approach and follow fishing vessels, furthermore small and difficult to identify species will likely be underestimated.

Various references (e.g. Scofield & Stephenson, 2013; Robertson *et al*., 2017; New Zealand Birds Online, 2019) have been used to identify the seabirds that are most likely to be observed in and around the Operational Area. Seabirds have a large home range so their presence within the Operational Area is not guaranteed and is likely to be transient. DOC has assessed each New Zealand seabird species and assigned a threat classification; with many of the species potentially present having been assigned a threatened status (i.e. classified as Nationally Critical, Nationally Endangered, or Nationally Vulnerable). A summary of the seabirds including their threat classifications (IUCN and New Zealand threat status) is presented in **Table 14**.

Multiple data sources have been used to predict which seabird species may be present within the Operational Area. Data sources for this assessment include:

- Sightings data from independent fisheries observers on-board commercial fishing vessels (e.g. Richard *et al*., 2011);
- Knowledge of New Zealand distributions within, or in close proximity to the Operational Area based on avifauna surveys (Robertson *et al.* 2007); and
- Knowledge of habitat preferences of each species which may overlap with, or are in close proximity to, the Operational Area (e.g. Scofield & Stephenson (2013) and New Zealand Birds Online (2019)).

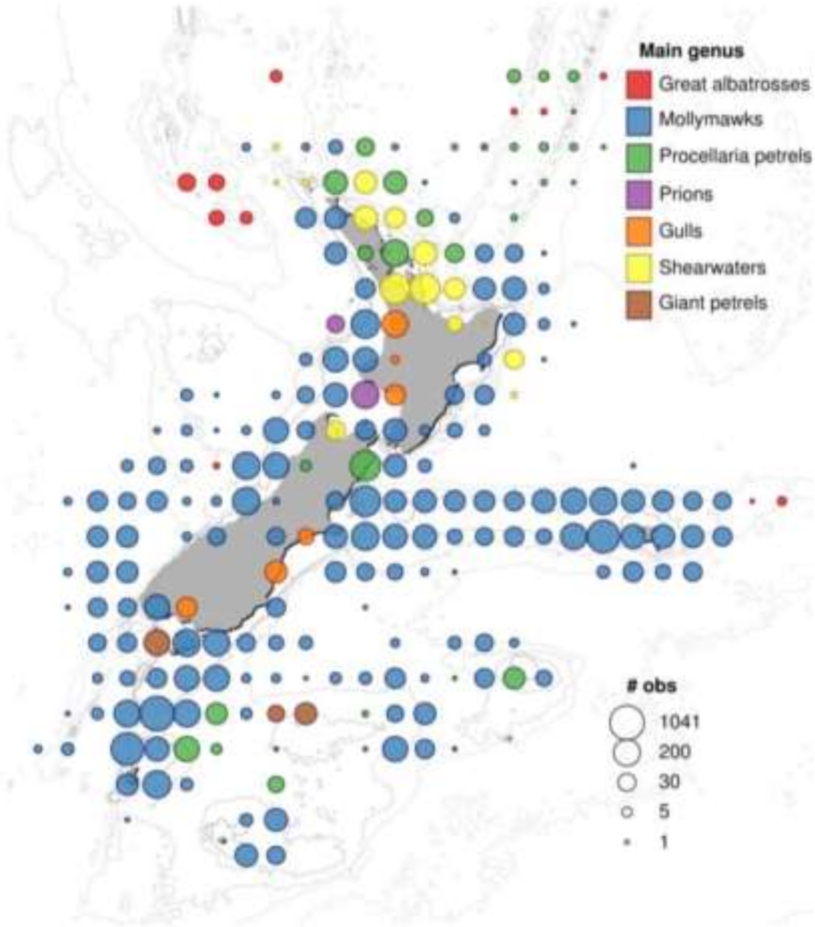
It is important to exercise caution when assessing the likelihood of a seabird species being present within the Operational Area as:

- Data gaps in sighting data do not necessarily indicate an absence of birds, but can typically reflect a lack of observation effort, with at-sea distributions particularly poorly known; and
- Fisheries sightings are biased towards those species that are attracted to vessels.

The criteria used to assess the likelihood of a species being present in the Operational Area are presented in **Table 13**, with the assigned likelihood reported in **Table 14**.

Most seabirds have strong natal site fidelity and typically return to, or in the general vicinity of, the same breeding colony where they were reared (Taylor, 2000). Due to its offshore location there are no seabirds breeding within the Operational Area.

Figure 17 Most Abundant Seabird Groups Throughout New Zealand's EEZ Based on Observer Records Between January 2004 and June 2009



Source: Richard *et al.,* 2011

Table 13 Criteria Used to Assess the Likelihood of Seabirds Being Present in the Operational Area

Criteria	Description
Likely	Species that are represented in the fisheries observations (Richard *et al*., 2011) within, or in the vicinity of, the Operational Area or which have been GPS tracked over the Operational Area.
Possible	Species that have been identified in Robertson *et al*. (2007) in the vicinity of the Operational Area and have known habitat preferences that overlap with the Operational Area.
Occasional Visitor	Species that are represented in the fisheries observations from the area surrounding the Operational Area or have been identified in Robertson *et al.* (2007) in the wider vicinity but are listed as 'Migrant' in the New Zealand Threat Classification System (Robertson *et al*., 2017).
Unlikely	Species whose distribution within the general vicinity of the Operational Area has been reported in Scofield and Stephenson (2013) but have not been reported in avifauna surveys (Robertson *et al*., 2007) or fisheries observations (Richard *et al*., 2011); or those species that are reported in Robertson *et al.* (2007) but which do not have habitat preferences overlapping with the Operational Area.

Table 14 Likelihood of Occurrence of Seabirds in the Operational Area

Common Name	Scientific Name	IUCN Threat Status	New Zealand Threat Status[1]	Likelihood of Occurrence
Antipodean albatross	*Diomedea antipodensis antipodensis*	Vulnerable	Nationally critical	Likely
Gibson's albatross	*Diomedea antipodensis gibsoni*	Not assessed	Nationally critical	Likely
Salvin's mollymawk	*Thalassarche salvini*	Vulnerable	Nationally critical	Likely
Yellow-eyed penguin	*Megadyptes antipodes*	Endangered	Nationally endangered	Unlikely
Black petrel	*Procellaria parkinsoni*	Vulnerable	Nationally Vulnerable	Likely
Campbell Island mollymawk	*Thalassarche impavida*	Vulnerable	Nationally vulnerable	Likely
Fiordland crested penguin	*Eudyptes pachyrhnchus*	Vulnerable	Nationally Vulnerable	Unlikely
Flesh-footed shearwater	*Puffinus carneipes*	Not threatened	Nationally Vulnerable	Likely
Grey-headed mollymawk	*Thalassarche chrysostoma*	Endangered	Nationally vulnerable	Likely
Hutton's shearwater	*Puffinus huttoni*	Endangered	Nationally vulnerable	Unlikely
Little penguin	*Eudyptula minor*	Least concern	Declining	Unlikely
Sooty shearwater/Muttonbird	*Puffinus griseus*	Near threatened	Declining	Likely
White-capped/shy mollymawk	*Thalassarche cauta steadi*	Not assessed	Declining	Likely
Northern giant petrel	*Macronectes halli*	Least concern	Recovering	Likely
Broad-billed prion	*Pachyptla vittata*	Least concern	Relict	Possible
Cook's petrel	*Pterodroma cookii*	Vulnerable	Relict	Possible
Fairy prion	*Pachyptila turtur*	Least concern	Relict	Likely
Fluttering shearwater	*Puffinus gavia*	Least concern	Relict	Likely
Grey-backed storm petrel	*Garrodia nereis*	Least concern	Relict	Likely
Mottled petrel	*Pterodroma inexpectata*	Near threatened	Relict	Possible
White-faced storm petrel	*Pelagodroma marina maoriana*	Least concern	Relict	Likely
Antarctic prion	*Pachyptila desolata*	Least concern	Naturally uncommon	Unlikely
Brown skua/southern skua	*Catharacta antarctica lonnbergi*	Least concern	Naturally uncommon	Unlikely
Buller's mollymawk	*Thalassarche bulleri bulleri*	Not assessed	Naturally uncommon	Likely
Buller's shearwater	*Puffinus bulleri*	Vulnerable	Naturally uncommon	Likely
Chatham Island mollymawk	*Thalassarche eremita*	Vulnerable	Naturally uncommon	Likely
Grey petrel	*Procellaria cinerea*	Near threatened	Naturally uncommon	Likely
Fulmar prion	*Pachyptila crassirostris crassirostris*	Least concern	Naturally uncommon	Unlikely
Northern royal albatross	*Diomedea sanfordi*	Endangered	Naturally uncommon	Likely
Snare's petrel	*Daption capense australe*	Not assessed	Naturally uncommon	Likely
Soft-plumaged petrel	*Pterodroma mollis*	Least concern	Naturally uncommon	Unlikely
Southern royal albatross	*Diomedea epomophora*	Vulnerable	Naturally uncommon	Likely
Antarctic/Southern fulmar	*Fulmarus glacialoides*	Least concern	Migrant	Unlikely

Common Name	Scientific Name	IUCN Threat Status	New Zealand Threat Status[1]	Likelihood of Occurrence
Cape pigeon	*Daption capense capense*	Least concern	Migrant	Occasional visitor
Pomarine skua/jaeger	*Coprotheres pomarinus*	Least concern	Migrant	Unlikely
Snowy albatross	*Diomedea exulans*	Vulnerable	Migrant	Unlikely
Southern giant petrel	*Macronectes giganteus*	Least concern	Migrant	Occasional visitor
Wilson's storm petrel	*Oceanites oceanicus*	Least concern	Migrant	Occasional visitor
Black-browed mollymawk	*Thalassarche melanophris*	Least concern	Coloniser	Likely
Indian yellow-nosed mollymawk	*Thalassarche carteri*	Endangered	Coloniser	Likely
Australasian gannet	*Morus serrator*	Least concern	Not threatened	Likely
Grey-faced petrel	*Pterodroma gouldi*	Least concern	Not threatened	Unlikely
Subantarctic diving petrel	*Pelecanoides urinatrix exsul*	Least concern	Not threatened	Likely
White-chinned petrel	*Procellaria aequinoctialis*	Vulnerable	Not threatened	Likely
White-headed petrel	*Pterodroma lessonii*	Least concern	Not threatened	Unlikely

1 Roberston *et al*., 2017.

5.2.9.1 Culturally Important Species

A number of seabirds are identified within the Ngāi Tahu Claims Settlement Act 1998 as being particularly significant, or taonga (treasured), to Ngāi Tahu people. Species that are considered taonga to the people of Ngāi Tahu and which are of relevance to the Operational Area include: hoiho (yellow-eyed penguin), kororā (little blue penguin), tītī (sooty shearwater, Hutton's shearwater, common diving petrel, fairy and broad-billed prion, white-faced storm petrel, and Cook's and mottled petrel), and toroa (albatrosses and mollymawks).

The importance of tītī to the people of Ngāi Tahu is further acknowledge by the allowance of Rakiura (Stewart Island) Māori and their whānau to continue the traditional harvest of tītī chicks and small fledglings from the small islands adjacent to Rakiura during the harvesting season of 1 April – 31 May. Under the Tītī (Muttonbird) Islands Regulations 1978, people can arrive on the islands from 15 March to prepare for the upcoming season. Harvested birds are used for their meat, feathers and down (Te Ara, 2019f). Although these islands are to the south of the Operational Area, the Operational Area represents foraging habitat of tītī.

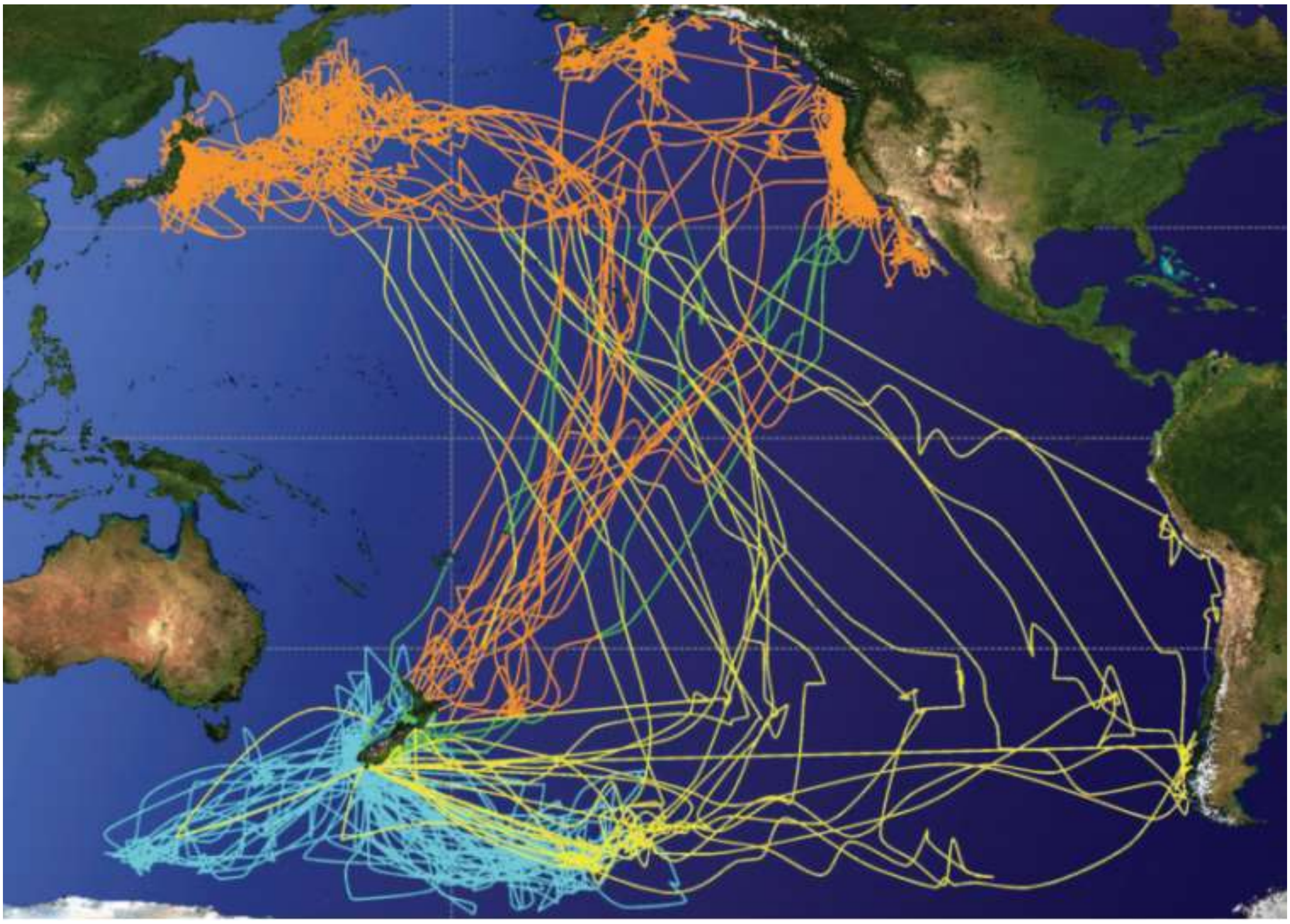
Due to their cultural importance to the people of Ngāi Tahu and the Otago region, details on the foraging behaviours of sooty shearwaters, yellow-eyed and little penguins, and royal albatrosses are briefly discussed below.

5.2.9.1.1 Sooty Shearwater (*Puffinus griseus*)

Sooty shearwaters breed in New Zealand in the austral summer, migrate to the North Pacific in autumn, and return to New Zealand in spring (Spear & Ainley, 1999). While at New Zealand breeding colonies, breeding birds follow a cycle of foraging trips, alternating between long (11 – 14 day) and short (1 – 2 day) voyages (Shaffer *et al.,* 2009). Sooty shearwaters typically travel to cold oceanic waters of the Polar Front during the longer foraging trips, while the birds remain in warmer neritic waters along New Zealand's shelf during the shorter foraging trips.

Following the breeding season, some sooty shearwaters are known to undergo migrations to the North Pacific (**Figure 18**) from approximately 35°N to the Bering Sea (Shaffer *et al*., 2006; Scofield & Stephenson, 2013). Migrations are thought to take 192 ± 17 days (Shaffer *et al*., 2006). Northern movements of sooty shearwaters occur between March and May, with birds returning to their New Zealand breeding colonies from September to December (Spear & Ainley, 1999). During short foraging trips from breeding colonies, sooty shearwaters travel 515 km (± 248 km) from the colony (Shaffer *et al*., 2009), and are therefore likely to utilise waters of the Operational Area during these foraging trips.

Figure 18 Sooty Shearwater Migration Tracks from New Zealand Breeding Colonies



Source: Shaffer *et al.*, 2006

Note: Light blue = interpolated geolocation tracks of sooty shearwaters during breeding; yellow = start of migration and northward transit; orange = wintering grounds and southward transit.

5.2.9.1.2 Little Penguins (*Eudyptula minor*)

Although little penguins have been tracked foraging at distances of up to 214 km from nesting sites in the Marlborough Sounds (Poupart *et al*., 2017), their foraging range is typically limited to within 30 km of nest sites (Mattern *et al*., 2001; Zhang *et al*., 2015) and in water depths less than 50 m (Chiaradia *et al*., 2007). Due to the water depths within the Operational Area, it is likely that this area is well outside the typical foraging habitat of little penguins and it is unlikely that this species will be present in the offshore waters of the Operational Area.

5.2.9.1.3 Yellow-eyed Penguins (*Megadyptes antipodes*)

The endemic yellow-eyed penguin breeds along the southeast coast of the South Island (McClung *et al*., 2004) inshore of the Operational Area, and due to its pelagic lifestyle is capable of covering large distances during foraging trips (Wilson, 1995). Foraging behaviour of yellow-eyed penguins from colonies in Oamaru (Mattern *et al*., 2007) and the Otago Peninsula (Moore, 1999) was investigated using GPS tracking devices fitted to penguins. Mattern *et al.* (2007) recorded penguins travelling up to 20 km from the coast, while Moore (1999) recorded foraging trips up to 57 km from Otago Peninsula colonies. Mattern *et al.* (2007) further looked at the penguin's foraging strategy and reported that this species feeds exclusively on the seabed. Based on this feeding strategy, and the typical foraging range, it is likely that the Operational Area lies at the offshore extremity of the foraging range of this species and therefore does not represent important yellow-eyed penguin foraging habitat.

5.2.9.1.4 Royal Albatross (*Diomedea sanfordi* and *D. epomophora*)

Waugh *et al.* (2005) carried out GPS tracking of incubating southern royal albatrosses (*D. epomophora*) from the Otago Peninsula. Foraging birds were found to favour areas around the shelf breaks off the east coast of the South Island, particularly around areas associated with commercial fishing activity. Incubating birds spent an average of 8.2 days at sea, travelled approximately 2,081 km, and ranged an average distance of 529 km from the colony (Waugh *et al.,* 2005). While a large number of birds foraged along the Chatham Rise and Mernoo Bank, foraging activity also occurred in the vicinity of the Operational Area, with waters within 100 km of the colony considered to be particularly important (Waugh *et al*., 2005). Tracked northern royal albatrosses (*D. sanfordi*) (from Campbell Island colonies) showed similar foraging destinations (Waugh *et al*., 2002). Waugh and Weimerskirch (2003) suggest that royal albatrosses forage over shallower water depths than other albatross species (i.e. wandering albatross), preferring waters shallower than 1,500 m.

Satellite tracking of the foraging range of northern royal albatross suggests birds move within 1,000 km of breeding sites (including Taiaroa Head on the Otago Peninsula) over the continental shelf and shelf edge (Robertson *et al*., 2003). Most northern royals winter off southern South America (Scofield & Stephenson, 2013). Juvenile northern royals fly north from the Taiaroa Head colony on their migration to the coast of Chile (Thomas *et al*., 2010); therefore, only adult northern royals can be expected to utilise waters of the Operational Area for foraging.

5.3 Cultural Environment

Aotearoa's (New Zealand) marine environment is highly valued by all Māori communities and plays an important role in historic and present-day culture. The values placed on the marine environment stem in particular from the importance of coastal waters as a valuable source of kaimoana (seafood), raranga (weaving) materials and rongoā (traditional medicines). The marine environment is also regarded as a sacred and spiritual pathway that provides a means of transportation and communication (Nga Uri O Tahinga Trust, 2012). Many of Aotearoa's ika (marine fauna) play important roles in legends. In particular, Māori have a deep spiritual connection with whales and dolphins, which are believed to provide safety at sea, and reportedly, guided the founding waka (canoes) on their great journey to Aotearoa from ancestral homelands in the Pacific.

Māori believe in the importance of protecting Papatūānuku (the earth) including the footprints and stories left by ancestors. In accordance with this, the role of kaitiakitanga (guardianship) is passed down between generations. It is the intergenerational responsibility and right of tangata whenua to take care of the environment and resources upon which they depend (MKT, 2013). The responsibilities of kaitiakitanga are to protect mauri (life force) and to pass the environment to future generations in a state that is as good as, or better than, the current state (MKT, 2013). Kaitiakitanga is central to the preservation of wāhi tapu (sacred places or sites) and taonga (treasures).

The traditional coastal takiwā (territory) of Ngāi Tahu is from the boundary of Pari-nui-o-Whiti (White Cliffs) south of Blenheim on the east coast, and northernmost boundary at Kahurangi on the west coast. Ngāi Tahu's takiwā covers all of Te Waipounamu's (the South Island) coast south of these eastern and western boundaries (Ngāi Tahu Seafood, 2019). The GSB is known to Māori as Te Moana Tapokopoko a Tawhaki; the wild and turbulent seas of Tawhaki (KTKO, 2013).

Ngāi Tahu have several settlements located at, or in close proximity to, the coast, where kaimoana (seafood) provides one of the major forms of sustenance. Abundant kaimoana has long been targeted at offshore fishing grounds, including trolling behind waka for makaa (barracouta), and longline fishing for ling, hapuka and cod. Inshore reefs were also targeted for koura (lobster/crayfish), while tōroa (albatross and mollymawks), kekeno (fur seals), and the occasional whale were also harvested. The ability of Otago hapū to provide sweet shellfish such as tuaki and pipi to guests was a way of increasing the mana (status) of the community (Kāi Tahu ki Otago, 2005). It is this relationship with the marine environment, and wider natural environment, that was at the heart of Te Kerēme (the Ngāi Tahu Claim), with the settlement giving expression to this relationship (Ngā Tahu, 2019).

The coastline inshore of the Operational Area is of relevance to Ngāi Tahu and Ngāi Tahu Whānau. Under the Ngāi Tahu Claims Settlement Act 1998, this includes '*individuals who descend from the primary hapū of Waitaha, Ngāti Mamoe, and Ngāi Tahu, namely Kāti Kurī, Kāti Irakehu, Kāti Huirapa, Ngāi Tuahuriri, and Kai Te Ruahikihiki*'.

Ngāi Tahu is comprised of 18 Papatipu Rūnanga within Te Waipounamu. Each of these Papatipu Rūnanga exist to uphold the mana of their people over the land, the sea and the natural resources. Each of the 18 rūnanga appoints a tribal member to represent its interests at Te Rūnanga o Ngāi Tahu, the governing council overseeing the tribe's activities. Details on each Papatipu Rūnanga are provided in **Table 15** (Te Puni Kōkiri, 2019). These 18 Papatipu Rūnanga are represented by Te Rūnanga o Ngāi Tahu. Te Rūnanga o Ōtākou and Kāti Huirapa Rūnaka Ki Puketeraki are the closest Papatipu Rūnanga to the Operational Area; however, all Ngāi Tahu Papatipu Rūnanga have been included for completeness.

Table 15 Ngāi Tahu Papatipu Rūnanga

Papatipu Rūnanga	Marae	Location
Awarua Rūnanga	**Te Rau Aroha**	**Bluff**
Hokonui Rūnanga	O Te Ika Rama	Gore
Kāti Huirapa Rūnaka Ki Puketeraki	**Huirapa (Puketeraki)**	**Karitāne**
Ōnuku Rūnanga	Ōnuku	Akaroa
Ōraka-Aparima Rūnaka	Takutai o te Titi	Riverton
Te Hapū o Ngāti Wheke	Rāpaki (Te Wheke)	Governors Bay
Te Ngāi o Tūāhuriri Rūnanga	Tuahiwi	Tuahiwi
Te Rūnanga o Arowhenua	Arowhenua	Temuka
Te Rūnanga o Kaikōura	Takahanga	Kaikōura
Te Rūnanga o Koukourārata	Koukourarata	Koukourarata/Port Levy
Te Rūnanga o Makaawhio	Te Tauraka Waka a Māui	Bruce Bay
Te Rūnanga o Moeraki	**Moeraki**	**Moeraki**
Rūnanga o Ngāti Waewae	Arahura	Arahura
Te Rūnanga o Ōtākou	**Ōtākou**	**Otago**
Te Rūnanga I Waihao	Waihao	Waimate
Te Taumutu Rūnanga	Ngāti Moki	Taumutu
Waihōpai Rūnaka	Murihiku	Invercargill
Wairewa Rūnanga	Wairewa	Little River

Note: Papatipu Rūnanga presented in bold text are those closest to the Operational Area

5.3.1 Statutory Acknowledgement Areas

Statutory Acknowledgements are acknowledgements by the Crown of a statement of Ngāi Tahu's particular cultural, spiritual, historical, and traditional association with specified areas (Ngāi Tahu, 1999).

There are two Statutory Acknowledgement Areas inshore of the Operational Area; Te Tai O Arai Te Uru (Otago CMA) and Rakiura/Te Ara a Kiwa (Rakiura/Foveaux Strait CMA). Due to the restricted spatial extent of potential effects from the GSB Checkshot Survey, these two areas have not been further discussed.

5.3.2 Taonga Species

Schedule 97 and Schedule 98 of the Ngāi Tahu Claims Settlement Act 1998 outlines taonga (treasured, prized, or valued) bird, plant, marine mammal, fish and shellfish species. Inclusion of these species in the Ngāi Tahu Claims Settlement Act 1998 is acknowledgement by the crown of Ngāi Tahu's cultural, spiritual, historic, and traditional association with the listed species. Marine taonga species of relevance to the Operational Area and the GSB Checkshot Survey are identified in **Table 16** below. Note that while these species have been identified by Ngāi Tahu as taonga, the list is not exhaustive, and all marine species are valued.

Whales are of particular importance to Ngāi Tahu and are significant features in Ngāi Tahu creation, migration and settlement traditions. The beaching of whales was considered an act of the gods providing the gift of life for people. This is reflected in the whakataukī proverb "*He taoka no Takaroa, I waihotia mo tātou, ke te tohora ki uta – this whale cast on the beach, is the treasure left to us all, by the great god Takaroa*" (MKT, 2013).

Table 16 Marine Taonga Species Identified within the Ngāi Tahu Claims Settlement Act 1998 and of Relevance to the Operational Area

Māori name	English name	Scientific name
Birds		
Hoiho	Yellow-eyed penguin	*Megadyptes antipodes*
Kororā	Little penguin	*Eudyptula minor*
Pokotiwha	Snares crested penguin	*Eudyptes robustus*
Tawaki	Fiordland crested penguin	*Eudyptes pachyrhynchus*
Tītī	Sooty shearwater	*Puffinus griseus*
	Hutton's shearwater	*Puffinus huttoni*
	Common diving petrel	*Pelecanoides urinatrix*
	South Georgian diving petrel	*Pelecanoides georgicus*
	Westland petrel	*Procellaria westlandica*
	Fairy prion	*Pachyptila turtur*
	Broad billed prion	*Pachyptila vittata*
	White-faced storm petrel	*Pelagodroma marina*
	Cook's petrel	*Pterodroma cookie*
	Mottled petrel	*Pterodroma inexpectata*
Toroa	Albatrosses and mollymawks	*Diomedea and Thalassarche sp.*
Marine mammals		
Ihupuku	Southern elephant seal	*Mirounga leonina*
Kekeno	New Zealand fur seal	*Arctocephalus forsteri*
Paikea	Humpback whales	*Megaptera novaeangliae*
Parāoa	Sperm whale	*Physeter macrocephalus*
Rāpoka/Whakahao	New Zealand sea lion/Hooker's sea lion	*Phocarctos hookeri*
Tohorā	Southern right whale	*Eubalaena australis*

5.3.3 Customary Fishing and Iwi Fisheries Interests

Kaimoana provides sustenance for tangata whenua, it is an important food source for whānau, and is vital for provision of hospitality to manuhiri (guests) (Wakefield & Walker, 2005). Traditional management of the marine environment entails a whole body of knowledge on the sea's natural resources, their seasonality and the manner in which they can be harvested. This customary wisdom is held sacred by tangata whenua and only passed on to those who will value it.

Under the Māori Fisheries Act 2004, recognised iwi were allocated fisheries assets such as fishing quota. Each iwi were also assigned income shares in Aotearoa Fisheries Limited. Aotearoa Fisheries Limited harvests, procures, farms, processes, and markets kaimoana in New Zealand and internationally, and is managed and overseen by Te Ohu Kai Moana (the Māori Fisheries Commission).

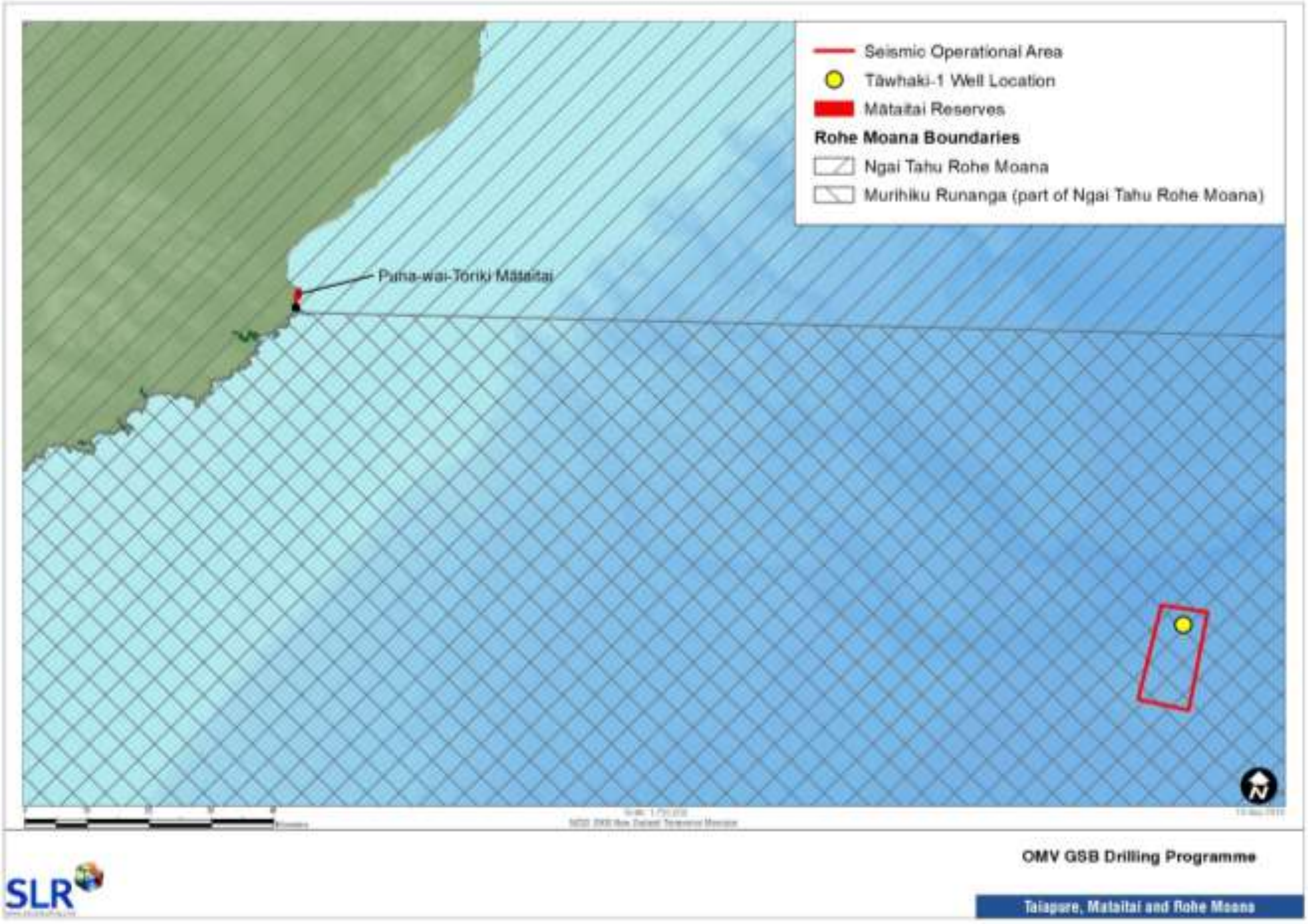
Separate from, and in addition to, commercial fisheries assets provided under the Māori Fisheries Act 2004, iwi within the South Island hold customary fishing rights under the Fisheries (South Island Customary Fishing) Regulations 1999. These regulations were developed as a result of the Treaty of Waitangi (Fisheries Claims) Settlement Act 1992 and the Ngāi Tahu Claims Settlement Act 1998. Under these regulations, tangata whenua may manage customary food gathering within the rohe moana for which they are tangata whenua.

5.3.3.1 Rohe Moana

Rohe moana may be established under the Fisheries (Kaimoana Customary Fishing) Regulations 1998 as recognised traditional food gathering areas for which Kaitiaki (customary managers) can be appointed to manage kaimoana collection in accordance with traditional Māori principles. They allow for the establishment of management controls, the issuing of permits for customary take, the enforcement of penalties for management breaches, and for restrictions to be established over fisheries areas in order to prevent stock depletion or overexploitation. The intention of a rohe moana is for the better provision for the recognition of Rangatiratanga (sovereignty) and of the right secured in relation to fisheries by Article II of the Treaty of Waitangi. The legally recognised boundaries of each rohe moana typically mirror the landward boundary of the CMA.

Ngāi Tahu and Murihiku Rūnanga have a rohe moana which extends around the southern part of the South Island; the Operational Area is located within the Ngāi Tahu rohe moana (**Figure 19**).

Figure 19 Rohe Moana of relevance to the Operational Area



5.3.3.2 Ngāi Tahu Seafood

Ngāi Tahu Seafood is a wholly owned subsidiary of Ngāi Tahu Holdings Corporation, the commercial arm of Te Rūnanga o Ngāi Tahu (the governing body overseeing the activities of Ngāi Tahu). Ngāi Tahu Seafood was established following the recommendations of the Waitangi Tribunal in order to manage the fishing quota Ngāi Tahu received following their settlement with the crown (Ngāi Tahu Seafood, 2019).

Ngāi Tahu Seafood manages its own fisheries assets as well as the fisheries settlement assets owned by Ngāi Tahu Fisheries Settlement Limited. Key species managed under Ngāi Tahu Seafood are kōura (rock lobster/crayfish), paua, rāwaru (blue cod), tio (Bluff oysters), and kūtai (greenshell mussels). Fishing quota for other species is also held by Ngāi Tahu Seafood, with the majority of seafood offered by Ngāi Tahu Seafood caught against Ngāi Tahu quota by Ngāi Tahu fishers (Ngāi Tahu Seafood, 2019).

The Ngāi Tahu Seafood Head Office is located in Christchurch. Operating facilities and landing ports are also located in Christchurch, Bluff, Kaikōura, and Picton (Ngāi Tahu Seafood, 2019).

5.3.4 Interests under the Marine & Coastal Area (Takutai Moana) Act 2011

The Marine and Coastal Area (Takutai Moana) Act 2011 acknowledges the importance of the marine and coastal area to all New Zealanders while providing for the recognition of the customary rights of iwi, hapū and whānau in the CMA. Iwi, hapū or whānau groups may be granted recognition of two types of customary interest under the Marine and Coastal Area Act; Customary Marine Title and Protected Customary Rights.

Customary marine title recognises the relationship of an iwi, hapū or whānau with a part of the common marine and coastal area. Public access, fishing and other recreational activities are allowed to continue in customary marine title areas; however, the group that holds customary marine title maintains the following rights:

- A 'Resource Management Act permission right' allowing the group to say yes or no to activities that need resource consents or permits in the area;
- A 'conservation permission right' allowing the group to say yes or no to certain conservation activities in the area;
- The right to be notified and engaged with when there is an application for a marine mammal watching permit in the area;
- The right to be engaged with about changes to relevant Coastal Policy Statements;
- A wāhi tapu protection right allows the group to seek recognition of a wāhi tapu and restrict access to the area if required to protect the wāhi tapu;
- The ownership of minerals other than petroleum, gold, silver and uranium found in the area;
- The interim ownership of taonga tūturu found in the area; and
- The ability to prepare a planning document that sets out the group's objectives and policies for the management of resources in the area.

Protected customary rights may be granted to allow for customary activities such as the collection of hāngi stones or launching of waka in the CMA.

If a group has a protected customary right recognised, they don't need resource consent to carry out that activity and local authorities cannot grant resource consents for other activities that would have an adverse effect on the protected customary right.

Due to the limited spatial extent of effects from the Operational Area, and distance of the areas applied for from the Operational Area, areas of Customary Marine Title and Protect Customary Rights have not been considered further. It is worth noting, however, that at the time of writing this MMIA the majority of applications inshore of the Operational Area were still being processed, the exception being Māori with customary interests in the islands of Pohowaitwai and Tamaitemioka. This application for customary marine title was granted on 22nd December 2016 in the High Court.

5.4 Socio-Economic Environment

Due to its distance from the coastline and restricted spatial extent of effects from the GSB Checkshot Survey, relevant socio-economic receptors are limited to commercial fisheries and commercial shipping.

5.4.1 Commercial Fisheries

The Operational Area lies within Fisheries Management Area 3 (South East (Coast)), which covers most of the east coast of the South Island, from the mouth of the Clarence River, south to Slope Point at the bottom of the South Island. Commercial fishing in the vicinity of the Operational Area is concentrated around coastal fisheries and deep-water fisheries along the shelf edge. On account of their distance from the Operational Area, coastal fisheries will not be affected by the activities associated with the GSB Checkshot Survey and are therefore are not discussed further.

FNZ provided an analysis of the commercial fishing events within PEP 50119 as part of the consents for the GSB EAD Programme. Fishing 'events' that crossed the boundaries of the analysed area (i.e. event started or ended inside the area) were included in this analysis; however, it is worth noting that only those events that reported by latitude and longitude were able to be included in the analysis, therefore some events were unable to be included (FNZ, 2019; 2019a).

Approximately 52 fishing events occurred within the analysed area during 2014 – 2018. Fishing methods used were bottom trawling and set-netting. Target species during this period were barracouta, black oreo, elephant fish, flatfish, school shark, silver warehou, smooth oreo, spiny dogfish, and terakihi, with an estimated total greenweight of 65,000 kg (FNZ, 2019).

Data on by-catch landed in the bottom trawling and set-netting fishery was also provided by FNZ (2019b). By-catch species and estimated greenweight of each species caught within the analysed area from 2014 – 2018 totalled 21,700 kg, with by-catch species provided in **Table 17**.

Table 17 By-catch Species and Weight Caught in the vicinity of Tāwhaki-1 (2014-2018)

Species/Species Code	Greenweight (kg)	Species/Species Code	Greenweight (kg)
Barracouta (BAR)	10	Ling (LIN)	2,704
Blue cod (BCO)	120	Lemon sole (LSO)	500
Bigeye thresher (BEE)	47	Blue moki (MOK)	50
Black oreo (BOE)	1,200	Orange roughy (ORH)	10
Brill (BRI)	5	Sharks and dogfish (OSD)	165
Seal shark (BSH)	160	Rattails (RAT)	320
Carpet shark (CAR)	100	Red cod (RCO)	1,241
Chimaera sp. (CHI)	20	Rough skate (RSK)	421
Elephant fish (ELE)	340	School shark (SCH)	70
New Zealand sole (ESO)	81	Starfish (SFI)	5
Baxter's lantern dogfish (ETB)	110	Sand flounder (SFL)	5
Flatfish (FLA)	5	Slickhead (SLK)	403
Grenadier cod (GRC)	160	Spiny dogfish (SPD)	2,200
Ghost shark (GSH)	30	Rig (SPO)	139

Species/Species Code	Greenweight (kg)	Species/Species Code	Greenweight (kg)
Pale ghost shark (GSP)	15	Squid (SQU)	2,040
Gurnard (GUR)	515	Smooth skate (SSK)	5
Hake (HAK)	7	Smooth oreo (SSO)	2,385
Hoki (HOK)	3,500	Giant stargazer (STA)	310
Hapuku and Bass (HPB)	95	Tarakihi (TAR)	550
Javelinfish (JAV)	1,012	Witch (WIT)	5
Leatherjacket (LEA)	652	Warty squid (WIT)	70
Giant lepidion (LEG)	15		

Source: FNZ, 2019a

Due to the water depths present in the Operational Area, the primary commercial fishery in the vicinity is a bottom-trawl fishery for various species of oreo: black oreo (*Allocyttus niger*), spiky oreo (*Neocyttus rhomboidalis*), warty oreo (*A. verrucosus*) and smooth oreo (*Pseudocyttus maculatus*).

Within the deep-water oreo fishery, smooth and black oreo are the target species, with spiky and warty oreo taken as by-catch (MPI, 2014). All four species are generally managed as a single species under the Quota Management System. The fishery is further managed through Quota Management Areas and stocks, with the SSO (Southland) Quota Management Area and OEO1 stock of relevance to the Operational Area.

Oreo occur over isolated topographical features as well as over extensive flat areas of seabed in water depths from 600 to 1,500 m. Younger fish are typically found at the shallower end of this depth range (MPI, 2014). The majority of fishing activity for oreo takes place in spring and summer from September through to March (MPI, 2014), with little to no fishing taking place in winter months (Gibbs, 2018).

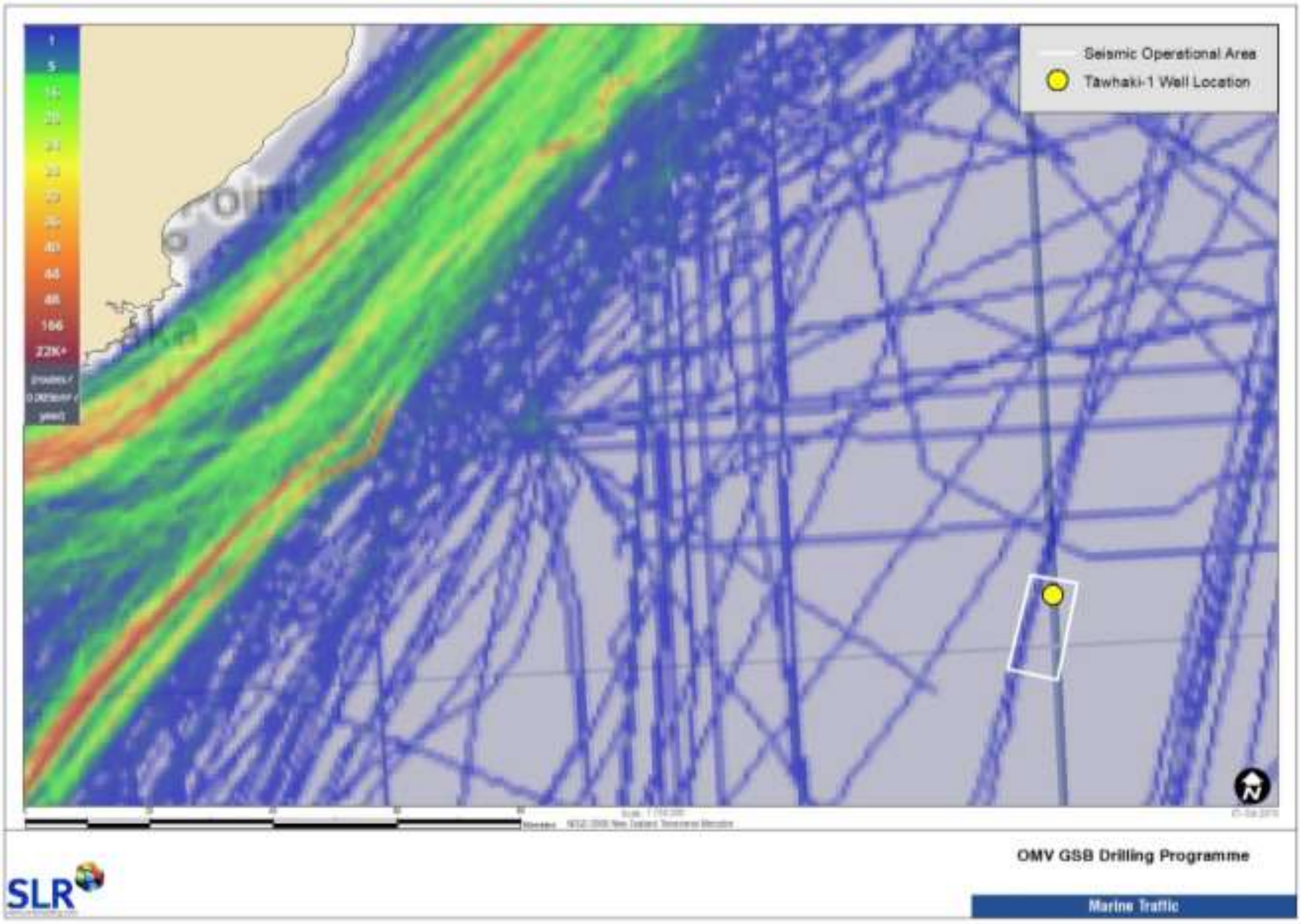
The majority of fishing in OEO1 takes place off the lower east coast of the South Island in the SSO Quota Management Area (MPI, 2014). The Total Allowable Commercial Catch for OEO1 is 2,500 tonnes; however, the full Total Allowable Commercial Catch is rarely caught. A limit of 400 tonnes has been set in agreement with MPI to protect the sustainability of Southland smooth oreo within the wider OEO1 stock (Gibbs, 2018). Historically most of the fishing effort has been concentrated in the 750 m to 1,250 m depth range (Gibbs, 2018), which overlaps with the bathymetric range within the Operational Area.

There are 67 quota owners for OEO1, with the main quota holders being: Pupuri Taonga Limited (the quota owning company of Sealord Limited), Sanford Limited, Talley's Group Management Limited, KPF Investments, Vela Quota Number One, Ngapuhi Asset Holding Company, and Ngāi Tahu Fisheries Settlement and Ngāi Tahu Seafood Resources (Gibbs, 2018). Pupuri Taonga Limited, Sandford Limited and Talley's Group Management Limited account for 74% of the OEO1 quota shares (Gibbs, 2018).

5.4.2 Commercial Shipping

Maritime New Zealand recommends that commercial vessels should stay a minimum of 5 NM off the mainland, any charted points of danger, or any offshore islands. There are no dedicated shipping channels into/out of or between New Zealand's ports, and as a result, vessels travelling to/from or between ports will generally take the most direct or shortest route possible, providing it is safe to do so. It is noted that the Operational Area lies further offshore than most of the typical national shipping routes. In general, limited vessel traffic within the Operational Area will be associated with the commercial maritime industry for national passages (**Figure 20**).

Figure 20 Marine Traffic Density within and inshore of the Operational Area



Source: Re-drawn from MarineTraffic.com (2019)

6 Potential Environmental Effects and Mitigation Measures

This section presents an overview of the potential environmental effects that may arise from the operation of the GSB Checkshot Survey. Effects could occur under normal operating situations (i.e. planned activities), or during an accidental incident (i.e. unplanned events). Proposed mitigation measures are provided throughout the relevant sections.

As the GSB Checkshot Survey will be conducted under the provisions of the marine consent for the GSB EAD Programme, some of the activities associated with the Checkshot Survey have been assessed under the marine consent for the GSB EAD Programme. As a result, certain activities, for example the physical presence of the MODU and support vessel, have not been addressed in detail within this MMIA.

6.1 Environmental Risk Assessment Methodology

The following steps were followed in order to assess the significance of potential effects from the checkshot surveys:

- Identification of the sources of potential effects (both positive and negative);
- Description of potential effects;
- Identification of the key potential environmental receptors and their sensitivity to potential effects;
- Description of mitigation measures that will be employed to minimise potential effects; and
- Assessment of the significance of any residual effects. This assessment considers the likelihood and magnitude of any residual effect in relation to the sensitivity of each environmental receptor. The ‘Assessment of Significance’ criteria used for residual effects are provided in **Table 18**.

Table 18 Assessment of Significance of Residual Effects

Negligible Effect

- No residual effects are predicted; or
- The risk of residual effects occurring is extremely low; and
- The effect is predicted to be of small enough magnitude that it does not require further consideration, and no recovery period is required.

Minor Effect

- The risk of residual effects occurring is low; and/or
- The residual effect is predicted to disappear rapidly (within hours) after cessation of the causative activity.
- No further management measures are required for the return to the original situation or behaviour.

Moderate Effect

- The risk of residual effects occurring is moderate; and/or
- The residual effect is predicted to occur at a level which requires only a short period of recovery (up to 24 hours) following cessation of the activity.
- No further management measures are required for the return to the original situation or behaviour.
- For acoustic effects on marine mammals, this effect is likely to occur when exposed to sound levels up to 171 dB re 1 $\mu Pa^2.s$; i.e. behavioural changes and masking are possible, but no threshold shifts will occur.

Major Effect

- The risk of residual effects occurring is high; and/or
- The residual effect is predicted to occur at a level which requires a long period of recovery (greater than 24 hours) following cessation of the activity.
- For acoustic effects on marine mammals, this effect is likely to occur when exposed to sound levels between 171 – 186 dB re 1 $\mu Pa^2.s$; i.e. temporary threshold shifts are possible.

Severe Effect

- The risk of residual effects occurring is very high; and/or
- The residual effect is predicted to occur at a level whereby no recovery is expected following cessation of the activity.
- For acoustic effects on marine mammals this effect is likely to occur when exposed to sound levels greater than 186 dB re 1 $\mu Pa^2.s$; i.e. Permanent Threshold Shift or other physiological damage is possible.

6.2 Planned Activities

6.2.1 Physical Presence of MODU and Support Vessel

Operation of the acoustic source will be carried out onboard the MODU used to drill the wells associated with the GSB EAD Programme. Two MMOs will be on the MODU for the marine mammal observations during daylight hours. A support vessel will be present around the MODU upon which the PAM Operators will be based to avoid the noise interference on the MODU and will be circling the MODU at a radius of approximately 1 km to acoustically detect any marine mammals.

As the GSB Checkshot Survey will be conducted under the provisions of the marine consent for the GSB EAD Programme, potential effects arising from the physical presence of the MODU and support vessel have been addressed within the marine consent applications and summarised within this MMIA for completeness.

6.2.1.1 Potential Effects on Marine Mammals

In the presence of vessels marine mammals tend to exhibit two stereotypical behaviours: avoidance or attraction (Wűrsig *et al*., 1998). These responses can affect the animal's energy expenditure when they become distracted from engaging in natural behaviours (e.g. feeding, resting, socialising etc.). Avoidance responses are more frequently documented than attraction responses, with avoidance most commonly leading to animals becoming temporarily displaced from an area (Wűrsig *et al*., 1998). Displacement is of particular concern when changes occur frequently over a prolonged period and/or when they affect critical behaviours (i.e. feeding, breeding and resting). While the physical presence of the MODU and support vessel has the potential to cause some changes in marine mammal behaviours, the short duration and stationary nature of the GSB Checkshot Survey means the disturbance would be temporary and localised.

'Ship strike' refers to the collision between a vessel and animal and has been recognised as an increasing global conservation concern for marine mammals (IWC, 2014). The potential for ship strike is present in all areas where marine mammals and vessel traffic overlap. The potential effects of the MODU and support vessel on marine mammals were covered in specific detail in the Marine Consent documents, and the short-term, largely stationary operations during the GSB Checkshot Survey provides no greater risk for collision/entanglement than that assessed in the GSB EAD Marine Consent applications..

Overall, it is considered that the risk to marine mammals arising from the physical presence of the MODU and support vessel during the GSB Checkshot Survey is **negligible**.

6.2.1.2 Potential Effects on Seabirds

Seabird interactions with all vessel types are relatively common in both coastal and open waters. Although most interactions are harmless or even positive (e.g. the provision of perching opportunities), some can be detrimental and may cause injury or death (e.g. bird strike and/or entanglement with vessel structures). Seabirds have been shown to respond to vessels by avoidance of heavily used areas and disruption of feeding behaviours (Schwemmer *et al.*, 2011; Velando & Munilla, 2011).

Due to their taonga status, concerns were raised by some local iwi groups that were consulted prior to a seismic survey acquiring seismic data within PEP 50119 and PEP 50120. Concerns raised were with regard to the potential for a ‘dazzle’ effect on sooty shearwaters at night time and the potential for sooty shearwaters to be attracted to the vessel’s lights causing a fatal collision. During the approximately 100-day seismic survey, no sooty shearwater interactions were observed with the vessel (RPS, 2012). This seismic survey differs to the proposed GSB Checkshot Survey in that a large seismic vessel and expansive towed equipment was required. As the single acoustic source will be lowered from the side of the stationary MODU and given the lack of effects on sooty shearwaters reported in RPS (2012), no significant effects on this species due to the presence of the MODU and support vessel are expected.

The potential effects of the MODU and support vessel on seabirds were covered in specific detail in the Marine Consent documents, and the short-term, largely stationary operations during the GSB Checkshot Survey provides no greater risk for collision/entanglement than that assessed in the GSB EAD Marine Consent applications. Overall, the risk to seabird populations from the physical presence of the MODU and support vessel during the GSB Checkshot Survey would be **negligible**.

6.2.1.3 Potential Effects on Other Marine Users

The short duration and stationary, highly localised nature of the GSB Checkshot Survey means there is unlikely to be a hazard of collision and the temporary displacement of other marine users from the Operational Area would not increase above the already consented presence for the wider GSB EAD Programmes.

Other commercial users in the GSB area will be notified of presence of the MODU and support vessel through notices to mariners and coastal navigation warnings, and the fact that the MODU will have been on location for 30 – 90 days prior to any checkshot survey commences. Other marine users will be restricted from transiting in close proximity to the MODU due to the enforced non-interference zone around the MODU. In addition, all vessels involved in the GSB Checkshot Survey will comply with COLREGS (e.g. radio contact, day shapes, navigation lights, etc.). With these mitigation measures and management practices in place, the environmental risk to other marine traffic around the well areas due to the presence of the MODU and support vessel during the GSB Checkshot Surveys is considered to be **negligible**.

6.2.2 Acoustic Disturbance to the Marine Environment

The acoustic source produces a predominantly low frequency noise that is of a short duration and with high peak source levels. The acoustic pulses are directed downwards and propagate efficiently through the water column with little loss from attenuation (i.e. absorption and scattering). Upon activation of the acoustic source, most of the emitted energy is of low frequencies between 0.1 and 0.3 kHz; however, pulses also contain higher frequencies of 0.5 – 1 kHz, albeit in small amounts (Richardson *et al*., 1995). The low-frequency component of the sound spectrum attenuates slowly, while the high-frequency component rapidly attenuates to levels similar to those produced by natural sources.

The acoustic pulse produces a steep-fronted wave that is transformed into a high-intensity pressure wave (i.e. a shock wave with an outward flow of energy in the form of water movement). This results in an instantaneous rise in maximum pressure, followed by an exponential drop in pressure. The environmental effects on animals in the vicinity of a source are defined by individual interactions with these sound waves. The potential effects of an acoustic disturbance can be grouped into the following four categories:

- Physiological effects – e.g. changes in hearing thresholds, damage to sensory organs, or traumatic injury;
- Behavioural effects and related impacts – e.g. displacement/avoidance, startle response, disruption of feeding, breeding or nursery activities, etc.;
- Perceptual effects/auditory masking – interference with communication; and
- Indirect effects – e.g. behavioural changes in prey species that affects other species higher up in the food chain and could lead to ecosystem level effects.

A high-intensity external stimulus such as an acoustic disturbance will typically elicit a behavioural response in animals; usually avoidance or a behavioural change. The duration and intensity of the animal's response is impacted by the nature (continuous vs. pulsed noise), source (visual, chemical or auditory), and intensity of the stimulus, as well as the animal's species, gender, reproductive status, health and age. A behavioural response is an instinctive survival mechanism that serves to protect animals from injury. Consequently, animals may suffer temporary or permanent physiological effects on cases when the external stimulus is too high, or the animal is unable to elicit a sufficient behavioural response (e.g. swim away fast enough). Temporary or permanent physiological effects may also be incurred due to a behavioural response (e.g. getting the 'bends' from swimming quickly to the surface from depth).

When considering the effects of the GSB Checkshot Survey on marine fauna, caution must be taken in interpretation of results as most studies have focused on vessel-based 2D and 3D surveys. During the GSB Checkshot Survey the small volume acoustic source is stationary, and relatively few shots are fired over a short survey period (i.e. hours). In comparison, most 2D and 3D seismic survey programmes typically run continuously for multiple days to months, and utilise a large acoustic source fired approximately every 10 seconds.

The Code of Conduct was developed specifically to minimise the potential behavioural and physiological effects on marine mammals of acoustic disturbance from seismic surveys. Compliance with the Code of Conduct represents the primary way in which the potential effects of acoustic disturbance during the GSB Checkshot survey will be managed. The Code of Conduct requires STLM for any Level 1 survey that will occur within an Area of Ecological Importance (**Figure 4**). STLM uses input parameters specific to the source array, and Operational Area-specific bathymetry and geological data. Although the Tāwhaki-1 Operational Area lies outside of the Area of Ecological Importance, STLM for this Operational Area has been included. A summary of the STLM results is presented in **Section 6.2.2.1**, while the full STLM report is provided in **Appendix A**.

6.2.2.1 Sound Transmission Loss Modelling

SLR undertook STLM to predict received SELs from the GSB Checkshot Survey within the Tāwhaki-1 Operational Area to assess for compliance with the mitigation zones in the Code of Conduct. The modelling of the STLM addresses the horizontal and vertical directionality of the acoustic array and takes into consideration the water depth and substrate within the Operational Area. The results of the modelling report are summarised below, with the complete report provided in **Appendix A**.

A single source location (i.e. the well location) was selected within the Operational Area for the purpose of short-range modelling. The short-range modelling location represents the proposed Tāwhaki-1 well location within the Operational Area, as shown in **Figure 1**. Short-range modelling predicts the received SELs over a range of a few kilometres from the source location, in order to assess whether the proposed survey complies with the regulatory mitigation zones SEL requirements defined within the Code of Conduct. The STLM short-range modelling results for the Operational Area are provided below.

The Continental Shelf of New Zealand is mainly covered with land-derived sand, gravel and mud sediments which have been predominantly introduced by riverine inputs. In order to predict the highest SELs possible during the GSB Checkshot Survey, the most reflective (i.e. worst-case) substrate was used for the modelling, resulting in the use of a sandy seabed. As the actual commencement for the GSB Checkshot Survey was not known at the commencement of the STLM, a winter sound speed profile was selected as this season favours the propagation of sound (i.e. it represents the worst-case season).

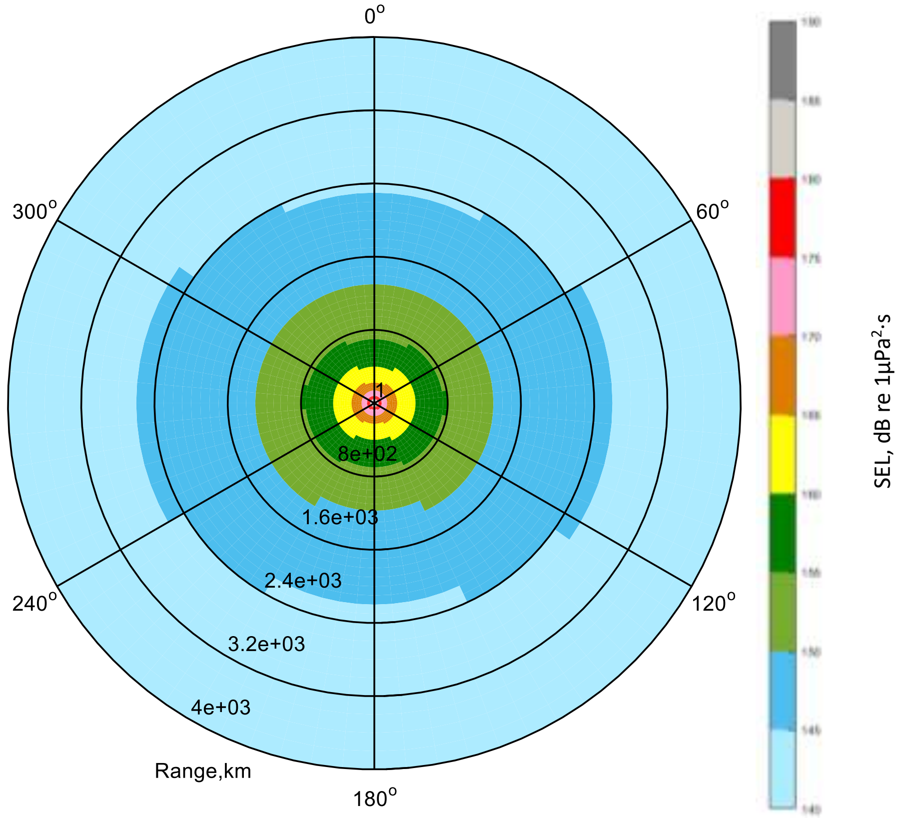
6.2.2.1.1 Tāwhaki-1 Modelling Results

The results of the short-range modelling at Tāwhaki-1 are depicted in **Figure 21** and **Figure 22**. **Figure 21** depicts the maximum received SELs across the water column as a function of azimuth and range from the centre of the array. The scatter plot (**Figure 22**) shows the predicted maximum SEL across the water column from the source array for all azimuths as a function of range from the centre of the acoustic source. The mitigation threshold levels (186 dB re 1µPa^2·s for PTS and 171dB re 1µPa^2·s for TTS) and Code of Conduct mitigation zones (200 m injury mitigation zone, and 1.0 km and 1.5 km behaviour mitigation zone for species of conern with and without calf present respectively) are also shown.

The results for modelling at Tāwhaki-1 are summarised in **Table 19**. The ranges from the centre of the array where the Code of Conduct SEL thresholds are, is provided in **Table 20**.

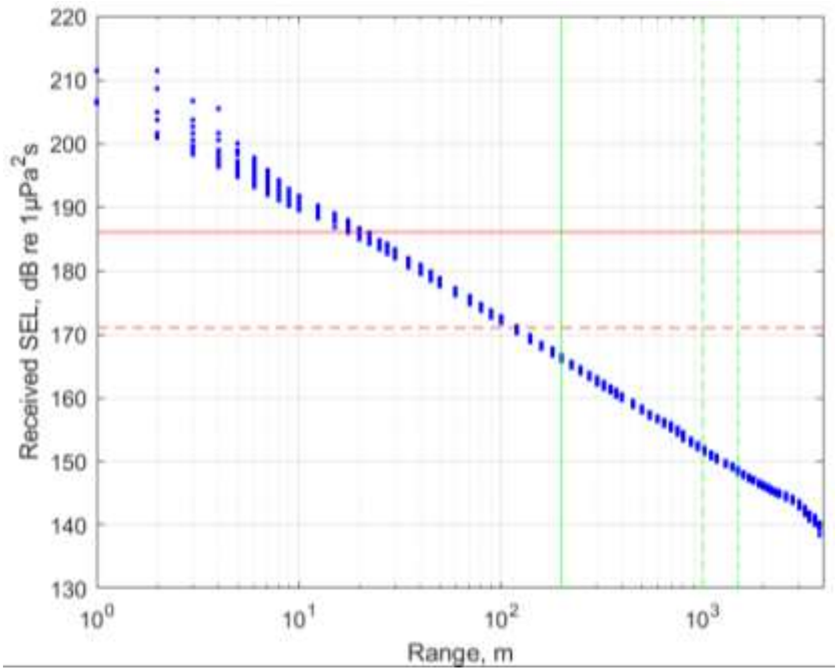
The results provided in **Table 19** demonstrate that the maximum received SELs from the GSB Checkshot Survey within the Tāwhaki-1 Operational Area are predicted to be below 186 dB re 1µPa^2·s at 200 m and below 171 dB re 1µPa^2·s at 1 km and 1.5 km. The ranges from the centre of the array where the predicted maximum SELs will reach the Code of Conduct SEL thresholds are 22.1 m for the 186 dB re 1µPa^2.s threshold, and 123.5 m for the 171 dB re 1µPa^2.s threshold (**Table 20**).

Figure 21 Predicted Maximum Received SELs across the Water Column at the Tāwhaki-1 Location as a Function of Azimuth and Range from the Centre of the Array



Note: Dark blue circles represent the mitigation zones of 200 m (solid), 1.0 km (dash), and 1.5 km (dash-dot).

Figure 22 Scatter Plot of Maximum Received SELs from the Acoustic Source at the Tāwhaki-1 Location



Note: Horizontal red lines show mitigation thresholds of 186 dB re 1µPa²·S (solid) and 171 dB re 1µPa²·S (dash). Vertical green lines show mitigation ranges of 200 m (solid), 1 km (dash) and 1.5 km (dash-dot).

Table 19 Predicted Maximum SELs at the Standard Code of Conduct Mitigation Zones for Modelled Locations within the Tāwhaki-1 Operational Area

Location	Water Depth (m)	SELs at different ranges (dB re 1µPa²·S)		
		200 m	1.0 km	1.5 km
Tāwhaki-1	1,323	166.7	152.4	148.9

Table 20 Ranges from the Centre of the Array where the Predicted Maximum SEL Equals the SEL Threshold Levels within the Tāwhaki-1 Operational Area

	Ranges complying with the SEL thresholds (m)	
Source Location	186 dB re 1µPa²·S	171 dB re 1µPa²·S
Tāwhaki-1	22.1	123.5

6.2.2.2 Potential Physiological Effects

Intense underwater noises could cause lethal and non-lethal physiological trauma or injury in marine organisms (Gordon *et al*., 2003). The Code of Conduct outlines threshold levels aimed at protecting marine mammals from physiological effects; however, such impacts are not limited to marine mammals. Tissue damage to sensory organs from acoustic releases associated with seismic surveys have been experimentally studied in fish, cephalopods and invertebrates, while shifts in hearing thresholds have been experimentally observed in some small pinnipeds and small cetaceans and hypothesised based on observed effects in terrestrial animals.

The sections below discuss the potential for physiological effects (trauma or damage) to faunal groups.

6.2.2.2.1 Zooplankton

Zooplankton do not have hearing structures; however, they are able to detect changes in surrounding pressure (Richardson *et al,* 2017). Until recently it was believed that exposure to acoustic emission from seismic has no significant effects on zooplankton abundance or mortality (e.g. Pearson *et al.,* 1994; Parry *et al.,* 2002; Dalen *et al,* 2007; Payne *et al*., 2009), with physiological effects only occurring at distances up to 5 m from the active source, and mortality out to 3 m (Booman *et al.,* 1996; Payne *et al,* 2009). Other studies report no adverse effects to zooplankton at an individual (e.g. Dalen & Knutsen, 1987; Bolle *et al*., 2012) or population (Saetre & Ona, 1996) level.

McCauley *et al*. (2017) provided evidence to suggest that seismic surveys may cause significant mortality to zooplankton populations. McCauley *et al*. (2017) assessed the health of the plankton community in relation to exposure to a single 150 in^3 acoustic source using sonar surveys and zooplankton net tows to determine zooplankton abundance and counts of dead zooplankton before and after seismic exposure. McCauley *et al*. (2017) found reductions on zooplankton abundance within 509 – 658 m from the source, with the range of no impact on zooplankton abundance occurring at 973 – 1,119 m. Post-exposure there was two to three times more dead zooplankton and 100% mortality in krill larvae at all distances. Sonar backscatter showed a 'hole' in the plankton community up to 30 m deep that followed the prevailing track of the seismic source and was detectable from 15 minutes after exposure (McCauley *et al*., 2017).

In response to McCauley *et al*. (2017), the Australian Petroleum Production and Exploration Association commissioned CSIRO to model the potential local and regional impacts of a typical seismic survey in the Northwest of Australia based on the results of McCauley *et al*. (2017). The CSIRO study showed that although zooplankton populations were impacted out to a distance of 15 km within the seismic survey area, impacts were barely discernible within 150 km of the survey area, and there was no apparent effect at a regional scale. Following exposure, zooplankton populations rapidly recovered due to fast growth rates and the dispersal and mixing of individuals from inside and outside of the impacted region (Richardson *et al*., 2017).

An additional independent review (IAGC, 2017) was also done in order to address the results published by McCauley *et al*. (2017) as the results were so inconsistent with previously documented effects. Overall, the reviewers "*expressed the opinion that although the results of the study should be considered further, the data were not sufficient to support the conclusions offered by McCauley et al. (2017)*". The reasons for this were:

1. The sample size was inadequate;
2. Water column movement data were insufficient to support the contention of a "hole" in the plankton field;
3. Towed net and acoustic survey data disagreed regarding zooplankton class size;
4. The acoustic "hole", which was taken to indicate dead zooplankton, may simply have resulted from zooplankton which had swum to the bottom which was just 10 m away;
5. Bottom sampling should have been conducted to address the questions of whether the large zooplankton were present, whether they had been killed and sunk to the bottom, or whether they actively swam to the bottom;
6. The wrong sized nets were used and were not towed correctly; and
7. There was statistical error in the net tow data.

The results of the review were shared with the authors of McCauley *et al*. (2017) and the authors concurred with many of the shortcomings identified by the reviewers.

It is important to put the results from Richardson *et al*. (2017) and McCauley *et al*. (2017) into context with regard to the GSB Checkshot Survey. Richardson *et al*. (2017) modelled an acoustic source with a volume of 3,200 in^3, with the model run over an area of 2,900 km^2 for 35 days. The acoustic source used in the GSB Checkshot Survey will have a total volume of 450 in^3 so is significantly smaller than that used in Richardson *et al.* (2017). Furthermore, the findings of Richardson *et al*. (2017) and McCauley *et al.* (2017) are based on a 3D seismic survey operating over a wide area for an extended period of time. The GSB Checkshot Survey will occur from a single fixed location within the Operational Area, where previous surveys have taken up to 12 hours to complete; however, it is more likely they will be completed within 5.5 hours (assuming no delays or shut downs). The number of activations of the acoustic source will be significantly lower than that of a 3D seismic survey whereby the acoustic source is activated approximately every ten seconds.

Recently, Fields *et al*. (2019) exposed the copepod *Calanus finmarchius* to acoustic releases from two acoustic sources with a combined total volume of 520 in^3. *C. finmarchius* is a key component of the Norwegian planktonic community that is found in high abundances and supports a valuable commercial fishery. Immediate mortality was significantly different from controls at distances of 5 m or less, and mortality after one week was significantly higher at distances of 10 m from the acoustic source but not at distances of 20 m. Increase in mortality relative to the controls did not exceed 30% at any distance from the acoustic source. Fields *et al*. (2019) concluded that acoustic waves from seismic activity have limited effects on the mortality or escape response of *Calanus sp*. within 10 m of the source and no measurable impact at greater distances. The findings of Fields *et al*. (2019) contradict those of McCauley *et al*. (2017) while supporting previous studies such as Booman *et al.* (1996) and Payne *et al.* (2009), with effects limited to within a few tens of meters of the acoustic source.

While the potential for mortality of zooplankton during the GSB Checkshot Survey cannot be completely ruled out, based on the small volume acoustic source that will be used, any effects will likely be restricted to within the immediate vicinity of the acoustic source (i.e. within a few meters). Due to the stationary nature of the MODU and acoustic source and surrounding high energy marine environment (replenishing plankton populations), there will not be any wide-ranging or population-level effects on zooplankton. The residual risk of physiological effects on zooplankton populations due to acoustic disturbance from the GSB Checkshot Survey is considered to be **minor**.

6.2.2.2.2 Benthic Invertebrates

Many marine invertebrates have mechanoreceptors (sensory hairs or organs), which bear some resemblance to vertebrate ears, and are sensitive to sound. For example, in crustaceans, the main vibration receptors are in the statocysts and the walking legs (Aicher *et al*., 1983). McCauley (1994) reported that for many benthic species, these receptors will perceive seismic acoustic outputs, but this will only occur within a few metres from the sound source.

The Royal Society of Canada (2004) reported that research has shown that macro-invertebrates (e.g. scallops, sea urchins, mussels, periwinkles, crustaceans, shrimp, and gastropods) suffer very little mortality below sound levels of 220 dB re 1 µPa @ 1 m, while some show no mortality at 230 dB re 1 µPa @ 1 m. This resilience to sound exposure attributed to the lack of a swim bladder (Moriyasu *et al.*, 2004). The potential for physiological damage of shellfish varies with the species exposed and the exposure circumstances (e.g. source level and duration, etc.).

Moriyasu *et al*. (2004) compiled a literature review of some early studies, the results of which are summarised below:

- Dalen (1994) exposed amphipods to a seismic source with a source level of 223 dB re 1 µPa at distances of 0.5 m or greater with no physiological effects detected;
- Webb and Kempf (1998) saw no mortality or evidence of reduced catch rate for brown shrimp exposed to a source level of 190 dB re 1 µPa @ 1 m in water depths of 2 m;
- Dalen (1994) observed no physiological effects in blue mussels (Mytilus edulis) exposed to a seismic source with a source level of 223 dB re 1 µPa at distances of 0.5 m or greater; and
- Matishov (1992) recorded shell damage associated with high intensity seismic source exposure for one of three species of mollusc exposed to a source level of 233 dB re 1 µPa at a distance of 2 m.

The presiding theory of relative resilience for crustaceans has been challenged by Day *et al*. (2016) who exposed red rock lobster (*Jasus edwardsii*; also found in New Zealand) to a 150 in^3 source in field studies off Tasmania. Key findings from this study were:

- Statocyst hair cells sustained long-term damage following seismic exposure; however, these lobsters did not show impaired righting reflexes suggesting that affected individuals had adapted to cope with this damage; and
- Haemolymph biochemistry showed no response to seismic exposure, indicating that lobsters were physiologically resilient to acoustic disturbance; however, haemolymph counts were slightly lower in exposed lobsters than in control lobsters and the relevance of this lowered haemolymph count is unknown.

Day *et al* (2016) also exposed scallops (*Pecten fumatus*) and found exposed animals had significantly lower haemocyte levels (a proxy for circulation, immunity and stress) in response to seismic exposure when compared to control scallops). Day *et al*. (2016) noted that the ecological implications of these changes warrant further investigation, although it seems that exposed scallops could suffer from a depressed immune response.

A number of coral species were observed during the Tāwhaki-1 Pre-drill Survey, including Scleractinia (stony corals) at densities that meet the Schedule 6 criteria for a sensitive environment (**Section 5.2.3.1**); however, these coral species were located beyond the Operational Area and associated with the seamount features. Heyward *et al*. (2018) investigated the effects of a four-day seismic run on Scleractinian corals and found no detectable effect on soft tissues or skeletal integrity. A subsequent full 3D seismic survey occurred in the broader reef lagoon over a period of two months. There was with no effect of seismic activity measured immediately after and up to four months following the 3D survey, i.e. there was no coral mortality, skeletal damage, or visible signs of stress (Heyward *et al*., 2018). Based on these results, there will be no effects on Scleractinia corals arising from the GSB Checkshot Survey. The closest Scleractinia corals were observed 18.9 km from the Tāwhaki-1 well location; this distance, as well as the small acoustic volume and short duration of the survey act to further reduce the likelihood of any effects occurring on corals.

Xenophyophores and brachiopods have also been identified in the vicinity of the Operational Area at densities that meet the Schedule 6 criteria for a sensitive environment; however, again the brachiopods were associated with the hard substrate features on the seamounts. There have been no studies into the effects of seismic on these invertebrates.

Due to the short-term nature of the proposed GSB Checkshot Survey, the highly localised area of potential effects and low abundance of invertebrates expected in close proximity of the MODU, the overall residual risk of physiological effects on benthic invertebrates is assessed as **negligible**.

6.2.2.2.3 Cephalopods

Controlled exposure experiments have been undertaken on captive cephalopods to determine possible physiological effects of underwater noise. Andre *et al.* (2011) exposed four cephalopod species to low-frequency sounds with SELs up to 175 dB re $1\mu Pa^2$-s. All of the exposed animals exhibited similar changes to the sensory hair cells of the statocysts that are responsible for the animal's sense of balance. This damage gradually became more pronounced in animals that were continuously exposed to the noise source for up to 96 hours. Andre *et al*. (2011) estimated that such trauma effects could occur out to 1.5 – 2 km from an operating acoustic source. Kaifu *et al.* (2007) investigated the effects of sound on the octopus *Octopus ocellatus* and found that respiration rates were suppressed during periods of exposure to low-frequency sound.

While not specifically targeted within the Operational Area, arrow squid (*Nototodarus gouldii* and *N. sloanii*) are caught throughout New Zealand's waters. Squid form pelagic schools over the continental shelf in waters up to 500 m deep but are most prevalent in water depths less than 300 m, reducing their potential presence within the Operational Area. Furthermore, arrow squid are short-lived, fast growing and have high fecundity rates (MPI, 2017). These life history traits mean that populations are well adapted to cope with episodes of disturbance or decreased survival rates.

As various squid and octopus were observed during the Tāwhaki-1 Pre-drill Survey, there is the potential for cephalopods to be exposed to acoustic disturbance during the GSB Checkshot Survey. However, their mobile nature means that cephalopods can readily move away from the highest sound levels close to the acoustic source to avoid physiological damage. It is therefore anticipated that there will be no long-term effects to squid and octopus populations as a result of the GSB Checkshot Survey, with only occasional individuals affected.

No specific mitigation measures will be in place to reduce the potential effects of seismic surveys on cephalopods; and based on the information above the residual risk of physiological trauma to cephalopod species from acoustic disturbance during the GSB Checkshot Survey is considered to be **negligible**.

6.2.2.2.4 Fish

Sound may affect fish physiology in a number of ways depending on the source level and species involved. Observed physiological effects include increased stress levels (e.g. Santulli *et al*., 1999; Smith, 2004; Busciano *et al*., 2010), temporary or permanent threshold shifts (e.g. Smith, 2004; Popper *et al*., 2005), or damage to sensory organs (McCauley *et al*., 2003). Fish will typically move away from a loud acoustic source if they experience discomfort (see **Section 6.2.2.3.3**), minimising their exposure and the potential for physiological effects (Vabø *et al*., 2002; Pearson *et al*., 1992; Wardle *et al*., 2001; Hassel *et al*., 2004; Boeger *et al*., 2006).

In a major literature review undertaken by scientific experts attending a Fisheries and Oceans Canada-run workshop, the following conclusions on fish physiological effects and mortality were made (DFO, 2004):

- There are no documented cases of fish mortality upon exposure to seismic sound under field operating conditions; and
- Exposure to seismic sound is considered unlikely to result in direct fish mortality.

The workshop conclusions indicated that under experimental conditions sub-lethal and/or physiological effects have sometimes been observed in fish exposed to seismic outputs; however, the experimental designs make it impossible to determine the sound intensity required to elicit the observed effects, and the biological significance of the results. It was concluded that current information was inadequate to evaluate the likelihood of sub-lethal or physiological effects under field operating conditions. The ecological significance of effects could range from trivial to important, depending on their nature (DFO, 2004).

Popper *et al*. (2014) developed guidelines to predict at what threshold levels seismic surveys may cause physiological damage to fish. Using fish with a swim bladder that is involved with hearing as a worst-case scenario, mortality and potential mortal injury may occur at levels greater than 207 dB re 1 µPa. Based on the STLM results, such noise levels would only occur within a few meters of the acoustic source. High densities of fish are not expected to be present in close proximity to the acoustic source, and any species present are likely to be highly mobile with no fixed territories so able to move away from the disturbance.

The potential for residual physiological effects on fish populations from acoustic disturbance during the GSB Checkshot Survey has been assessed as **negligible**.

6.2.2.2.5 Seabirds

As high intensity acoustic disturbances have the potential to cause physiological injury to other faunal groups it is reasonable to assume that diving seabirds could also suffer physiological harm. Seabirds on the sea surface are unlikely to suffer physiological effects as the "Lloyd mirror effect" (see discussion in **Section 6.2.2.3.5**) means that noise levels at the surface are lower than those deeper in the water column (Carey, 2009). Therefore, only seabirds that dive in close proximity to the acoustic source will be at risk of suffering physiological damage. To date there is limited evidence of physiological effects from seismic surveys on seabirds, with all documented effects limited to behavioural effects (see **Section 6.2.2.3.4**).

Due to their largely aquatic lifestyle and lack of flight ability, penguins are more susceptible to physiological effects from seismic activities than other seabirds. Three species of penguin have been assessed as potentially present in the wider GSB (i.e. yellow-eyed penguin, Fiordland crested penguin, and little penguin), although no penguin species is considered to have a likely occurrence in the Operational Area (see **Table 14** and **Section 5.2.9**) on account of the depths present within the Operational Area and its distance from the nearest coastline.

While diving birds may occur within the Operational Area during the GSB Checkshot Survey due to the MODU acting as an attractant (see **Section 6.2.1.2**), foraging in close proximity is unlikely as the small fish that constitute seabird prey will likely be temporarily displaced from the immediate vicinity of the active acoustic source. Seabirds would detect changes in prey distribution and cease foraging, reducing their exposure to sound and potential physiological effects.

The residual risk of physiological effects to seabirds from acoustic disturbance during the GSB Checkshot Survey is considered to be **negligible**.

6.2.2.2.6 Marine Mammals

Marine mammals are highly vocal and dependent on sound for almost all aspects of their lives (Weilgart, 2007). In the event that a marine mammal is exposed to high-intensity underwater noise at close range, lethal and sub-lethal physiological effects may occur (Gordon *et al*., 2003). The sound intensities required to elicit such effects are largely unknown for most species, and current knowledge on traumatic thresholds is based on few experimental species (e.g. Southall et al., 2007; NOAA, 2018).

The main type of auditory damage documented in marine mammals is known as a 'threshold shift' whereby exposed individuals exhibit an elevation in the lower limit of their auditory sensitivity; they experience hearing loss. Threshold shifts can be permanent or temporary, with temporary shifts more common in marine mammals as noise levels that elicit TTS will be experienced over much larger areas than those that elicit PTS and therefore more animals are potentially exposed. However, exposure to sounds that can cause a temporary threshold shift can usually cause a permanent threshold shift (i.e. permanent hearing loss) if the animal is repeatedly exposed for a sufficient period of time (Gordon *et al*., 2003) Very high SELS are believed to be required to cause immediate serious permanent physiological damage in marine mammals (Richardson *et al*., 1995). A permanent threshold shift is thought to occur at 186 - 198 dB re 1 µPa^2-s (Southall *et al*., 2007).

The Code of Conduct sets thresholds that predict the physiological effects on marine mammals during seismic surveys. These thresholds follow Southall *et al*. (2007). The 'injury criteria' (i.e. threshold above which a permanent threshold shift would be expected) is exceeded if marine mammals are subject to SELs greater than 186 dB re 1μPa^2.s. A temporary threshold shift is predicted to occur at 183 dB re 1 μPa^2-s for all cetaceans and 171 dB re 1 μPa^2-s for pinnipeds. An onset threshold for TTS of 171 dB re 1μPa^2.s SEL has been adopted by the Code of Conduct for minimising disturbances to marine mammals. The Code of Conduct requires mitigation measures that have been specifically designed to minimise the potential for marine mammals to be subject to SELs that could cause temporary or permanent threshold shifts. Compliance with the Code of Conduct mitigation measures (see **Section 3.5**) is the fundamental way in which auditory damage in marine mammals will be avoided during the GSB Checkshot Survey. The protocol that the MMOs and PAM Operators will follow during the GSB Checkshot Survey is detailed in the MMMP (**Appendix C**).

STLM results for the GSB Checkshot Survey indicated that compliance with the 186 dB re 1μPa^2.s threshold occurs at a maximum distance of 22.1 m (**Table 20**). As sound levels that could cause physiological damage would only occur in very close proximity to the acoustic source, compliance with the standard Code of Conduct mitigation zones will sufficiently protect marine mammals from physiological effects. As per the Code of Conduct requirements, ground-truthing during the survey will be carried out to verify the results of the STLM.

Based on the results of the STLM, the onset threshold for TTS will be met at distances of 123.5 m from the acoustic source (**Table 20**). Hence, the standard Code of Conduct mitigation zones of 1 km and 1.5 km will be sufficient to protect marine mammals (without and with calf respectively) from TTS during the GSB Checkshot Survey.

The risk of physiological injury increases for any marine mammal that approaches the acoustic source closer than approximately 22 m (based on STLM results). New Zealand fur seals have been known to aggregate around platforms and Floating Production Storage and Offloading (**FPSO**) units in the Taranaki Basin and will likely be present within the Operational Area during the GSB Checkshot Survey. As the MODU from which the acoustic equipment will be deployed will have been on location for up to 90 days, New Zealand fur seals may have aggregated around the MODU and so may be close enough to experience physiological injury. The design of the MODU associated with the drilling of the Tāwhaki-1 well reduces the likelihood of New Zealand fur seals settling on the MODU structure (i.e. a semi-submersible MODU with no exposed structure for resting sites); however, as per the Code of Conduct, start up will be delayed if a New Zealand fur seal is observed during pre-start observations within 200 m of the source.

In the event that a marine mammal stranding event occurs inshore of the Operational Area during the GSB Checkshot Survey, or up to two weeks following the completion of each survey, OMV will on a case-by-case basis consider covering the cost of a necropsy in an attempt to determine the cause of death. This will be considered following discussions with DOC. DOC would be responsible for all logistical aspects associated with the necropsy such as coordination with Massey University pathologists to undertake the work.

If exceedances of the physiological thresholds for individual marine mammals do occur during the GSB Checkshot Survey, a temporary threshold shift may occur. However, any incidents of TTS from the GSB Checkshot Survey are expected to be confined to within the immediate vicinity of the acoustic source. In the event that TTS does occur, affected animals will recover once the survey is complete or they move away from the MODU. Permanent threshold shifts are unlikely during the GSB Checkshot Survey on account of the typical avoidance behaviour exhibited by marine mammals, and compliance with the Code of Conduct (i.e. pre-start observations, delayed starts, and shutdowns). This serves to minimise the risk to marine mammals to as low as reasonably practicable. Marine mammals would have to be in extremely close proximity to the acoustic source to experience permanent physiological trauma. On this basis the residual risk of physiological effects on marine mammals is considered to be **moderate**.

6.2.2.3 Potential Behavioural Effects

A behavioural response is a demonstrable change in an animal's activity in response to a disturbance (Nowacek *et al*., 2007). Behavioural responses include movement away from an area to avoid the disturbance, or a change in normal behaviour (e.g. diving, respiration, swimming speed). The most commonly observed behavioural response is avoidance and has been widely documented in marine mammals (e.g. Goold, 1996; Stone & Tasker, 2006; Thompson *et al*., 2013) and fish (e.g. Engas *et al*., 1996; Slotte *et al*., 2004) during seismic operations. Some animals may be attracted to a disturbance.

Displacement from an area can lead to relocation into sub-optimal or high-risk habitats, resulting in negative consequences such as increased exposure to predators, decreased foraging or mating opportunities, alterations to migration routes, etc. Indirect effects may also occur as a result of displacement, such as disruption of a predator's feeding activities due to the displacement of prey species.

The potential for behavioural effects in each faunal grouping is discussed below.

6.2.2.3.1 Benthic Invertebrates

Exposure to seismic sound can elicit various behavioural responses in benthic invertebrates which have the potential to adversely affect a population by, for example, reducing foraging and/or predator avoidance rates, or avoidance of/movement from an area where a seismic survey has occurred. Conversely, they may elicit responses that are brief and pose no overall risk (e.g. a startle response).

Research has shown that avoidance behaviours to sound have longer-lasting effects on populations than startle responses. Hawkins *et al*. (2015) reports that, at lower sound levels, behavioural responses are more likely to occur than physical and/or physiological responses. Behavioural responses are, however, the most difficult to monitor *in situ* and consequently, many studies investigating the effects of seismic operations on the behaviour of benthic invertebrates are conducted under laboratory conditions or by deploying caged individuals in the field (Carroll *et al*. 2017).

Day *et al.* (2016) conducted a field experiment in Tasmanian waters to assess the behavioural responses of rock lobsters (*Jasus. edwardsii*) to a 150 in^3 acoustic source. This study found that seismic exposure significantly increased righting time of lobsters that had been placed on their backs. The ecological result of this could potentially increase the predation rates of exposed individuals

Christian *et al*. (2003) examined snow crab behaviour before, during and after exposure to seismic outputs and observed that in the laboratory crabs reacted slightly when sharp sounds were made near them. However, in the field, caged crab showed no readily visible reactions to the 200 in^3 acoustic source operating 50 m above the cages. Tagged crabs did not undergo any large-scale movements out of the area.

There is a lack of information with regard to the behavioural effects of seismic surveys on shellfish. As reported by Carroll *et al*. (2017), two studies have shown evidence of a startle response in bivalves at realistic sound exposure levels (Day *et al*. 2016; Roberts *et al*. 2015), although only Day *et al*. (2016) used seismic outputs as the sound source. Day *et al*. (2016) reported that scallops exposed to seismic display a distinctive flinching response, an increase in burial rate and are slower at righting themselves than control scallops. No energetically costly responses, such as swimming, have been observed in scallops due to exposure to an acoustic source.

Benthic infauna communities within the Operational Area are dominated by polychaetes with relatively high abundances of discrete foraminiferas also present (**Section 5.2.3**). Large epifuana present include ophiuroids, sponges/Porifera, anemones/Actinaria, echinoids, gastropods, holothurians, terebellid worms, foraminifera, bryozoans, and scaphopods. Stony corals, xenophyophores and brachiopods have been identified in the vicinity of the Operational Area in densities that meet the criteria for a 'sensitive environment'. As the majority of these invertebrate species (including those considered a sensitive environment) are sedentary or slow moving, behavioural responses such as avoidance are unlikely. There are no commercially fished benthic invertebrates (e.g. crustaceans and shellfish) present in the Operational Area which may be affected by the GSB Checkshot Survey.

The nature of the GSB Checkshot Survey provides protection of benthic invertebrates from the effects of seismic, namely the short period of time required to complete the survey (up to 12 hours), low number of acoustic activations required, and use of a stationary, low volume acoustic source. As such, the residual risk of behavioural impacts on benthic invertebrates from seismic exposure during the GSB Checkshot Survey has been assessed as **negligible**.

6.2.2.3.2 Cephalopods

Behavioural changes in response to acoustic disturbance have been documented for cephalopods. Caged cephalopods exposed to acoustic sources demonstrated a startle response above 151 – 161 dB re 1 µPa and tended to avoid the acoustic disturbance by exhibiting surface behaviours (McCauley *et al*., 2000). McCauley *et al*. (2000) suggested that thresholds affecting squid behaviour occur at 161 – 166 dB re 1 µPa rms. McCauley *et al*. (2000) also found that the use of soft starts effectively decreased the startle response; soft starts will be undertaken in accordance with the Code of Conduct (**Section 3.5.7**).

Fewtrell (2003) looked at the response of southern calamari squid (*Sepioteuthis australis*) to seismic survey noise and found avoidance behaviours once the noise levels exceeded 158 dB re 1 µPa, with significant increases in alarm responses with noise exceeding 158 – 163 dB re 1 µPa. There was a decrease in the frequency of alarm responses from repeated exposures, suggesting that the animals were becoming habituated (Fewtrell, 2003).

A subsequent study (Fewtrell & McCauley, 2012) further demonstrated that a source level of 147 dB re 1 µPa was necessary to induce an avoidance reaction in squid. Fewtrell & McCauley (2012) observed other reactions, including alarm responses (such as inking and jetting away from the source), increased swimming speed and aggressive behaviour. The authors found that there was an increase in the alarm response from the squid as the acoustic release noise levels increased beyond 147 – 151 dB re 1 µPa SEL. As in Fewtrell (2003) the reaction of the animals decreased with repeated exposure to the acoustic source suggesting either habituation or impaired hearing (Fewtrell & McCauley, 2012).

Given their pelagic lifestyle, there is the potential for squid to come near the acoustic source during the GSB Checkshot Survey. However, squid are generally short-lived, fast growing species with high fecundity rates. These life history traits mean they are well adapted to disturbance, and it follows that there is no anticipated long-term risk to squid populations given the very short-term nature of the GSB Checkshot Survey. Various octopus species were observed during the Tāwhaki-1 Pre-drill Survey; however, due to the stationary nature of the GSB Checkshot Survey, only those octopuses in close proximity to the MODU will be likely to experience behavioural effects. Consequently, the residual risk of behavioural impacts to cephalopods from seismic sound exposure during the GSB Checkshot Survey has been assessed as **minor**.

6.2.2.3.3 Fish and Commercial Fisheries

Behavioural responses of fish to acoustic disturbances vary depending on species traits, with the presence or absence of a swim bladder a major factor; species with swim bladders or other gas-filled chambers are generally more sensitive to sound and more likely to suffer adverse effects.

Studies into the behavioural impacts of seismic on fish are typically experimental whereby caged fish are exposed to an acoustic source or involve assessments of fisheries catch-effort data before and after a seismic survey. Variability in experimental design (e.g. source level, line spacing, timeframe, geographic area, etc.) and subject (e.g. species, wild vs. farmed, demersal or pelagic, migratory or site-attached, etc.) often makes overall conclusions and comparisons difficult. Captive studies typically only provide information on the behavioural responses of fish during and immediately after the onset of noise (Popper & Hastings, 2009), and laboratory experiments often apply intensities or durations of sound exposures that are unlikely to be encountered in the wild (Gray *et al.,* 2016). Caged studies are potentially biased as subjects are constrained and may be unable to exhibit avoidance behaviours like those that would be possible in the wild.

In general, there is little evidence of long-term behavioural disruption in fish. Slotte *et al*. (2004) provided the only evidence of a long-term behavioural effect of fish in response to a commercial 3D seismic survey off the coast of Norway. The distribution of herring and blue whiting within the seismic area and surrounding waters (up to 30 – 50 km away) was acoustically mapped. Acoustic abundance was consistently higher outside the seismic area than inside, with this interpreted to be an indication of long-term displacement.

Short-term responses are relatively common, and include startle responses (Pearson *et al*., 1992; Wardle *et al*., 2001; Hassel *et al*., 2004; Boeger *et al*., 2006), modification in schooling patterns and swimming speeds (Pearson *et al*., 1992; McCauley *et al*., 2000; Fewtrell & McCauley, 2012), freezing (Sverdrup *et al*., 1994), and changes in vertical distribution within the water column (Pearson *et al.,* 1992; Fewtrell & McCauley, 2012).

Short-term displacement has been documented during seismic surveys through observed vertical and horizontal avoidance away from the active seismic source (e.g. Pearson *et al*., 1992; McCauley *et al*., 2000; Colman *et al*., 2008; Handegard *et al*., 2013), while some studies have failed to detect any changes (e.g. Wardle *et al*., 2001; Peña *et al.,* 2013). Hassel *et al.* (2004) found evidence of habituation to underwater noise through time based on a decrease in the degree of startle response.

A concern around changes to fish behaviours is the potential for flow-on effects on commercial fisheries (McCauley *et al*., 2000). Studies into the effects of seismic on catch rates have revealed contradictory results, with some studies demonstrating a reduction in catch per unit effort (e.g. Skalski *et al*., 1992; Engas *et al*., 1996; Bendell, 2011; Handegard *et al*., 2013), while no observable change was documented by others (e.g. Pickett *et al*., 1994; Labella *et al*., 1996; Jakupsstovu *et al*., 2001). Observed effects were typically short-term, with no evidence of long-term displacement. Jakupsstovu *et al*. (2001) noted that although many fishers perceived a decrease in catch during seismic operations, logbook analysis revealed no statistically significant effects. Gausland (2003) has debated reported reductions in catch per unit effort, attributing changes instead to natural fluctuations in fish stocks or long-term negative trends.

While the above studies report various effects of seismic surveys on catch rates in commercial fisheries, it is important to note that these studies have reported on the effects of large-scale seismic surveys, using significantly larger acoustic sources than the GSB Checkshot Survey. A low level of commercial fishing effort occurs within the Operational Area (**Section 5.4.1**), and the area is not considered significant for commercial fishers. In the event that behavioural effects occur in fish around the Operational Area, these effects would occur in close proximity to the MODU and are not expected to affect the already low level of catch within the Operational Area.

Based on the lack of evidence of long-term effects on fish stocks, extremely short-term duration of behavioural effects, restricted spatial extent of any effects, and low level of commercial fishing within the Operational Area, the residual risk of behavioural effects on fish and flow-on effects on commercial fishery catch rates has been assessed as **minor**.

6.2.2.3.4 Seabirds

There is little information about the behaviour effects from seismic acquisition on seabirds; however, a number of authors have raised the possibility of disruption to seabird feeding activities. Goudie and Ankney (1986) suggests that seabird feeding behaviours could possibly be interrupted by acoustic disturbance from the seismic vessel passing through feeding grounds, and MacDuff-Duncan and Davies (1995) postulated that birds in the area could be alarmed as the seismic operations pass close-by, causing them to temporarily stop diving; however, these studies relate to seismic surveys from a vessel transiting through feeding grounds, with the vessel's movement a potential source of disturbance, not just the acoustic release.

Lacroix *et al*. (2003) assessed the effect of seismic operations on the foraging behaviour of moulting male long-tailed ducks in the Beaufort Sea. These birds are incapable of flying during the moult and increase their foraging time during this period to compensate for the nutritionally costly moult process. The findings of Lacroix *et al*. (2003) indicated that the abundance and distribution of ducks in both seismic and control areas changed similarly following the start of seismic operations suggesting that other influencing factors (e.g. wind) were more important for duck distribution than seismic activities, and that seismic activity did not significantly change the diving intensity of ducks. Overall, Lacroix *et al*. (2003) concluded that there was no evidence to suggest any displacement away from active seismic operations.

Pichegru *et al*. (2017) assessed the foraging behaviour of African penguins before, during and after a seismic survey that occurred within 100 km of penguin breeding colonies. Penguins foraging within 100 km of the active seismic source showed a change in foraging direction, increasing the distance between feeding area and seismic vessel (Pichegru *et al.,* 2017). Displaced penguins reverted back to normal foraging behaviours following the cessation of seismic activities, suggesting effects are relatively short-lived (Pichegru *et al.,* 2017). It is worth noting that the Pichegru *et al*. (2017) study was unable to differentiate between penguins shifting foraging activities in direct response to the survey (i.e. behavioural effect) or indirectly due to a change in prey distribution; however, a behavioural response was determined as the most likely cause. While the penguins were able to locate to alternative feeding grounds, the displacement from traditional grounds resulted in an increase in energy expenditure (Pichegru *et al.,* 2017).

Although the Lacroix *et al.* (2003) and Pichegru *et al*. (2017) studies were not carried out on species potentially present within the Operational Area, their results suggest that, at most, seabirds will be temporarily displaced from areas of active seismic operations. In addition, these displacement effects are anticipated to be short-lived, with animals able to return to traditional feeding grounds after seismic operations are complete. The very short-term duration of the GSB Checkshot Survey will minimise the amount of disturbance to seabird behaviour during seismic operations. Consequently, the residual risk of behavioural effects on seabirds from seismic exposure have been assessed as **negligible**.

6.2.2.3.5 Marine Mammals

Many authors have documented an avoidance of seismic operations in marine mammals (e.g. Goold, 1996; Stone & Tasker, 2006; Thompson *et al*., 2013). While behavioural responses may not have direct lethal effects, there is potential for sub-lethal effects such as increases in energy expenditure and demand, decreased foraging efficiency, disruption of group dynamics (e.g. group cohesion), and lowered reproductive rates leading to population-wide effects (Weilgart, 2007; 2013). Behavioural effects may also be harmless (Weilgart, 2007).

A number of factors determine the response of marine mammals to acoustic disturbance, including species, individual, age, sex, prior experience with noise, and behavioural state (Weilgart, 2007). Most studies typically have focused on opportunistic observations of surface behaviours (Verfuss *et al*., 2018); although behavioural responses may be subtle and barely detectable and may potentially be interpreted as an apparent tolerance of the studied animal/s (Weilgart, 2007).

Increased surface behaviours such as breaching or increases in time spent at the surface has been interpreted as a way of reducing exposure to high sound levels on account of the 'Lloyd mirror effect' (Carey, 2009). The Lloyd mirror effect significantly reduces the sound intensity within the upper-most part of the water column. For example, observations of migrating humpback whales off Australia in response to an operating 3D seismic survey suggested humpback whales extended surface behaviours in order to reduce received sound levels (McCauley *et al*., 2000). Whales also consistently undertook avoidance manoeuvres in the form of altered course and speed (McCauley *et al*., 2000). Other stress-related behaviours that have been documented in the vicinity of operating seismic surveys include changes in respiration rate (Richardson *et al*., 1995), swimming speed (Stone & Tasker, 2006), and alterations to diving behaviour (Richardson *et al*., 1995).

McCauley *et al*. (2000) hypothesised that migrating whales are less sensitive to acoustic disturbance from seismic sources and are at low risk to seismic activities, while whales engaging in resting behaviours at key habitats are particularly sensitive. Humpback whales carry out migrations to breeding grounds using migration routes that include the GSB, from late May to early August for northern migrations, and from September to December during southern migrations. In open seas, such as within the GSB, it is unlikely that a temporary displacement would have significant energetic consequences for migrating whales; consequences of displacement more severe in confined areas. While behavioural responses have been observed in humpback whales to operating seismic surveys, the open nature of the Operational Area means that it is unlikely that a temporary displacement would have significant energetic consequences for migrating whales. The short duration of the GSB Checkshot Survey further reduces the likelihood of the survey having any significant effect on migrating humpback whales.

There is anecdotal evidence of attraction of marine mammals to seismic operations. McCauley *et al.* (2000) observed what are believed to be male humpback whales approaching an operating acoustic source and hypothesised that this was due to the similarity to sounds produced by humpback whale breaching. New Zealand fur seals are also known to approach operating seismic vessels (Lalas & McConnell, 2016) and will likely be present within GSB waters during the GSB Checkshot Survey.

With regard to the potential behavioural impacts on marine mammals during the GSB Checkshot Survey, the following considerations should be noted:

- The GSB Checkshot Survey will run for a short period of time (i.e. up to 12 hours) and will use a relatively small volume acoustic source (i.e. total 450 in^3), minimising sound emissions into the marine environment;
- The GSB Operational Area is located in an open ocean environment and not an enclosed or confined area; and
- Any avoidance or displacement will be temporary and will cease as soon as the survey is complete.

Compliance with the Code of Conduct will be the primary mitigation measure employed during the GSB Checkshot Survey to manage behavioural effects on marine mammals. In accordance with the Code of Conduct, the following will be employed:

- Qualified MMOs and PAM Operators will be present on the support vessel and will maintain visual and acoustic watch (including pre-start observations) for marine mammals and will implement the mandatory management actions when required (e.g. delayed starts and shut-downs); and
- The specifications of the PAM system proposed for the GSB Checkshot Survey will be assessed by DOC to ensure that the system meets the standards described in the Code of Conduct (i.e. suitable to detect vocalisations from all Species of Concern that could potentially be in the Operational Area). Full technical specifications of the PAM system are provided in **Appendix B**.

In addition to the above measures, STLM has been undertaken to assess the validity of the Code of Conduct standard mitigation measures. STLM results confirm that the standard mitigation measures will be sufficient to protect marine mammals from behavioural effects.

The full protocol that the MMOs and PAM Operators will be following during the GSB Checkshot Survey is detailed in the MMMP. The MMMP is provided in **Appendix C**.

Based on the discussions above and mitigation measures that will be implemented, no long-term behavioural effects or long-term displacement are predicted. As a result, the residual risk of behaviour effects on marine mammals from the GSB Checkshot Survey is considered to be **moderate**.

6.2.2.4 Potential Perceptual Effects

Many marine species produce sound for a variety of functions (e.g. navigation, communication, predator and prey detection, etc.), and even those that do not produce sound will utilise the surrounding soundscape to gain overall awareness of the environment (Fay & Popper, 2000). Additional noise in the marine environment can disrupt an animal's communication potential and/or ability to detect biologically important signals (Dunlop *et al*., 2010); referred to as 'masking'. Masking is an increase in the threshold for detection or discrimination of one sound as a consequence of another (Brumm & Slabbekoorn, 2005), and can be either complete (i.e. signal is not detected at all) or partial (i.e. signal is detected by unable to be properly understood) (Clark *et al*., 2009).

The effects of masking on an animal's fitness and survival include:

- Blocking or alteration of signals alerting to the presence of predators (Lowry *et al*., 2012);
- Incorrect assessment of the quality of rivals or potential mates lowering reproductive success (Halfwerk *et al*., 2011);
- Disruption in the ability to locate prey/food and decrease in foraging efficiency (e.g. Clark *et al.,* 2009; Siemers & Schaub, 2010); and
- Disruption in group cohesion through a breakdown in communication particularly between parents and offspring (Leonard & Horn, 2012).

The following provides a discussion on the effects of masking on auditory communication of fish and marine mammals (particularly cetaceans).

6.2.2.4.1 Fish

Many fish species produce sounds for communication, with vocalisations typically within a frequency band of 100 Hz to 1 kHz (Ladich *et al*., 2006; Bass & Ladich, 2008). Although there have been no studies into the masking of fish communications by seismic surveys, other anthropogenic sounds (such as boat noise) have reportedly caused masking (e.g. Picciulin *et al*., 2012); therefore, it is reasonable to assume that sound emissions from a seismic survey could also result in the masking of fish calls. Popper *et al*. (2014) suggested that for fish with good hearing, there is a greater likelihood of masking further from the acoustic source than close to it as masking is more likely for these fish when the animals are far enough away from the source for the sounds to merge and become more or less continuous.

Radford *et al*. (2014) suggested that fish might adapt to masking in the following ways:

- Spatial or temporal avoidance of noise. Temporal avoidance involves taking advantage of gaps or fluctuations in competing noise, for example Luczkovich *et al.* (2000) reported that silver perch vocalised less frequently when recordings of a predator (i.e. bottlenose dolphin) were played;
- Temporal adjustments. Signal detection enhances as signal duration increases as a consequence of an increase in the probability that some of the signal is detected during a quieter period. Fine and Thorsen (2008) recorded an increase in toadfish call rate to compete acoustically in the presence of rival males;
- Frequency shifts. Broadband sounds are more difficult to detect in a noisy environment than pure tones, for example freshwater gobies in waterfall habitats produce vocalisations in a frequency different from that of the waterfall noise. The gobies utilise available 'windows' in the background frequency range (Lugli *et al*., 2003);
- Amplitude shifts. In a noisy environment, an increase in amplitude increases signal detection (i.e. the Lombard Effect). While the Lombard Effect has been demonstrated in a number of vertebrates, it is yet to be demonstrated in fish in response to anthropogenic noise; and
- Change in signalling modality. The repertoire of a species usually consists of more than one signal component; hence when one signal type is ineffective, the caller may swap to another signal type to increase the chance of detection, e.g. a change from vocalisations to visual signals.

Although little is known on the vocalisations of fish throughout the GSB, it is reasonable to assume that the GSB Checkshot Survey may lead to masking for some fish species. However, based on the highly mobile nature and likely low abundances of the fish potentially present in the Operational Area, and the short duration of the GSB Checkshot Survey (up to 12 hours), no biologically significant effects are expected and the residual risk of perceptual effects on fish is considered to be **negligible**.

6.2.2.4.2 Marine Mammals

The ability to perceive biologically important sounds is crucial to marine mammals; marine mammals use sounds to gain an overall awareness of the surrounding environment, and to inform a variety of behaviours including foraging, navigation, communication, reproduction, parental care, predator avoidance (Thomas *et al*., 1992; Johnson *et al*., 2009). Sounds in the same frequency as biological signals can interfere with biologically important sounds and potentially lead to significant individual effects (Gausland, 2000). Masking is a common effect of acoustic disturbance on marine mammals (Erbe *et al*., 2016). The level of masking that will occur depends on a number of factors other than the noise doing the masking, such as the location of the sender and receiver, source level and spectral characteristics of the signal, and the receiving animal's auditory capabilities (Erbe *et al*., 2016).

Cetaceans are broadly separated into three categories based on hearing capability (Southall *et al*., 2007):

- Low frequency cetaceans: have an auditory bandwidth between 0.007 kHz and 22 kHz. Species from this group that could occur in the Operational Area include Antarctic minke whale, dwarf minke whale, fin whale, humpback whale, blue whale, sei whale, and southern right whale;
- Mid-frequency cetaceans: with an auditory bandwidth between 0.15 kHz and 160 kHz. Species from this group that could occur in the Operational Area include Andrew's beaked whale, Arnoux's beaked whale, bottlenose dolphin, common dolphin, Cuvier's beaked whale, dusky dolphin, false killer whale, Gray's beaked whale, Hector's beaked whale, killer whale, long-finned pilot whale, Shepherd's beaked whale, short-finned pilot whale, southern bottlenose whale, southern right whale dolphin, sperm whale, and strap-toothed whale; and
- High frequency cetaceans: which an auditory bandwidth between 0.2 kHz and 180 kHz. Species from this group that could occur in the Operational Area include pygmy sperm whale, spectacled porpoise, and Hector's dolphin.

Sound frequencies emitted by seismic acoustic sources are broadband, with most of the energy concentrated between 0.1 kHz and 0.25 kHz. The greatest potential for interferences with cetacean vocalisations is at the highest end of the seismic spectrum and the lowest end of the cetacean vocalisation spectrum (**Table 21**) i.e. the lowest frequency cetaceans are particularly affected since they have the most overlap with the frequencies of the seismic survey acoustic sources (**Figure 23**). Auditory masking of mid and high frequency cetacean vocalisations is less likely as these species generally operate at higher frequencies than those generated by a seismic survey.

Table 21 Examples of Cetacean Communication and Echolocation Frequencies

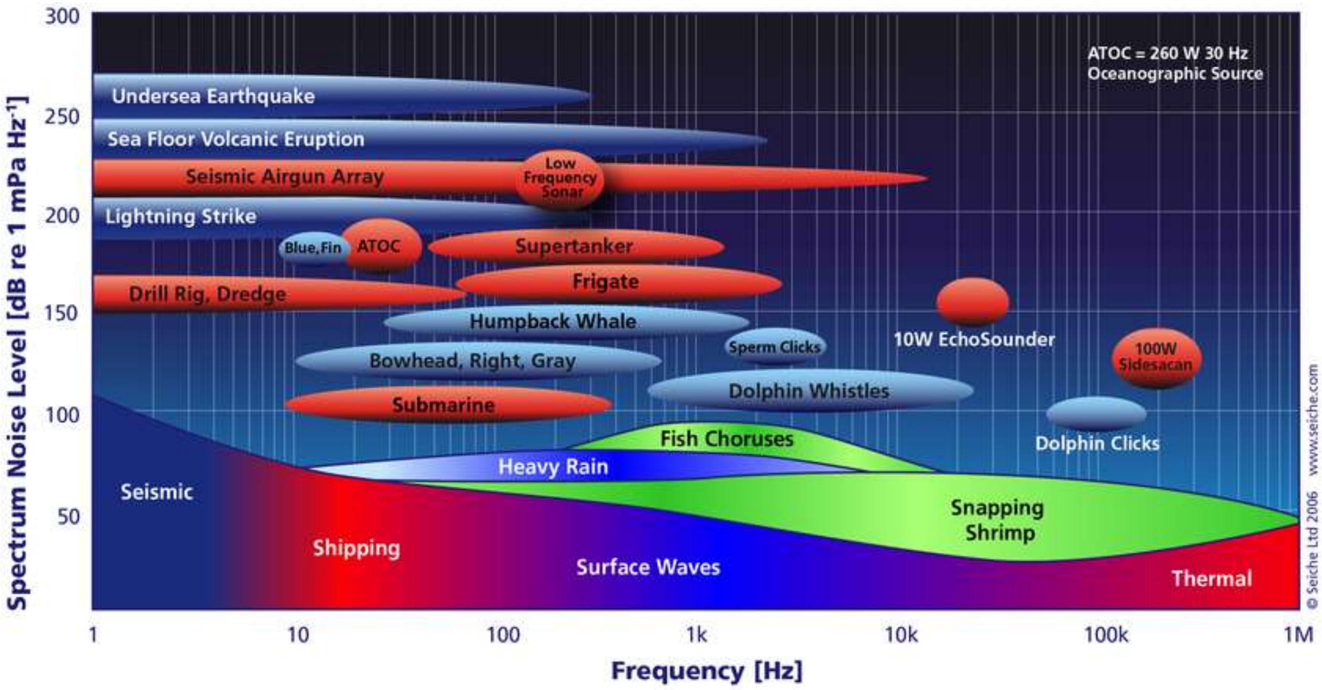
Species	Communication Frequency (kHz)	Echolocation Frequency (kHz)
Southern right whale	0.03 – 2.2	N/A
Minke whale	0.06 – 6	N/A
Sei whale	1.5 – 3.5	N/A
Blue whale	0.0124 – 0.4	N/A
Fin whale	0.01 – 28	N/A
Humpback whale	0.025 – 10	N/A
Sperm whale	0.1 - 30	0.1 – 30
Pygmy sperm whale	No data available	60 – 200
Beaked whales*	3 – 16	2 – 26
Shepherd's beaked whales	No data available	4 – 45 **
Common dolphin	0.5 – 18	0.2 – 150
Pilot whale	1 – 18	1 – 18
Killer whale	0.1 – 35	12 – 25
Bottlenose dolphin	0.2 – 24	110 – 130

* Using the bottlenose whale as an example

** Leunissen et al., 2018

Source: Summarised from Simmonds *et al.*, 2004 unless otherwise stated

Figure 23 Ambient and Localised Noise Sources in the Ocean



Source: Professor Rodney Coates, The Advanced *SONAR* Course, Seiche (2002)*; from* www.seiche.com

Erbe *et al*. (2016) documented a number of studies demonstrating adaptive responses/anti-masking strategies in cetaceans reacting to underwater anthropogenic noise, including changes in vocalisation strength, frequency, and timing. For example, blue whales increase their calls (emitted during social encounters and feeding) when a seismic survey is operational in the area (Di lorio & Clark, 2009). Adaptations have also been documented in humpback whales (McCauley *et al*., 1998; 2003a), beluga whales (Lesage *et al*., 1999), right whales (Parks *et al*., 2007, 2011), killer whales (Holt *et al.*, 2008), and bottlenose dolphins (van Ginkel *et al*., 2017). It is thought that an increase in calling leads to an increase in the probability that signals will be successfully received by conspecifics due to a reduction in the effects of auditory masking.

Cetaceans may also cease vocalising in response to anthropogenic noise, as has been demonstrated in humpback whales at breeding grounds off Angola in response to a MSS whereby singing activity declined with the presence of the MSS and increasing received levels of the seismic pulses (Cerchio *et al*., 2014). This cessation in singing at a breeding ground was implied to have the potential to affect mating behaviour and success (Cerchio *et al*., 2014). Cessation in clicking was also observed in sperm whales by Bowles *et al.* (1994) in response to weak seismic survey pulses (received level of 115 dB re 1 µPa). Contradictory to the findings of Bowles *et al.* (1994), Madsen *et al*. (2002a) did not document any changes in male sperm whale clicks in response to a seismic survey off Norway. Sperm whales did not cease clicking and did not alter normal acoustic behaviour during feeding (Madsen *et al*., 2002a).

Adaptations to masking for some species may be limited to circumstances when whales are subject to low to moderate SELs. For example, Blackwell *et al*. (2015) demonstrated that the calling rates of bowhead whales varied with changes in received SEL. As SELs increased, calling rates levelled off (as SELs reached 94 dB re 1 µPa^2-s), then began decreasing (at SELs greater than 127 dB re 1 µPa^2-s), with whales falling virtually silent once SELs exceeded 160 dB re 1 µPa^2-s.

Masking levels are difficult to predict, and no auditory thresholds exist for masking effects on cetaceans (Erbe *et al*.,2016); however, as outlined above masking responses have been documented to occur at relatively low exposure levels (i.e. lower than what would elicit a behavioural response). It is likely that cetaceans in the vicinity of the Operational Area during the GSB Checkshot Survey may be subject to some masking effects. However, any masking effects will cease at the completion of the GSB Checkshot Survey and based on the short duration of the survey (i.e. up to 12 hours) it is highly unlikely that any masking will have detectable population effects on the cetaceans present in the GSB. Overall, the residual risk of perceptual effects on cetaceans has been assessed as **moderate**.

6.2.2.5 Potential Indirect Effects

In addition to the previously discussed physiological, behavioural and perceptual effects (**Sections 6.2.2.2.6**, **6.2.2.3.5** and **6.2.2.4.2** respectively) on marine mammals from underwater noise, there is also the potential for marine mammals to be affected through indirect effects of noise exposure. Potential indirect effects include changes to the distribution and abundance of prey species (Simmonds *et al*., 2004), decreased foraging efficiency, higher energetic demands, lower group cohesion, higher predation rates and decreased reproductions rates (Weilgart, 2007). It is important to note that indirect effects may or may not be detrimental depending on the specific circumstances of exposure. Indirect effects are difficult to detect and measure.

The most significant and immediate potential indirect effect of noise on marine mammals is considered to be the change in prey distribution and abundance. The distribution and abundance of zooplankton and fish can change as a result of underwater noise, as per the assessments within **Sections 6.2.2.2.1**, **6.2.2.2.4**, and **6.2.2.3.3**. These effects can in turn lead to a decrease in foraging efficiency of marine predators, such as marine mammals, which can in turn lead to compromised growth, body condition, reproduction and ultimately survival.

No information is available with regard to how adult krill are affected by seismic surveys, but the mortality of krill larvae as described by McCauley *et al*. (2017) suggests that seismic surveys may alter the distribution and abundance of krill in the vicinity of seismic operations. In response to McCauley *et al.* (2017), Richardson *et al*. (2017) reported that zooplankton populations recovered quickly after seismic exposure due to their fast growth rates, and the high rates of dispersal and mixing of zooplankton in the offshore marine environment. While this is encouraging it does not completely remove the possibility that krill availability may be reduced.

In addition to the potential impacts on the distribution and abundance of krill, the distribution and abundance of fish can also change in response to exposure to underwater noise (e.g. Pearson *et al*., 1992; McCauley *et al*., 2000; Colman *et al*., 2008; Handegard *et al*., 2013); the potential impacts on fish are detailed within **Sections 6.2.2.2.4** and **6.2.2.3.3**. Based on these discussions, indirect effects on predatory fish species and piscivorous marine mammals could occur.

While there is some potential for indirect effects on marine mammals and fish from the GSB Checkshot Survey, there is a general lack of scientific information about such effects. On account of the difficulty to predict with any certainty what indirect effects might occur, the ability to target management measures to avoid, remedy or mitigate indirect effects is also difficult. However, the very short timeframe associated with the GSB Checkshot Survey is a key measure in mitigating any potential indirect effects. Based on this, the residual risk of indirect effects from the GSB Checkshot Survey is assessed as **negligible**.

6.2.3 Waste Discharges and Emissions

The MODU and support vessel will produce wastes during the GSB Checkshot Survey as biodegradable and non-biodegradable wastes, and atmospheric emissions from exhausts.

Inappropriate discharges of these wastes have the potential to cause adverse effects on the surrounding environment. However, given that the volume of waste produced depends predominantly on the number of personnel onboard the vessels and duration of the survey, the volume produced during the GSB Checkshot Survey period is likely to be small. Wastes produced outside of this period still have the potential to cause adverse effects to the marine environment but are not directly assessed as part of this MMIA.

All produced wastes will be managed in accordance with OMV environmental practices, and MARPOL requirements (as enacted by the Marine Protection Rules).

6.2.3.1 Potential Effects from Biodegradable Waste

Biodegradable wastes likely to be produced on the MODU and support vessel during the GSB Checkshot Survey include:

- Black water (sewage/faecal wastewater from toilets);
- Grey water (wastewater from sinks, showers, laundering, etc.);
- Galley wastes; and,
- Oily water (from bilges).

Upon discharge from the MODU/support vessel to the surrounding marine environment wastes such as those detailed above will undergo a bacterial decomposing process either within the water column or upon reaching the seabed resulting in two consequences for the surrounding environment (Perić, 2016; Wilewska-Bien *et al*., 2016); decreased oxygen concentrations as a result of increased biological oxygen demand by bacteria decomposing the discharged wastes, and increased nitrogen and phosphorous released from decomposed materials. In areas of low flow or restricted mixing oxygen can become low enough to be biologically limiting for marine organisms. Increased nitrogen and phosphorous concentrations can also stimulate the growth of algae (phytoplankton) including potentially toxic species or cause further increased oxygen demand as a bloom crashes and dying plankton begin to decay. Black water and grey water could also contain human pathogens including *Salmonella* and gastro-intestinal viruses (Perić, 2016; Wilewska-Bien *et al*., 2016).

The following will be followed throughout the duration of the GSB Checkshot Survey to mitigate against adverse effects from the discharge of biodegradable wastes in line with the marine consent for the GSB EAD Programme:

- Discharges will occur in accordance with the New Zealand Marine Protection Rules;
- Biodegradable wastes will be comminuted to less than 25 mm prior to discharge;
- Sewage and grey water will pass through sewage treatment facilities prior to discharge; and
- Discharges containing oils will pass through onboard treatment systems and will only be discharged when below oil-in-water concentrations of 15 ppm.

The residual risks to the marine environment from routine discharges of biodegradable waste generated by the MODU and support vessel are considered to be **negligible**.

6.2.3.2 Potential Effects from Non-biodegradable Waste

Non-biodegradable wastes/garbage (e.g. plastics used in food wrapping and packaging) entering the marine environment can have severe detrimental and even lethal effects on marine fauna. Smaller pieces of such wastes are often ingested by animals and can accumulate in the gut leading to internal injury, blockage of intestinal tracts, and a reduction in fitness (Derraik, 2002). Larger objects may cause entanglement, injury, disfigurement or even death for certain animal species that become caught. By their nature non-biodegradable wastes often persist in the marine environment for extensive periods of time and can accumulate on the surface or on the seabed or may be transported large distances from the original discharge point (Li *et al*., 2016).

All non-biodegradable wastes will be appropriately stored onboard the MODU or support vessel to ensure they cannot escape to the surrounding marine environment and will be returned to shore for disposal in adherence to local waste management requirements. Suitable chain of custody records for all waste sent to onshore processing facilities will be retained.

The residual environmental risk of any non-biodegradable discharges to the marine environment during the GSB Checkshot Survey is considered to be **negligible**.

6.2.3.3 Potential Effects from Atmospheric Emissions

The primary sources of atmospheric emissions during the GSB Checkshot Survey will be the result of exhaust gasses produced by internal combustion engines (e.g. main engines, generators, deck equipment, etc.) onboard the MODU and support vessel. Exhaust emissions will be primarily composed of carbon dioxide and carbon monoxide but will also include small quantities of other toxic inorganic gasses such as nitric oxide and nitrogen dioxide (Steiner *et al*., 2016). Exhaust gasses can reduce the ambient air quality.

Effects of the GSB EAD Programme on human health, including effects from atmospheric emissions were assessed within the GSB EAD marine consents as negligible. The GSB Checkshot Survey will not add to this risk. The residual environmental risk of atmospheric emissions during the GSB Checkshot Survey is considered to be **negligible**.

6.2.4 Cumulative Effects

Cumulative effects can occur where multiple sound sources combine leading to an overall increase in underwater sound levels. Of primary concern for seismic surveys is the potential for cumulative acoustic effects that could result when multiple sources of underwater noise combine to significantly increase the underwater sound profile above its natural baseline level. Assessing cumulative effects in a quantitative manner is fraught with difficulties and therefore few studies have broached this topic in relation to seismic surveys.

Of particular concern is the potential for cumulative noise effects arising from multiple seismic surveys overlapping temporally (i.e. at the same time) or spatially (i.e. over the same area but not necessarily over the same time period). With the exception of the GSB Checkshot Survey, there are no known planned seismic surveys in the GSB in the next 12 – 24-month period, therefore cumulative effects from multiple seismic surveys are not considered further.

Shipping traffic near the Operational Area is another potential contributor to cumulative effects of underwater noise during the GSB Checkshot Survey. **Figure 20** shows the location of the most commonly travelled routes between major ports inshore of the Operational Area and the most actively used areas for shipping. As can be seen in **Figure 20**, the waters within and surrounding the Operational Area are not well used by other marine users, therefore noise from shipping will be minimal within the Operational Area.

Despite low levels of shipping and other anthropogenic noise within and surrounding the Operational Area, the potential for cumulative effects cannot be ruled out. Di lorio and Clark (2009) assessed the calling rate of blue whales during a seismic survey and concluded that shipping noise in the operational area did not account for any of the observed changes in the acoustic behaviour of blue whales, and that the seismic survey was solely responsible for these changes. Where shipping levels are relatively low, the combined noise from the seismic and shipping could result in greater disturbance to marine mammals compared with either activity alone (Di Lorio & Clark, 2009). McGregor *et al*. (2013) showed that marine mammals sometimes adapted their vocalisations in order to mitigate against the effects of masking in areas of consistent underwater noise, supporting the generally held notion that masking effects of underwater noise are most significant in areas where baseline noise levels are typically low.

Based on the findings of Di lorio and Clark (2009) and McGregor *et al.* (2013) the addition of acoustic disturbance to the marine environment on top of noise from shipping may result in cumulative effects, with marine mammals in particular being more disturbed than would occur through noise from the acoustic source alone. However, the GSB Checkshot Survey will be very short in duration, and overlap between multiple sound sources will be restricted to the 3.8 – 5.5 hours it would take to run the GSB Checkshot Survey.

The MODU and support vessel will contribute to background noise levels within the Operational Area prior to, and during the GSB Checkshot Survey. Noise levels will be emitted from machinery onboard the support vessel and MODU, as well as engine noise from the support vessel and the MODU's thrusters whilst maintaining its position. Thruster noise emissions will be the main contributor of noise around the MODU and combined with noise emissions during the checkshot surveys, have the potential to increase cumulative noise levels. However, any overlap in noise emissions from the MODU's thrusters and the acoustic source will only be for a short duration (i.e. up to 12 hours) and during this time OMV will implement control measures such as the presence of MMOs and PAM Observers onboard. The short duration of the checkshot survey and the presence of observers onboard the MODU and support vessel provide the main mitigation measures to minimise the potential for cumulative effects arising during the GSB Checkshot Survey.

Given that the DOC Code of Conduct requirements act to manage the acoustic effects of seismic surveys (including checkshot surveys) to 'as low as reasonably practicable', the short duration of the active phase of the GSB Checkshot Survey, and the low volume of the acoustic source the incremental contribution of these surveys to cumulative effects will be limited. Therefore, there are no specifically applicable additional mitigation measures available to address cumulative effects with either shipping or multiple surveys.

The residual environmental risk of cumulative effects from the GSB Checkshot Survey across the offshore GSB area is considered to be **minor**.

6.3 Unplanned Events

Unplanned events are rare during checkshot survey operations; however, serious consideration must be given to the potential effects of any unplanned incident as consequences of such events can be severe. Unplanned events associated with operations may include equipment loss, or a vessel collision/sinking. These potential incidents are discussed below.

Note that the 'likelihood' assessment used for the unplanned events differs to that used for the planned events in that it is the likelihood of the activity occurring (compared to the likelihood of an effect occurring for planned events).

Some unplanned events (such as biosecurity incursion) are not covered in this document as these issues surrounding the MODU and support vessel involved in the GSB Checkshot Survey were covered in the marine consents for the wider GSB EAD Programme.

6.3.1 Potential Effects of Equipment Loss

The acoustic array proposed to be utilised for the GSB Checkshot Survey will be deployed over the side of the MODU on a crane on a wire cable. In the unlikely event that the acoustic source was lost it would likely rapidly sink to the seabed beneath the position it was deployed from. Upon contacting the seabed, the source could impact benthic communities; however, as can be seen in **Figure 3**, the triple acoustic source cluster is a small, open-framed structure.

The marine consent for the GSB EAD Programme requires that objects that are dropped/fall into the sea will be located by the Remotely Operated Vehicle and retrieved if safely feasible, where practicable. Any significant objects unable to be recovered must be reported to the EPA and if they remain floating other notifications may be needed (e.g. Maritime New Zealand).

All activities carried out during the GSB Checkshot Survey, including deployment of the acoustic source from the MODU crane, will be undertaken by experienced personnel, using lifting equipment that is suitably rated and in current test status. The relatively small physical size of source means the lifting and deployment would not be a difficult deployment for trained crane operators.

It is considered that the residual environmental risk from loss of equipment during the GSB Checkshot Survey would be **negligible**.

6.3.2 Potential Effects from Vessel Collision or Sinking, and Release of Hazardous Substances

The potential effects from vessel collision (involving either the support vessel or MODU) or sinking, and subsequent release of hazardous substances carried onboard the MODU/support vessel were assessed in detail within the marine consent for the wider GSB EAD Programme. The GSB marine consent assessed the environmental risk associated with a vessel collision as low, and the GSB Checkshot Survey will not add further risk to environmental receptors above what has been assessed within the Marine Consent; however, a brief summary is provided below.

In the event of a vessel collision and possible sinking, the biggest threats to the marine environment would be the vessel sinking and impacting the seafloor, pollution through the spread of debris, and the release of hazardous substances.

Measures in place to ensure that the risk of vessel collision/sinking and subsequent spills are minimised include:

- The location of the MODU will be supplied to marine users for the duration of the GSB EAD Programme through a Notice to Mariners and coastal navigation warnings. A 500 m non-interference zone will be in place around the MODU;
- A support vessel will be present at all times in close proximity to the MODU;
- The MODU and support vessel will adhere to all relevant safety requirements as per international regulations and conventions (e.g. COLREGS), maintain visual and radar watch for the presence of other vessels, scan and monitor VHF radio, transmit its location using AIS, and will display appropriate day shapes and lights; and
- Spill responses will be undertaken in accordance with the Shipboard Oil Pollution Emergency Plan.

Based on the information presented above and the mitigation actions in place, it is considered that the residual risks of vessel collision/sinking and subsequent release of hazardous substances during the GSB Checkshot Survey are **negligible**.

6.4 Environmental Risk Assessment Summary

Table 22 provides a summary of the ERA results.

Table 22 Summary of ERA Results for the GSB Checkshot Survey

Effects from Planned Activities	Significance
Physical presence of MODU, support vessel and acoustic source – effects on seabirds.	Negligible
Physical presence of MODU, support vessel and acoustic source – effects on marine mammals.	Negligible
Physical presence of MODU, support vessel and acoustic source – effects on other marine users.	Negligible
Acoustic disturbance – physiological effects on zooplankton.	Minor
Acoustic disturbance – physiological effects on benthic invertebrates.	Negligible
Acoustic disturbance – physiological effects on cephalopods.	Negligible
Acoustic disturbance – physiological effects on fish.	Negligible
Acoustic disturbance – physiological effects on seabirds.	Negligible
Acoustic disturbance – physiological effects on marine mammals.	Moderate
Acoustic disturbance – behavioural effects on benthic invertebrates.	Negligible
Acoustic disturbance – behavioural effects on cephalopods.	Minor
Acoustic disturbance – behavioural effects on fish and commercial fisheries.	Minor
Acoustic disturbance – behavioural effects on seabirds.	Negligible
Acoustic disturbance – behavioural effects on marine mammals.	Moderate
Acoustic disturbance – perceptual effects on fish.	Negligible
Acoustic disturbance – perceptual effects on marine mammals.	Moderate
Acoustic disturbance - Indirect effects	Negligible
Waste discharges and emissions – biodegradable waste	Negligible
Waste discharges and emissions – non-biodegradable waste	Negligible
Waste discharges and emissions – atmospheric emissions	Negligible
Cumulative effects	Minor
Effects from Unplanned Events	
Effects from equipment loss	Negligible
Effects from vessel collision or sinking	Negligible

7 Conclusion

A checkshot survey is required to identify specific characteristics within the geological features discovered below the seafloor during the drilling activities associated with the GSB EAD Programme. A checkshot survey may be undertaken if hydrocarbons are discovered at Tāwhaki-1. In the event that no hydrocarbon accumulations are discovered, no checkshot survey will be required; however, that is not going to be known until the well has been drilled and appropriate formation evaluation has been undertaken. During the GSB Checkshot Survey an acoustic receiver will be lowered down the borehole to receive the sounds emitted from the acoustic source deployed from the side of the MODU, 5 m below the sea surface.

During the GSB Checkshot Survey, OMV will comply with the Code of Conduct as the primary means of mitigating any potential environmental effects arising from the surveys on marine mammals. By committing to the mitigation measures required by the Code of Conduct, the potential effects of acoustic disturbance on marine mammals will be minimised to a level that is deemed acceptable in accordance with the Permitted Activities Regulations. Although not required by the Code of Conduct, OMV has undertaken STLM. The STLM short-range modelling prediction demonstrates that for the proposed Tāwhaki-1 well location, the maximum received SELs are predicted to comply with the 186 dB re 1µPa^2·s at 200 m, and 171 dB re 1µPa^2·s at 1.0 km and 1.5 km, therefore the standard mitigation zones are sufficiently large to protect marine mammals from physiological, behavioural, and perceptual effects during the GSB Checkshot Survey.

As per the Code of Conduct, there will be two MMOs on the MODU for daytime observations and two PAM Operators onboard the support vessel to provide 24-hour coverage with acoustic detections. These personnel will be independent and qualified through DOC approved training programmes. Visual and acoustic watch will be maintained around the clock, including during the required pre-start-up observation period. Detections of marine mammals within the mitigation zones will trigger the required mitigation action (e.g. delayed starts or shut-downs of the acoustic source).

This MMIA has identified all the potential environmental effects that may arise from the GSB Checkshot Survey and describes the mitigation measures that OMV will implement to ensure that any potential effects are reduced to levels that are as low as reasonably practicable. While this MMIA focuses on potential effects on marine mammals, effects on other environmental and socio-economic receptors have also been considered. The following mitigation measures will be employed by OMV during the duration of the GSB Checkshot Survey to mitigate against any potential effects from the survey:

- Compliance with all required and relevant regulations and conventions (e.g. COLREGS and MARPOL) to ensure safety of all crew and other marine users and to avoid adverse effects on the marine environment from potential discharges and vessel collisions;
- Compliance with the Code of Conduct including the following key points:
  - Two MMOs will be stationed onboard the MODU to maintain visual watch and two PAM Operators will be deployed onboard the support vessel to maintain acoustic watch with the PAM system. While it is preferred that MMOs and PAM Operators are trained and qualified, the Code of Conduct provides for a qualified MMO and PAM Operator to act as a supervisor/mentor. At a minimum there will be one qualified observer and one trained observer in each observation role (MMO or PAM Operator). The support vessel will circle the MODU at a radius of approximately 1 km during the GSB Checkshot Survey;

- The standard mitigation zones within the Code of Conduct will be used for delayed starts and shut-downs. STLM has confirmed that the survey complies with the regulatory mitigation zone SEL requirements defined within the Code of Conduct;
- Pre-start observations will be carried out for at least 30 minutes prior to activating the acoustic source. The acoustic source will only be activated in the event that no marine mammals (other than New Zealand fur seals) have been observed in the relevant mitigation zone for at least 30 minutes, and no New Zealand fur seal has been observed in the relevant mitigation zone for at least 10 minutes;
- Additional observation requirements for start-up in a new location at night or in poor sighting conditions will be followed at the commencement of the survey;
- If a marine mammal is observed within the relevant mitigation zone, the acoustic source will be shut-down or start-up will be delayed until the MMOs confirm the animal has left the mitigation zone for the required period of time; and
- Activation of the acoustic source will only occur following the soft start procedures after the above observation period.

If a stranding occurs during the GSB Checkshot Survey, or within two weeks following the completion of each survey OMV will, on a case-by-case basis, consider covering the cost of a necropsy in an attempt to determine the cause of death. OMV will seek advice from DOC as to the requirement for a necropsy.

Overall, the predicted effects of the GSB Checkshot Survey are considered to be sufficiently managed by the proposed mitigation measures, predominantly compliance with the Code of Conduct. Due to the small volume acoustic source that will be utilised during the survey, the potential for temporary threshold shifts on marine mammals will be restricted to within 200 m of the acoustic source, as demonstrated by STLM. Masking of animal vocalisations may occur; however, the short duration of thesurvey reduces the possibility of this masking having long-term effects. Discharges associated with the MODU and support vessel, the presence of these vessels within the Operational Area, and the potential for interactions with other marine users have been covered under the appropriate Marine Consents for the GSB EAD Programme.

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APPENDIX A

Sound Transmission Loss Modelling Report

GREAT SOUTH BASIN CHECKSHOT SURVEY

Sound Transmission Loss Modelling

Prepared for:

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PO Box 2621
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SLR Ref: 740.10078.00300-R01
Version No: -v2.0
November 2019

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with OMV GSB Limited (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
740.10078.00300-R01-v2.0	20 November 2019	[redacted]	[redacted]	[redacted]
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740.10078.00300-R01-v0.1	9 October 2019	[redacted]	[redacted]r	[redacted]

EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd (SLR) has been engaged by OMV GSB Limited (OMV) to provide Sound Transmission Loss Modelling (STLM) for the checkshot survey (should it be required) at the proposed exploration well Tāwhaki-1 located in the Great South Basin (GSB). The checkshot survey may be undertaken at the well in the event that there are indications of commercial accumulations of hydrocarbon, and this STLM is to assist with undertaking these activities in accordance with the Department of Conservation 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations.

This report details the STLM that has been carried out for the proposed checkshot survey, which includes the following two modelling components:

- Array source modelling – i.e. modelling the sound energy emissions from the array source, including its directivity characteristics; and
- Short range modelling – i.e. prediction of the received sound exposure levels (SELs) over a range of a few kilometres from the array source location, in order to assess whether the proposed survey complies with the mitigation zone requirements.

The detailed modelling methodologies and procedures for the above components are described in **Section 2** and **Section 3** of this report.

The source array proposed for the checkshot survey is the 450 cubic inch triple G-Gun source cluster array which will be deployed from a crane over the side of the Mobile Offshore Drilling Unit (MODU), approximately 5.0 m below the water surface. The cluster has an operating pressure of 2,000 pounds per square inch (psi).

The array source modelling illustrates strong array directivity which has significant angle and frequency dependence for the energy radiation from the array as a result of interference between signals from different array elements. The short range modelling prediction demonstrates that the highest SELs occur in the directions perpendicular to the cluster frame plane, as a result of the directivity of the source cluster array.

The short range modelling prediction demonstrates that for the assessed well location Tāwhaki-1, the maximum received SELs over all azimuths are predicted to comply with:

- The threshold level of 186 dB re 1µPa^2·s at 200 m; and
- The threshold level of 171 dB re 1µPa^2·s at 1.0 km and 1.5 km.

CONTENTS

DOCUMENT REFERENCES

TABLES

CONTENTS

FIGURES

APPENDICES

1 Introduction

1.1 Background

OMV GSB Limited and OMV New Zealand Limited (collectively referred to as OMV) will be undertaking a multi-well Exploration and Appraisal Drilling (EAD) Programme within the Great South Basin (GSB); the GSB EAD Programme. The GSB EAD Programme is expected to commence in 2020 with the drilling of the initial exploration well, the Tāwhaki-1. The purpose of the GSB EAD Programme is to determine the presence of hydrocarbons within a number of identified geological structures and to investigate the potential for future development of discovered hydrocarbons within OMV's permit area.

Drilling activities associated with the GSB EAD Programme will be undertaken within Petroleum Exploration Permit (PEP) 50119.

A checkshot survey may be undertaken if there are indications of potentially commercial accumulations of hydrocarbon present within the Tāwhaki-1 exploration well. In the event that no hydrocarbon accumulations are discovered, no checkshot survey is likely to be required. The objective of the GSB Checkshot Survey is to ascertain further information about the structure/strata where a commercial hydrocarbon accumulation has been identified, and the surrounding structures. The Tāwhaki-1 well is located in the GSB at a water depth of approximately 1,325 m. Planned well characteristics are provided in **Table 1** below.

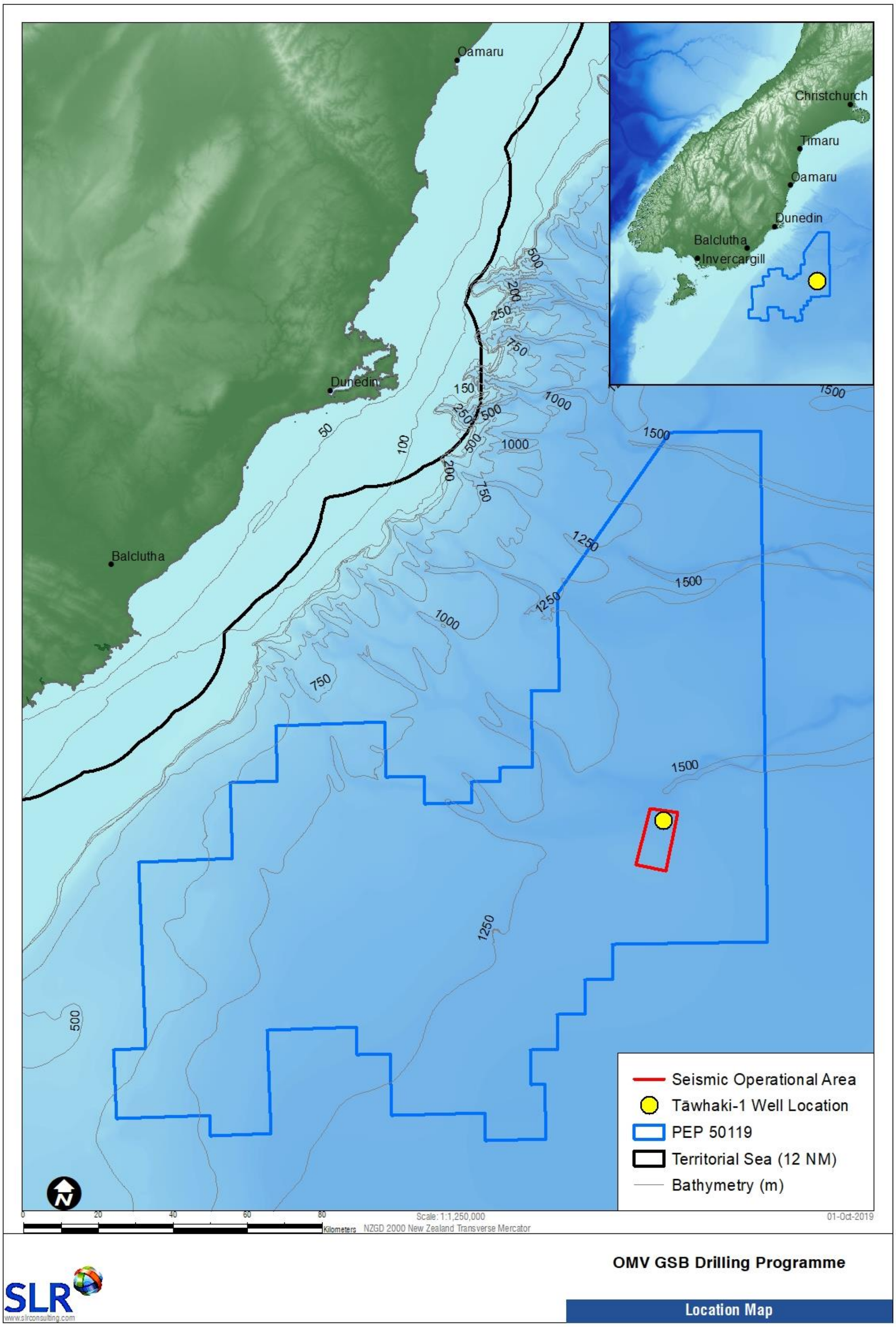
Table 1 Planned Well Characteristics for the Tāwhaki-1 well

Well	Water Depth (m bMSL)	Target Depth (m)	Last Casing Depth (m)	Length of Open Hole (m)
Tāwhaki-1	1,323	2,977	2,558	439

As shown in **Figure 1**, an Operational Area has been defined around the Tāwhaki-1 well location, which is the area where the acoustic source can be active, and is also the area which was assessed during the preparation of the Marine Mammal Impact Assessment (MMIA).

SLR Consulting Australia Pty Ltd (SLR) has been engaged by OMV to undertake sound transmission loss modelling (STLM) for the proposed checkshot survey, in order to predict the received sound exposure levels from the survey, and to demonstrate whether the surveys comply with the sound exposure level thresholds within the Department of Conservation (DOC) *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* (the Code).

Figure 1 Location of Tāwhaki-1 well and Associated Operational Areas



1.2 Statutory requirements for sound transmission loss modelling (STLM)

The Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (EEZ Act) came into force in 2013 and established the first comprehensive environmental consenting regime for activities in New Zealand's Exclusive Economic Zone (EEZ) and Continental Shelf. A marine seismic survey is classified as a permitted activity and is therefore covered under the Exclusive Economic Zone and Continental Shelf (Environmental Effects – Permitted Activities) Regulations 2013 (Permitted Activities Regulations). The Permitted Activities Regulations permit seismic surveys providing the operator undertaking the survey complies with the Code.

When a seismic survey is conducted within an Area of Ecological Importance, the Code requires STLM to be undertaken to determine whether received sound exposure levels (SELs) from the survey exceeds 171 dB re $1\mu Pa^2\cdot s$ (the behaviour criteria) at ranges of 1.0 km and 1.5 km from the source (for species of concern with and without calf present respectively) or 186 dB re $1\mu Pa^2\cdot s$ (the injury criteria) at a range of 200 m from the source. The Tāwhaki-1 well is located beyond the Area of Ecological Importance; however, OMV are still conducting STLM as best operator practice.

1.3 Structure of the report

This STLM study includes the following two modelling components:

- Array source modelling, i.e. modelling the sound energy emissions from the checkshot survey array source, including its directivity characteristics; and
- Short range modelling, i.e. prediction of the received SEL over a range of a few kilometres from the array source location, in order to assess whether the proposed checkshot survey complies with the near-field mitigation zone requirements imposed by the Code.

Section 2 of this report details the modelling methodology, procedure and results for the array source modelling. **Section 3** of the report outlines the methodology and procedure associated with the short range transmission loss modelling, with the major modelling results presented in **Section 4**. Relevant acoustic terminologies throughout the report are presented in **Appendix 1**.

2 Checkshot Survey Array Source Modelling

2.1 Source array configuration

The source array proposed for the checkshot survey is three 150 cubic inch guns mounted on a triple G-Gun source cluster, giving a total volume of 450 cubic inches as shown within the standard Delta deployment frame in **Figure 2**. The centre of the source array will be located approximately 5.0 m below the water surface, which will be deployed from a crane onboard the Mobile Offshore Drilling Unit (MODU), and the cluster has an operating pressure of 2,000 pounds per square inch (psi).

Figure 2 The 450 cubic inch triple G-Gun cluster inside standard Delta deployment frame (image courtesy of Schlumberger)

2.2 Modelling methodology

The outputs of the array source modelling required for the subsequent sound modelling predictions include:

- A set of “notional” signatures for each of the array elements; and
- The farfield signature of the source array and its directivity/beam patterns.

2.2.1 Notional signatures

The notional signatures are the pressure waveforms of each individual source, accounting for its interaction with other sources in the array, at a standard reference distance of 1 m.

Notional signatures are modelled using the Gundalf Designer software package (2018). The Gundalf array source model is developed based on the fundamental physics of the oscillation and radiation of source bubbles as described by Ziolkowski (1970), taking into account non-linear pressure interactions between sources (Ziolkowski et al., 1982; Dragoset, 1984; Parkes et al., 1984; Vaages et al., 1984; Laws et al., 1988 & 1990).

The model solves a complex set of differential equations combining both heat transfer and dynamics, and has been calibrated against multiple measurements of both non-interacting sources and interacting cluster sources for all common source types at a wide range of deployment depths.

2.2.2 Farfield signatures

The notional signatures from all sources in the array are combined using appropriate phase delays in three dimensions to obtain the farfield source signature of the array in all directions from the source. This procedure to combine the notional signatures to generate the farfield source signature is summarised as follows:

- The distances from each individual source to nominal farfield receiving locations are calculated. A 9 km receiver set is used for the current study;
- The time delays between the individual sources and the receiving locations are calculated from these distances with reference to the speed of sound;
- The signal at each receiver location from each individual source is calculated with the appropriate time delay. These received signals are summed to obtain the overall array farfield signature for the direction of interest; and
- The farfield signature also accounts for ocean surface reflection effects by inclusion of the “surface ghost”. An additional ghost source is added for each source element using a sea surface reflection coefficient of -1.

2.2.3 Beam patterns

The beam patterns of the source array are obtained as follows:

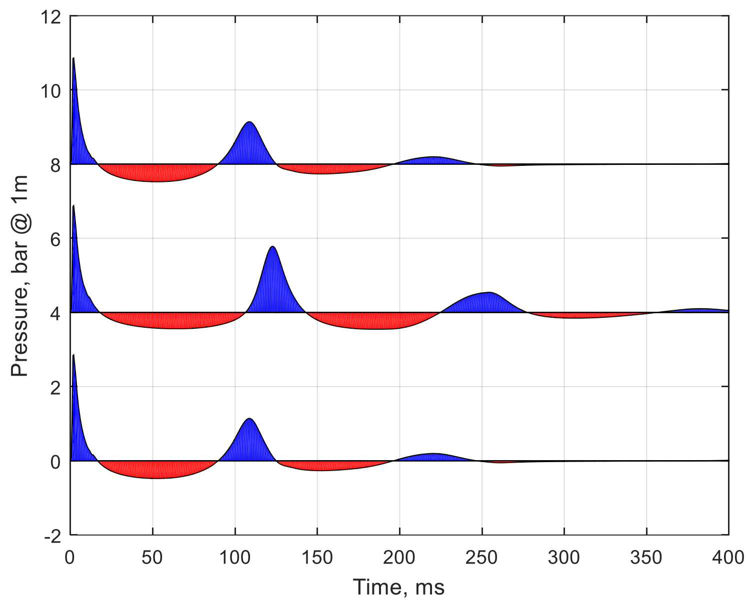
- The farfield signatures are calculated for all directions from the source using azimuthal and dip angle increments of 1-degree;
- The power spectral density (PSD) (dB re 1 µPa^{2}s/Hz @ 1m) for each pressure signature waveform is calculated using a Fourier transform technique; and
- The PSDs of all resulting signature waveforms are combined to form the frequency-dependent beam pattern for the array.

2.3 Modelling results

2.3.1 Notional signatures

Figure 3 shows the notional signatures for the 3 G-Gun sources of the 450 cubic inch source cluster.

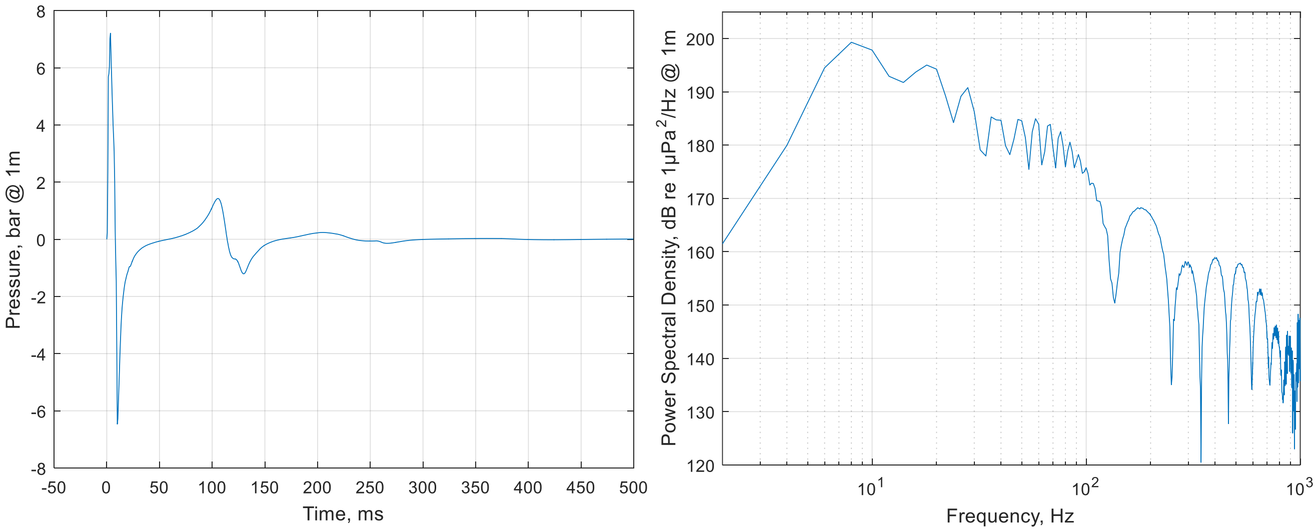
Figure 3 Notional source signatures for the three G-Gun sources of the 450 cubic inch source cluster. Time series of positive pressure and negative pressure indicated by blue fill and red fill respectively. The scale is the same for the signatures from all sources



2.3.2 Farfield signatures

Figure 4 shows the simulated signature waveform and its power spectral density based on Gundalf Designer software. The signature is for the vertically downward direction with surface ghost included.

Figure 4 The farfield signature of vertically downward direction (left) and the power spectral density (right) for the 450 cubic inch G-Gun cluster



The source modelling result shows that the peak sound pressure level (Pk SPL) is 7.3 bar (237.4 dB re 1 µPa @ 1m), the peak to peak sound pressure level (Pk-Pk SPL) 14.1 bar (243.0 dB re 1 µPa) @ 1m, the root-mean-square sound pressure level (RMS SPL) 225.2 dB re 1 µPa @ 1m with a 90%-energy pulse duration of 100 milliseconds, and the sound exposure level (SEL) 215.7dB re µPa^2·s @ 1m.

2.3.3 Beam patterns

Array farfield beam patterns of the following three cross sections are presented in **Figure 5**:

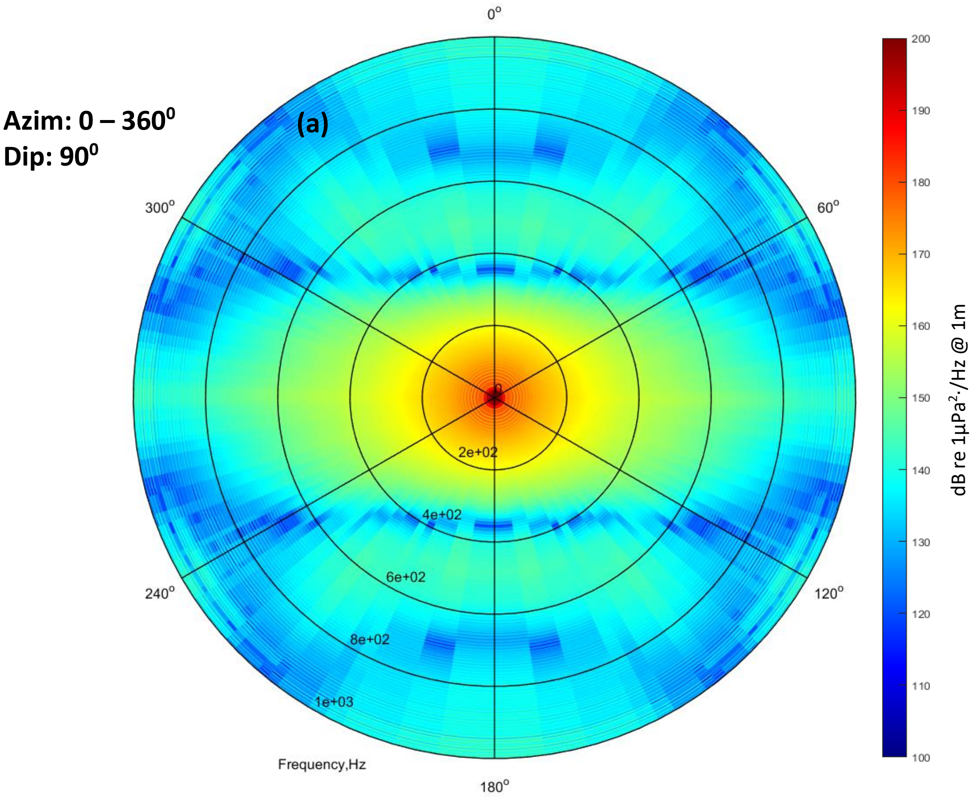
a) The horizontal plane (i.e. dip angle of 90 degrees) with azimuthal angle of 0 degree corresponding to the direction in parallel with the cluster frame plane;

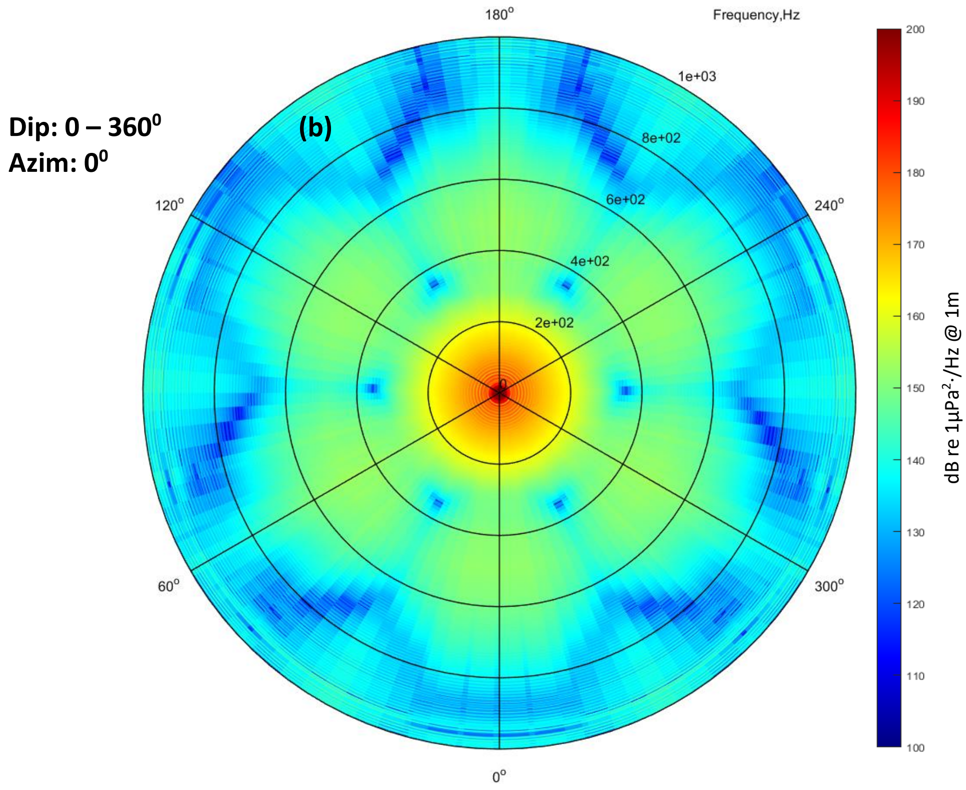
b) The vertical plane in parallel with the cluster frame plane (i.e. azimuthal angle of 0 degree) with dip angle of 0 degree corresponding to the vertically downward direction; and

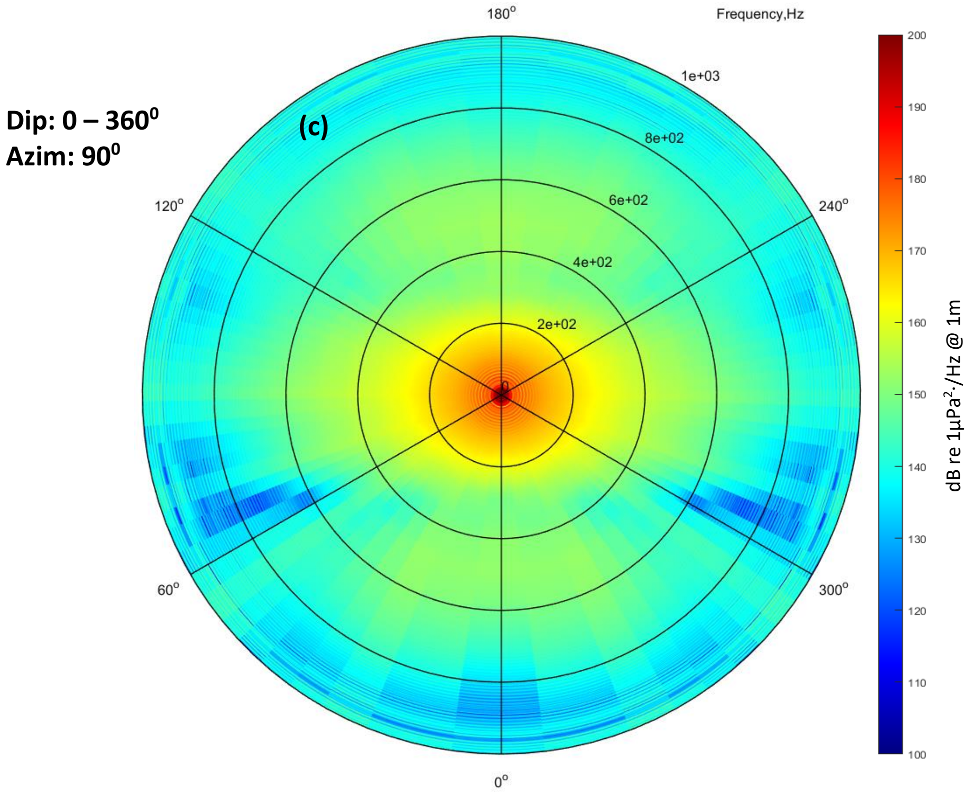
c) The vertical plane perpendicular to the cluster frame plane (i.e. azimuthal angle of 90 degrees) with dip angle of 0 degree corresponding to the vertically downward direction.

These beam patterns illustrate the strong angle and frequency dependence of the energy radiation from the array, as a result of interference between signals from different array elements.

Figure 5 Array farfield beam patterns as a function of orientation and frequency. (a) – The horizontal plane; (b & C) – The vertical planes in parallel with and perpendicular to the cluster frame plane respectively. 0 degree dip angle corresponds to vertically downward direction




Dip: 0 – 360⁰
Azim: 0⁰
(b)
180°
Frequency,Hz
1e+03
8e+02
6e+02
4e+02
2e+02
0
120°
240°
60°
300°
0°
200
190
180
170
160
150
140
130
120
110
100
dB re 1μPa²·/Hz @ 1m


Dip: 0 – 360⁰
Azim: 90⁰
(c)
180°
Frequency,Hz
1e+03
8e+02
6e+02
4e+02
2e+02
0
120°
240°
60°
300°
0°
200
190
180
170
160
150
140
130
120
110
100
dB re 1μPa²·/Hz @ 1m

3 Transmission loss modelling

3.1 Modelling input parameters

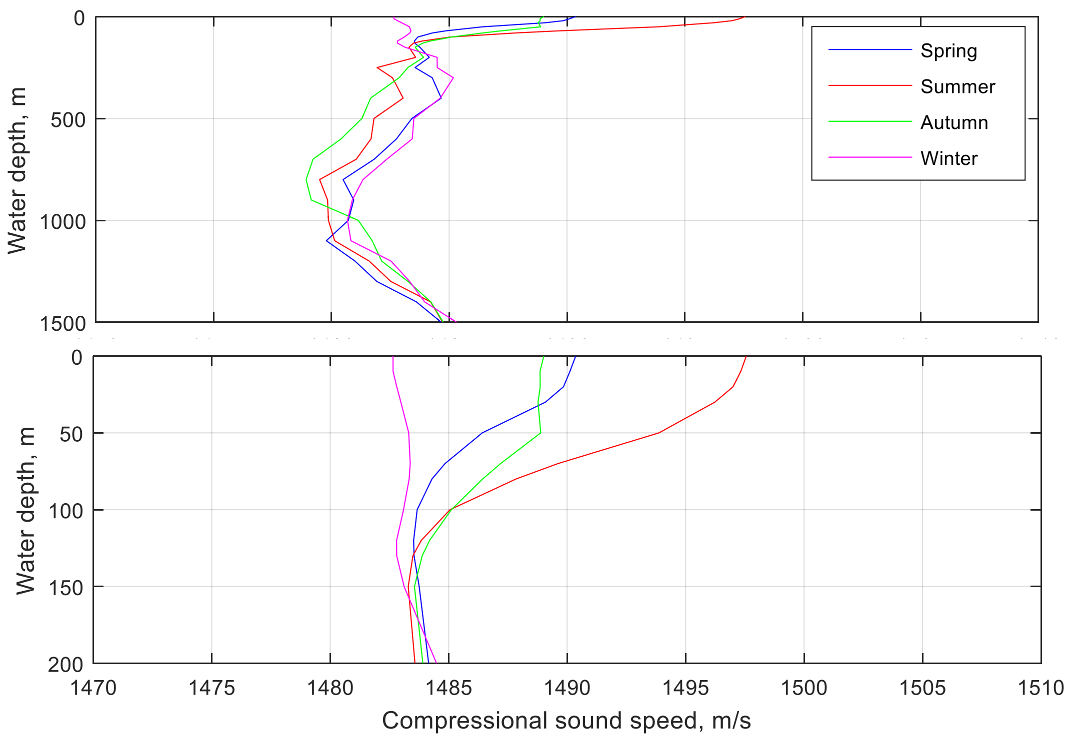
3.1.1 Sound speed profiles

Temperature and salinity data required to derive the sound speed profiles were obtained from the World Ocean Atlas 2009 (WOA09) (Locarnini et al., 2010; Antonov et al., 2010). The hydrostatic pressure needed for calculation of the sound speed based on depth and latitude of each particular sample was obtained using Sanders and Fofonoff's formula (Sanders and Fofonoff, 1976). The sound speed profiles were derived based on Del Grosso's equation (Del Grosso, 1974).

Figure 6 demonstrates typical sound speed profiles within the GSB for four southern hemisphere seasons. The most significant distinctions for the four profiles occur within the mixed layer near the sea surface. The spring, summer and autumn seasons have downwardly refracting near-surface profiles, with the summer profile having the stronger downwardly refracting feature. Winter season exhibits a strong and deep surface duct which will favour the propagation of sound from a near-surface source.

Based on a conservative consideration, the winter sound speed profile is selected as the worst case condition for the assessed sound propagation modelling scenario.

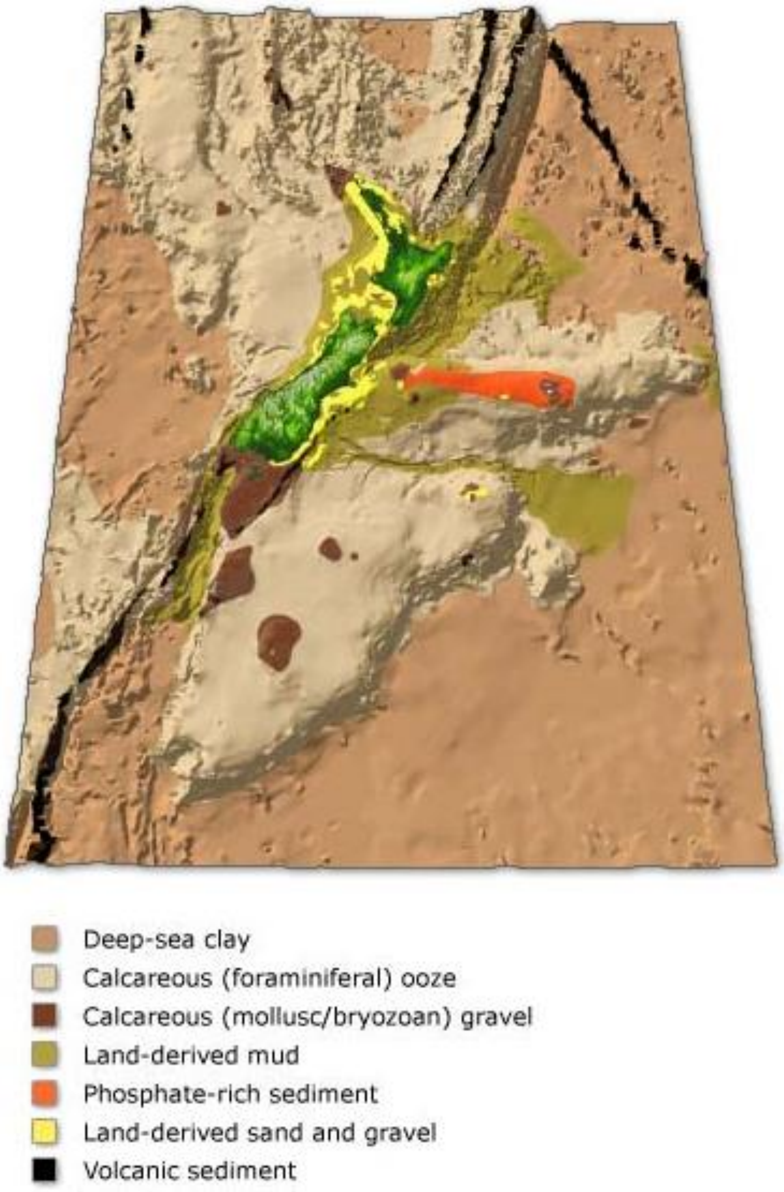
Figure 6 Typical sound speed profiles within the Great South Basin for different southern hemisphere seasons. Top panel shows profiles in deep water region, bottom panel shows profiles in continental shelf



3.1.2 Seafloor geoacoustic models

New Zealand has diverse seafloor sediments thanks to its variable and dynamic marine and terrestrial environments. NIWA has over many years produced a variety of marine sediment charts illustrating the ocean bottom types around coastal New Zealand and some offshore areas. The map in **Figure 7** extracted from NIWA illustrates the distribution of the main types of marine sediments found on the ocean floor around New Zealand (Lewis et al., 2012 & 2013).

Figure 7 The distribution of the main types of marine sediment on the seafloor within coastal and offshore regions around New Zealand



As can be seen from **Figure 7**, the continental shelf regions are covered mainly with land-derived sand, gravel and mud sediment, except at the northern and southern extremities where the shelly sediment from once-living sea creatures prevails due to the lack of major rivers. For offshore regions, the sediment materials are predominately pelagic sediments (i.e. mud to oozes, equivalent to silty clay) and deep-sea clay.

The geoacoustic properties for the various possible sediment types within the coastal and offshore regions are presented in **Table 2**. The geoacoustic properties for sand, silt and clay are as described in Hamilton (1980), with attenuations referred to in Jensen et al. (2011). The elastic properties of sand, silt and clay are treated as negligible.

Table 2 Geoacoustic properties for various possible sediment types within the coastal and offshore regions

Sediment Type	Density, ρ, (kg.m^{-3})	Compressional Wave Speed, c_p, (m.s^{-1})	Compressional Wave attenuation, α_p, (dB/λ)
Sand			
Coarse Sand	2,035	1,835	0.8
Fine Sand	1,940	1,750	0.8
Very Fine Sand	1,855	1,700	0.8
Silt - Clay			
Silt	1,740	1,615	1.0
Sand-Silt-Clay	1,595	1,580	0.4
Clayey Silt	1,490	1,550	0.2
Silty Clay	1,420	1,520	0.2

The reflection coefficients for sediments of sand, silt and clay are presented in **Figure 8** and **Figure 9** respectively. As can be seen, the sandy seafloor sediments are more reflective than the silt and clay sediments, particularly at low grazing angles.

Figure 8 Reflection coefficients (magnitude - top panel and phase – bottom panel) for sand sediments (coarse sand, fine sand and very fine sand)

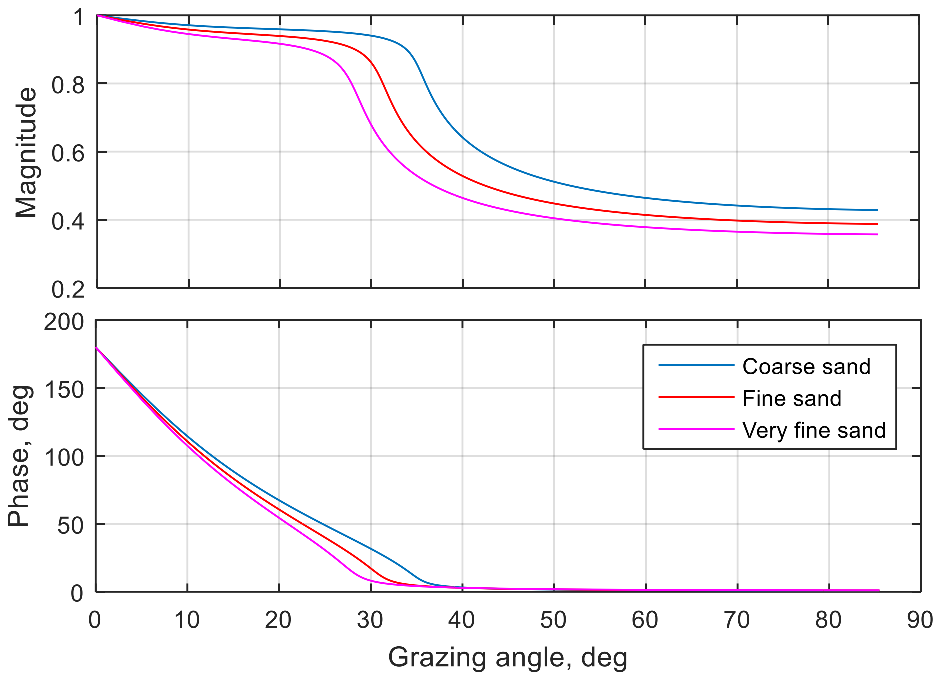
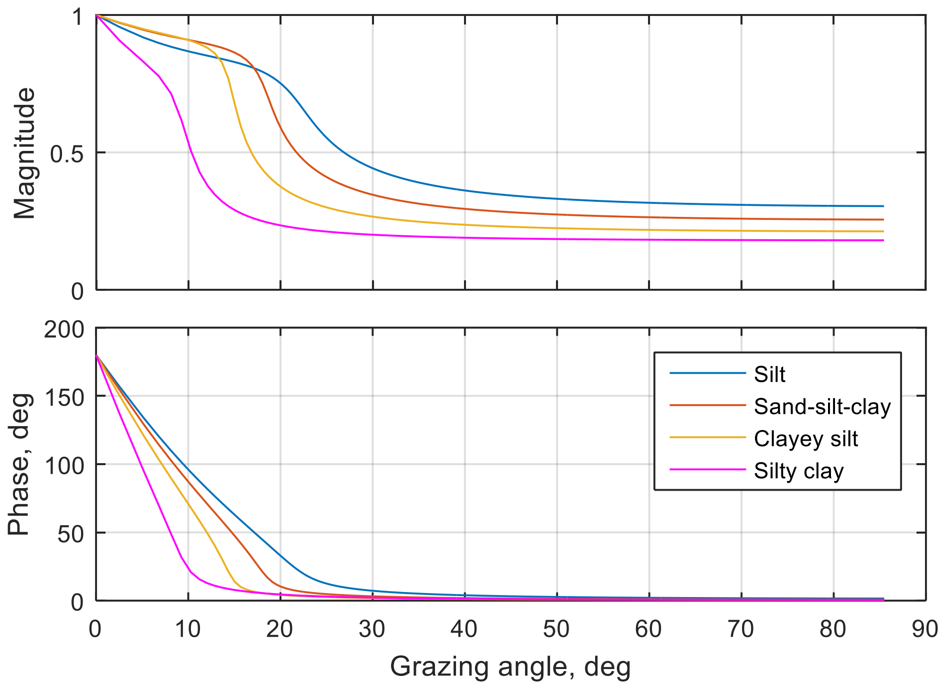


Figure 9 Reflection coefficient (magnitude - top panel and phase – bottom panel) for silt-clay sediments (silt, sand-silt-clay, clayey silt, silty clay)



3.2 Short range modelling - methodologies and procedures

3.2.1 Modelling methodology and procedure

The short range modelling is used to verify mitigation zones in relatively close proximity to the source array, and requires modelling predictions with high accuracy. In addition, interference between the signals arriving at any receiving location from different sources in the source array is expected to be significant and complex for such a near-field scenario. To account for these considerations, the predictions for the short range case are modelled by simulating the received signal waveforms from individual source units within the array.

The wavenumber integration modelling algorithm SCOOTER (Porter, 2010) is used to calculate the transfer functions (both amplitudes and phases) between sources and receivers. SCOOTER is a finite element code for computing acoustic fields in range-independent environments. The method is based on direct computation of the spectral integral, and is capable of dealing with an arbitrary layered seabed with both fluid and elastic characteristics.

The following procedures have been followed to calculate received SELs for short range cases:

1. The modelling algorithm SCOOTER is executed for frequencies from 1 Hz to 1 kHz, in 1 Hz increments. The source depth is taken to be the array depth of 5.0 m. A receiver grid of 1 m in range (maximum range 4.0 km) and 1 m in depth is applied for the selected receivers. For each gridded receiver, the received SEL is calculated by following steps 2) – 5);
2. The range from the source to each receiver is calculated, and the transfer function between the source and the receiver is obtained by interpolation of the results produced by modelling algorithm SCOOTER in Step 1). This interpolation involves both amplitude and phase of the signal waveform in frequency domain;

3. The complex frequency domain signal of the notional signature waveform for each source element is calculated via Fourier Transform, and multiplied by the corresponding transfer function from Step 2) to obtain the frequency domain representation of the received signal from the source element;
4. The waveform of received signal from the array source is reconstructed via Inverse Fourier Transform. The received signal waveforms from all airgun sources in the array are summed to obtain the overall received signal waveform; and
5. The signal waveform is squared and integrated over time to obtain the received SEL value. Alternatively, the SEL value can also be calculated via integration of the energy power density (ESD) over frequency in Step 3).

3.2.2 Modelling scenario

One short range modelling scenario will be conducted for the proposed exploration well with potential checkshot survey as shown in **Figure 1,** with the well characteristics as provided in **Table 1**, including the water depth.

The worst-case modelling conditions for underwater noise propagation applicable to the proposed checkshot survey (i.e., sandy seabed sediment and winter sound speed profile) have been assumed for the short range modelling case.

4 Short range modelling results

The received SELs from the 450 cubic inch G-Gun cluster array for the worst-case modelling scenario (i.e. winter season sound speed profile and sandy seabed properties) at the checkshot survey location Tāwhaki-1 have been calculated. Modelling results are outlined in detail in the following sections.

4.1 Tāwhaki-1

For the well location Tāwhaki-1, the maximum received SELs across the water column are presented as a function of azimuth and range from the centre of the array in **Figure 10**. The figure illustrates relatively higher SELs in directions perpendicular to the cluster frame plane as a result of the directivity of the source array.

The scatter plot of the predicted maximum SEL across the water column from the source array for all azimuths is displayed in **Figure 11** as a function of range from the centre of the source array, together with the mitigation threshold levels (i.e. 186 dB and 171dB re 1µPa²·s) and mitigation ranges (i.e. 200 m, 1.0 km and 1.5 km).

As can be seen from **Figure 11** and **Table 3**, the maximum received SELs over all azimuths are predicted to be 166.7 dB re 1µPa²·s at 200 m, 152.4 dB re 1µPa²·s at 1.0 km and 148.9 dB re 1µPa²·s at 1.5 km. These values are significantly lower than their corresponding mitigation threshold levels. As presented in **Table 4**, the received SELs are predicted to equal the threshold values of 186 dB re 1µPa²·s and 171 dB re 1µPa²·s at ranges of 22.1 m and 123.5 m respectively.

Figure 10 The predicted maximum received SELs across the water column from the 450 cubic inch array as a function of azimuth and range from the centre of the array. 0 degree azimuth corresponds to the direction in parallel with the cluster frame plane. The modelling scenario is for the well location Tāwhaki-1 with a water depth 1,323 m. Dark blue circles represent the mitigation zones of 200 m (solid), 1.0 km (dash) and 1.5 km (dash-dot)

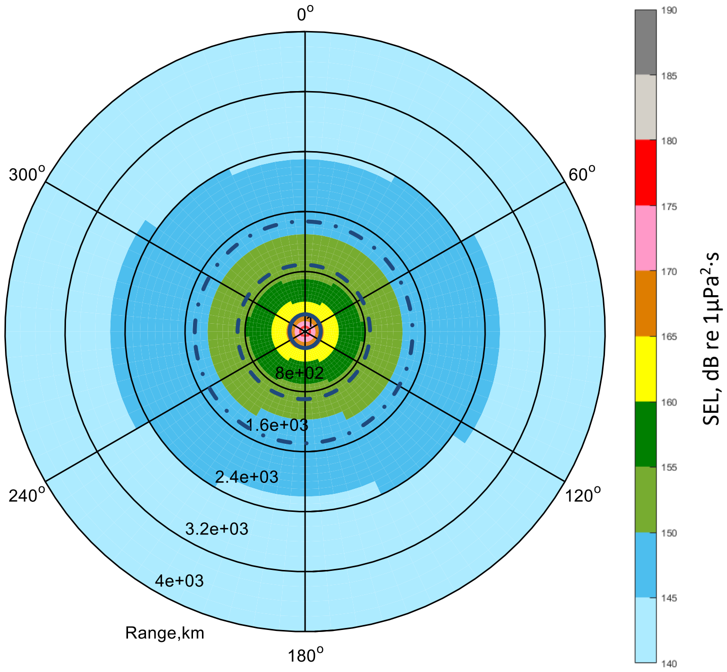


Figure 11 Scatter plot of predicted maximum SELs across the water column from the 450 cubic inch G-Gun cluster source array for all azimuths as a function of range from the centre of the source array. The modelling scenario is for well location Tāwhaki-1 with a water depth 1,323 m. Horizontal red lines show mitigation thresholds of 186 dB re 1µPa²·s (solid) and 171 dB re 1µPa²·s (dash). Vertical green lines show mitigation ranges of 200 m (solid), 1 km (dash) and 1.5 km (dash-dot)

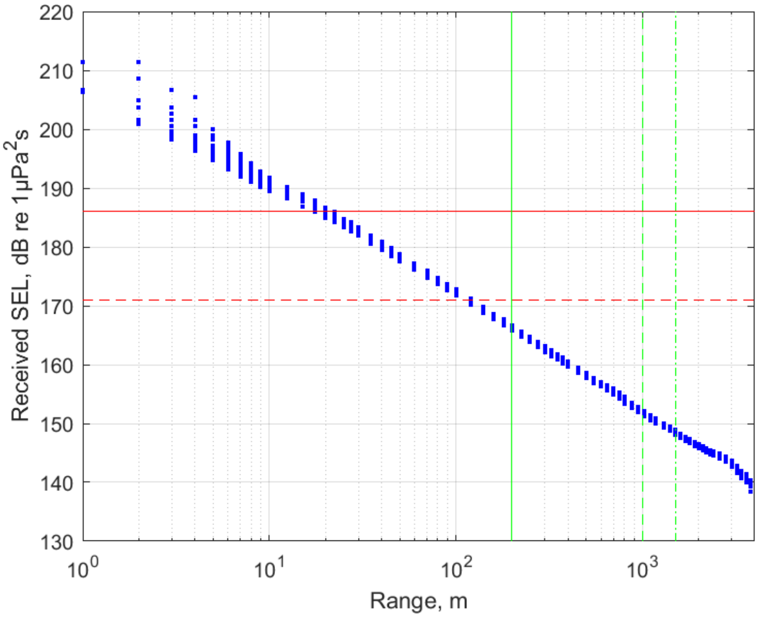


Table 3 Predicted maximum SELs for all azimuths at ranges of 200 m, 1 km and 1.5 km from the centre of the 450 cubic inch G-Gun cluster array for the well location Tāwhaki-1 with a water depth 1,323 m

Source location	Water depth, m	SELs at different ranges, dB re 1µPa²·s		
		200 m	**1.0 km**	**1.5 km**
Tāwhaki-1	1,323	166.7	152.4	148.9

Table 4 Ranges from the centre of the array where the predicted maximum SELs for all azimuths equals the SEL threshold levels for the 450 cubic inch G-Gun cluster array for the well location Tāwhaki-1 with a water depth 1,323 m

Source location	Water depth, m	Ranges complying with the following SEL thresholds, m	
		SEL < 186 dB re 1µPa²·s	**SEL < 171 dB re 1µPa²·s**
Tāwhaki-1	1,323	22.1	123.5

5 Conclusions

This report details the STLM study that has been carried out for the proposed checkshot survey at the exploration well Tāwhaki-1 OMV is proposing to drill as part of the GSB EAD Programme. The modelling study includes two modelling components, e.g. array source modelling and short range modelling. The detailed modelling methodologies and procedures for the two components are described in **Section 2** and **Section 3** of this report.

The short-range modelling prediction demonstrates that for the assessed exploration well location Tāwhaki-1, the maximum received SELs over all azimuths are predicted to comply with the thresholds stipulated within the Code, which are:

- 186 dB re 1µPa^2·s at 200 m, and
- 171 dB re 1µPa^2·s at 1.0 km and 1.5 km.

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APPENDIX 1

Acoustic Terminology

Sound Pressure	A deviation from the ambient hydrostatic pressure caused by a sound wave
Sound Pressure Level (SPL)	The logarithmic ratio of sound pressure to the reference pressure. The reference pressure underwater is P_{ref} = 1 µPa
Root-Mean-Square Sound Pressure Level (RMS SPL)	The mean-square sound pressure is the average of the squared pressure over the pulse duration. The root-mean-square sound pressure level is the logarithmic ratio of the root of the mean-square pressure to the reference pressure. Pulse duration is taken as the duration between the 5% and the 95% points on the cumulative energy curve
Peak Sound Pressure Level (Peak SPL)	The peak sound pressure level is the logarithmic ratio of the peak pressure over the impulsive signal event to the reference pressure
Peak-to-Peak Sound Pressure Level (Peak-Peak SPL)	The peak-to-peak sound pressure level is the logarithmic ratio of the difference between the maximum and minimum pressure over the impulsive signal event to the reference pressure
Sound Exposure Level (SEL)	SEL is a measure of energy. Specifically, it is the dB level of the time integral of the squared instantaneous sound pressure normalised to a 1-s period
Power Spectral Density (PSD)	PSD describes how the power of a signal is distributed with frequency
Source Level (SL)	The acoustic source level is the level referenced to a distance of 1m from a point source
1/3 Octave Band Levels	The energy of a sound split into a series of adjacent frequency bands, each being 1/3 of an octave wide
Sound Speed Profile	A graph of the speed of sound in the water column as a function of depth

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APPENDIX B

PAM Specifications

Specifications of the PAM equipment

Hardware

Blue Planet Marine can provide various customised passive acoustic monitoring systems suitable for detecting and monitoring cetaceans during seismic survey.

The towed hydrophone streamers are based on a well-established design by Marine Ecological Research in the United Kingdom. This design, which is a modern iteration of systems originally developed on a pioneering project funded by Shell UK to develop PAM for mitigation in the mid-1990s, has proven highly robust and reliable. It provides flexibility allowing the inclusion of various combinations of hydrophones and other sensors and can, if necessary, be disassembled and repaired in the field. Seismic PAM hydrophones operate in an environment in which the risk of hydrophone loss or damage is significant and options for external assistance are limited. While spare equipment is always provided, the use of a system that can be repaired in the field is, a distinct advantage. The systems that BPM would use for the survey will have a 340 m tow cable and an 80 m deck cable.

The variety of cetacean species likely to be encountered during seismic survey mitigation produce vocalisations over an extremely broad frequency range, from the infrasonic 15-30Hz calls of large baleen whales to the 130kHz pulses of harbour porpoise and Hectors dolphin. To be able to capture all of these, without being compromised by unwanted noise the PAM system uses two different hydrophone/premp pairs with different but overlapping frequency sensitivity: a low/medium frequency pair and a high frequency pair. These hydrophone pairs can be monitored, filtered and sampled independently. The high frequency hydrophones are fed through two different processing chains so that its typical to process and monitor 6 (3 pairs) acoustic channels (Figure 1).

Higher frequency filtering and amplification hardware is custom-built by Magrec to meet the specification required for cetacean monitoring. Important features include: adjustable low frequency filters from 0Hz to 3.2kHzs which can be applied to reduce low frequency noise allowing the available dynamic range to be conserved for capturing relevant marine mammal vocalisations within the frequency bands used each species. The Magrec HP27 preamp also provides an output with a fixed 20kHz low cut filter to optimise detection of the very high frequency vocalisations of porpoise, Hector's dolphins, beaked whales and Kogia.

(The HP27 also provides clean power for the hydrophone preamplifiers within the streamer and houses a depth sensor reader.)

Audio and low-ultrasonic frequency bands (up to 96 kHz) can be filtered and amplified as necessary using a high quality Behringer preamplifer. Ultra-high frequency click detection (which is particularly useful for porpoise, Hector's dolphins, kogia etc) is achieved by using a National Instruments Digital Acquisition card with a sampling rate of 1.2 mega samples s^{-1}. Other audio channels are captured at a sampling rate of 192kHz using a high-quality USB sound card.

Systems like this have been used from a wide variety of platforms ranging from sailing yachts to ocean-going research vessels, in waters from the tropics to the Antarctic. However, the need to monitor acoustically for mitigation has been a driver for much of the system's development. Seismic survey mitigation monitoring has been conducted from guard vessels and from the main seismic survey vessel itself.

Software

The system is optimised for use with PAMGUARD. A software suite specifically designed for detecting, classifying and localising a wide variety of marine mammals during seismic surveys. Much of the funding for the development of this program came from the oil exploration industry. MER was part of the team that initiated the PAMGUARD project and remains closely associated with its development. The hardware described here, has been developed in parallel with the PAMGUARD software.

PAMGUARD is an extremely flexible program with a range of modules that can be combined to provide customised configurations to suit particular applications. It includes modules for detecting both transient vocalisations (clicks) and tonal calls (e.g. whistles and moans). Cetacean click vocalisations range from the medium frequency clicks of sperm whales that can be detected at ranges of several miles, through the powerful broadband clicks produced by most delphinids to the specialised narrow band pulses of beaked whales, harbour porpoises and Hector's dolphins. High frequency tonal sounds include the whistle vocalisations produced by delphinids while low frequency tonals are produced by baleen whales. When data from two or more hydrophone elements are available PAMGUARD can calculate bearings to these vocalizations and provide locations by target motion analysis (e.g Figure 2).

PAMGUARD also includes routines for measuring and removing background noise, and for vetoing particularly intense sounds such as Airgun pules which are essential when monitoring is required during seismic survey operation.

In addition, PAMGUARD collects data directly from certain instruments. For example, it measures and displays the depth of the hydrophone streamer and takes NMEA data (such as GPS locations) from either the ship's NMEA data line or from the stand-alone GPS units provided with the equipment.

The ship's track, hydrophone locations, mitigation zones, airgun locations and locational information for acoustic detections are all plotted on a real-time map.

Species Detection

The frequency range, call type and vocal behaviour of cetaceans varies enormously between species and this affects the degree to which PAM provides additional detection capability, especially in the noisy environment of a seismic survey. This system has proven very effective in detecting small odontocetes and sperm whales, increasing detection reliability by an order of magnitude during trials (funded by Shell) conducted off the UK. PAM is particularly effective for the detection of sperm whales as they can be heard at significant ranges (several miles) and are consistently vocal for a large proportion of the time. Smaller odontocetes such as dolphins, killer whales, pilot whales and other "black fish" can be detected at useful ranges from both their whistle and click vocalisations but they often move so quickly that target motion may be difficult. The effective range for narrow band high frequency specialists, such as harbour porpoise is limited (usually to several hundred meters) by the high rate of absorption of their ultra-high frequency clicks. Detection range for these species is usually within proscribed mitigation ranges so that any reliable detection should lead to action. Towed hydrophones of this type have been very effective in picking up vocalisations from beaked whales during surveys and the narrow bandwidth and characteristic upsweep in their clicks greatly assists with their classification. However, beaked whales clicks are highly directional and vocal output can be sparse and intermittent so overall detection probability may remain low.

The value of PAM in mitigating the effects of seismic operations with baleen whales has yet to be fully explored. These whales generally vocalise at low frequencies making them particularly vulnerable to masking and interference from vessel and flow noise. Further, although some baleen whale vocalisations are very powerful, they are less consistently vocal than most odontocetes. Many of their vocalisations appear to be breeding calls and may be produced seasonally and either solely or predominantly by males.

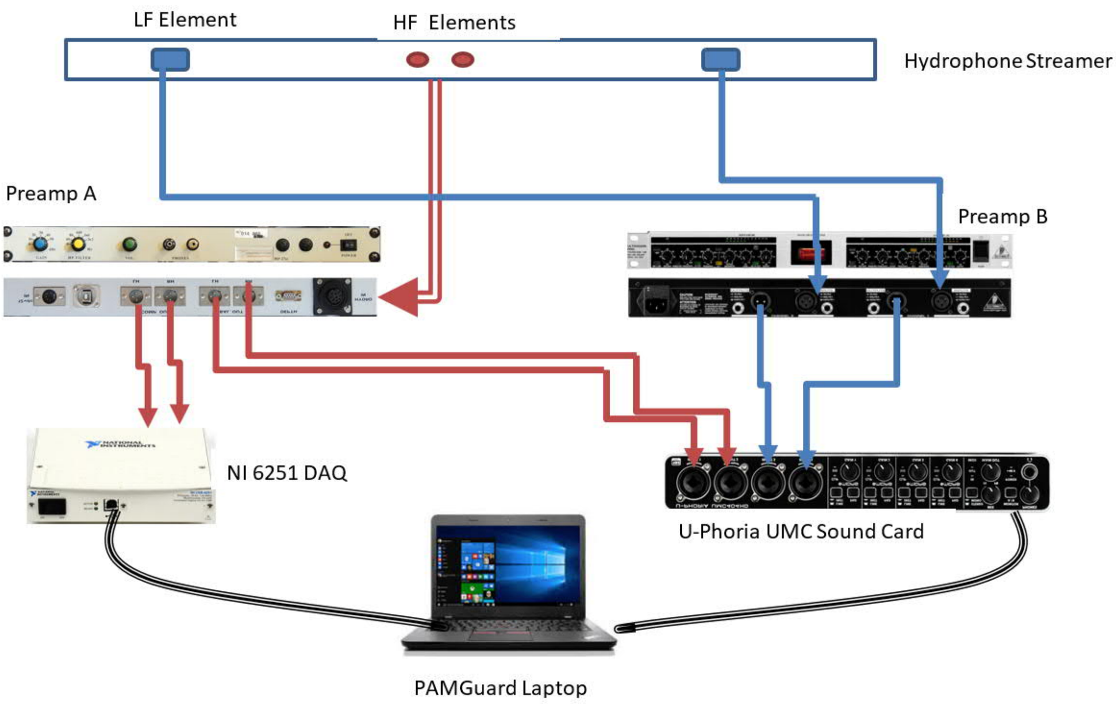

Figure 1 Schematic diagram showing the main elements of a typical six channel configuration of a Vanishing Point mitigation system.

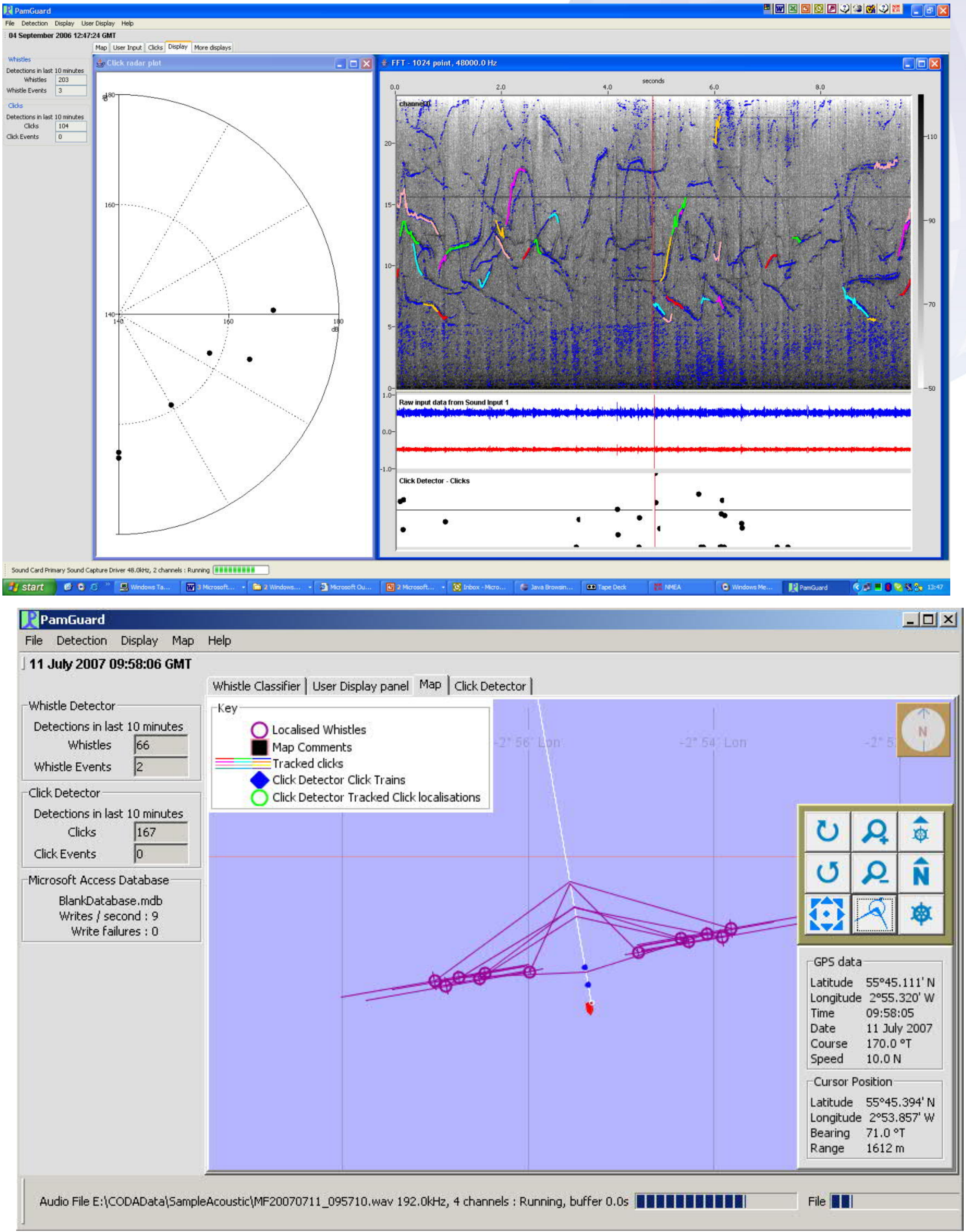

Figure 2 Screen shot from PAMGUARD Whistle and Click Detection and Mapping and Localisation Modules typical of a Seismic Mitigation configuration

Standard Seismic Mitigation Acoustic Monitoring System	
Towed Hydrophone	
Acoustic Channels	2 x Medium Frequency Benthos AQ4. –201 dBV re 1µPa (+/- 1.5 dB 1-15kHz) with Magrec HP02 broad band preamps (LF cut filter @ 100Hz or 50Hz as required) Near-flat sensitivity 50Hz- 15kHz with good sensitivity to higher frequencies
	2 x High Frequency Magrec HP03 units, comprising a spherical ceramic and HP02 preamp (low cut filter set at 2kHz) Near flat sensitivity 2kHz- 150kHz. +/-6 dB 500Hz to 180kHz
Depth Sensor	Keller 4-20mA 100m range Automatically read and displayed within PAMUARD
Streamlined housing	5m, 3 cm diameter polyurethane tube. Filled with Isopar M.
Cable	340m multiple screened twisted pair lines and power, with strain relief and Kellum's grip towing eye, Length deployed may vary to suit application
Connectors	19 pin Ceep IP68 waterproof
Deck cable	~75m 19pin Ceep to breakout box
Topside Amplifier Filter Unit	
Unit	Magrec HP/27ST
Supply Voltage	10-35 V DC
Supply current	200mA at 12 V
Input	Balanced input
Gain	Adjustable: 0,10,20,30,40,50 dB
High Pass Filter	-6db/octave selectable: 0, 40, 80, 400,1.6k, 3.2k
Output	2 X Balanced output via 3 pin XLR
Ultra HF Output	2 X Balanced output via 3 pin XLR (with 20kHz high pass filter for porpoise detection)
Headphone	Two outputs via ¼" jack
Overall Bandwidth	10Hz-200kHz +/–3dB
Unit	Behringer Mic 2200
Supply Voltage	220v AC
Input	Balanced
Gain	10- 60dB
High Pass Filter	0-20kHz
Overall Bandwidth	Frequency response 10 Hz to 200 kHz, +/- 3 dB
Headphone	Monitored via independent headphone amp.
GPS	
Input	Serial to USB adapter to interface with ship's NMEA supply
Backup	Standalone USB unit provided as independent backup
Computers	
	Up to date Laptop Computers
Digitisers	
Digitiser	NI USB 6251 high speed Digital Acquisition
Sound Card	High quality sound card 192kHz sampling rate e.g. Beghringer UMC 404HD or RME Fireface 400
Software	

General	PAMGUARD with appropriate configurations

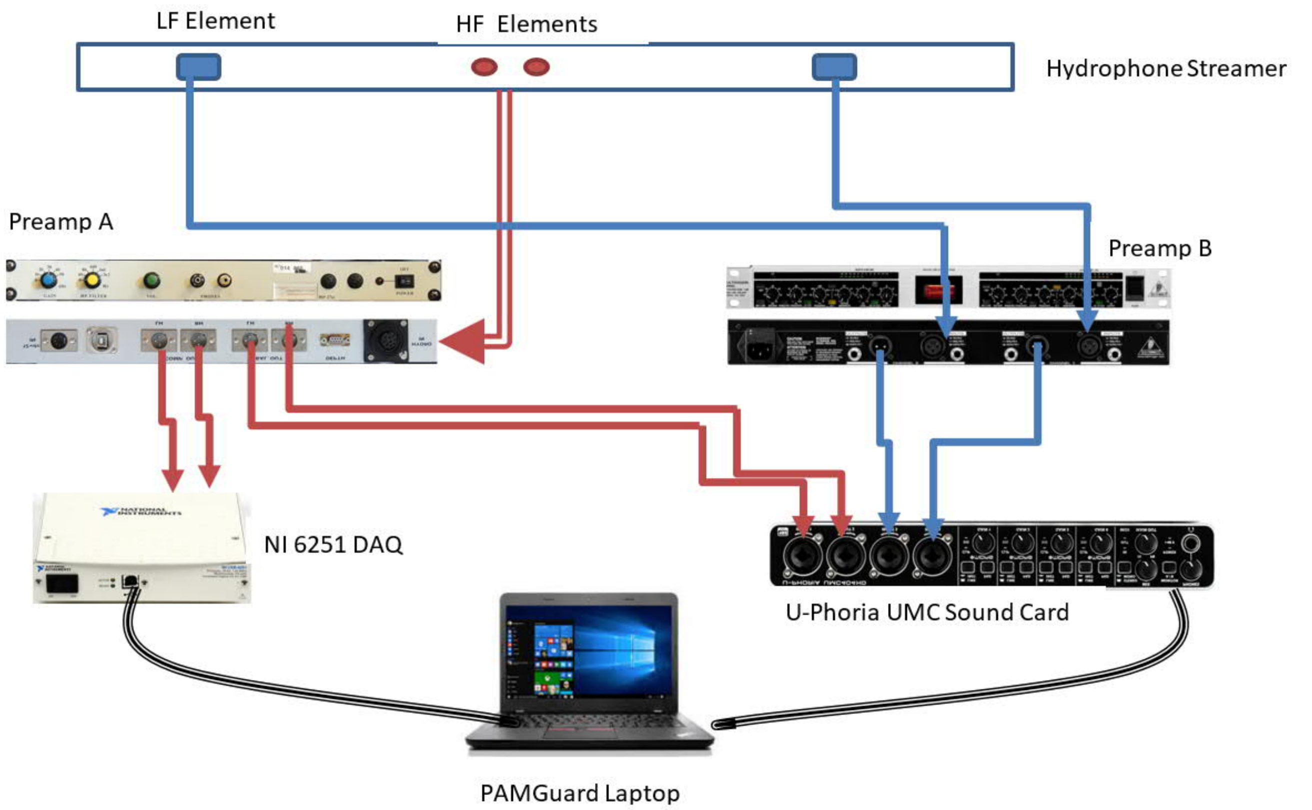

Figure 3 Schematic representation of BPM Multi-Channel PAM system

APPENDIX C

DOC Code of Conduct Species of Concern

LATIN NAME	COMMON NAME
Megaptera novaengliae	Humpback Whale
Balaenoptera borealis	Sei Whale
Balaenoptera edeni	Bryde's Whale
Balaenoptera bonaerensis	Antarctic Minke Whale
Balaenoptera acutorostrata subsp.	Dwarf Minke Whale
Balaenoptera musculus	Blue Whale
Balaenoptera physalus	Fin Whale
Balaenoptera musculus brevicauda	Pygmy Blue Whale
Eubalaena australis	Southern Right Whale
Caperea marginata	Pygmy Right Whale
Lissodelphis peronii	Southern Right-whale Dolphin
Globicephala melas	Long-finned Pilot Whale
Globicephala macrorhynchus	Short-finned Pilot Whale
Peponcephala electra	Melon-headed Whale
Physeter macrocephalus	Sperm Whale
Kogia sima	Dwarf Sperm Whale
Kogia breviceps	Pygmy Sperm Whale
Mesoplodon grayi	Gray's Beaked Whale
Berardius arnuxii	Arnoux's Beaked Whale
Ziphius cavirostris	Cuvier's Beaked Whale
Mesoplodon layardii	Strap-toothed Whale
Hyperoodon planifrons	Southern Bottlenose Whale
Mesoplodon bowdoini	Andrew's Beaked Whale
Mesoplodon mirus	True's Beaked Whale
Mesoplodon densirostris	Blainville's Beaked Whale
Mesoplodon gingkodens	Ginkgo-toothed Whale
Mesoplodon hectori	Hector's Beaked Whale
Mesoplodon peruvianus	Pygmy/Peruvian Beaked Whale
Tasmacetus shepherdi	Shepherd's Beaked Whale
Orcinus orca	Killer Whale
Pseudorca crassidens	False Killer Whale
Feresa attenuata	Pygmy Killer Whale
Cephalorhynchus hectori	Hector's Dolphin
Cephalorhynchus hectori maui	Maui's Dolphin
Phocarctos hookeri	New Zealand Sea Lion
Tursops truncatus	Bottlenose Dolphin

APPENDIX D

Marine Mammal Mitigation Plan

MARINE MAMMAL MITIGATION PLAN

Great South Basin
Checkshot Survey

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SLR Ref: 740.10083.00300-R01
Version No: -v1.0
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BASIS OF REPORT

This report has been prepared by SLR Consulting NZ Limited (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with OMV GSB Limited (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
740.10083.00300-R01-v2.0	20 December 2019	SLR Consulting Limited	[redacted]	[redacted]
740.10083.00300-R01-v1.0	10 December 2019	SLR Consulting Limited	[redacted]	[redacted]

CONTENTS

DOCUMENT REFERENCES

TABLES

FIGURES

APPENDICES

CONTENTS

ABBREVIATIONS AND DEFINITIONS

Code of Conduct	Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations
DOC	Department of Conservation
EAD	Exploration and Appraisal Drilling
EPA	Environmental Protection Authority
GSB	Great South Basin
MMIA	Marine Mammal Impact Assessment
MMMP	Marine Mammal Mitigation Plan
MMO	Marine Mammal Observer
MODU	Mobile Offshore Drilling Unit
OMV	OMV GSB Limited
PAM	Passive Acoustic Monitoring

1 Introduction

1.1 Purpose of the Marine Mammal Mitigation Plan

The purpose of this Marine Mammal Mitigation Plan (**MMMP**) is to outline the procedures to be implemented for the responsible operation of seismic activities around marine mammals during the Great South Basin (**GSB**) Checkshot Survey undertaken as part of the Great South Basin Exploration and Appraisal Drilling (**EAD**) Programme.

The MMMP will be used by observers and crew to guide operations in accordance with the Department of Conservation (**DOC**) 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations (**Code of Conduct**).

1.2 Survey Outline

OMV GSB Limited (**OMV**) will be undertaking an EAD Programme within the GSB which is expected to commence in Q1 2020: the GSB EAD Programme. The purpose of the GSB EAD Programme is to determine the presence of hydrocarbons within a number of identified geological structures and to investigate the potential for future development of discovered hydrocarbons within OMV's Petroleum Exploration Permit 50119. The GSB EAD Programme will commence with the drilling of the Tāwhaki-1 well, to which this MMMP relates. In the event that a hydrocarbon accumulation is discovered following the drilling of Tāwhaki-1, a checkshot survey will be undertaken. A checkshot survey will not be required in the event of a 'dry' well.

An Operational Area has been identified, within which all seismic operations will be restricted, as illustrated in **Figure 1.** The coordinates for the corners of the Operational Area are provided in **Table 1**. The water depth at the proposed Tāwhaki-1 well location is approximately 1,325 m while water depths in the wider Operational Area range from 1,235 – 1,476 m. The Operational Area does not enter the 12 Nm territorial sea, and does not approach or enter the Catlins Coast Marine Mammal Sanctuary.

Table 1 Tāwhaki-1 Operational Area Coordinates

	Easting (m)	Northing (m)	Latitude	Longitude
(Target well depth)	NZTM-East	NZTM-North	WGS84 Decimal Degrees	
3,065 m	1492880	4804240	-46.9067	171.5934
	1500300	4803060	-46.9185	171.6906
	1489160	4789110	-47.0422	171.5409
	1497180	4787340	-47.0594	171.646

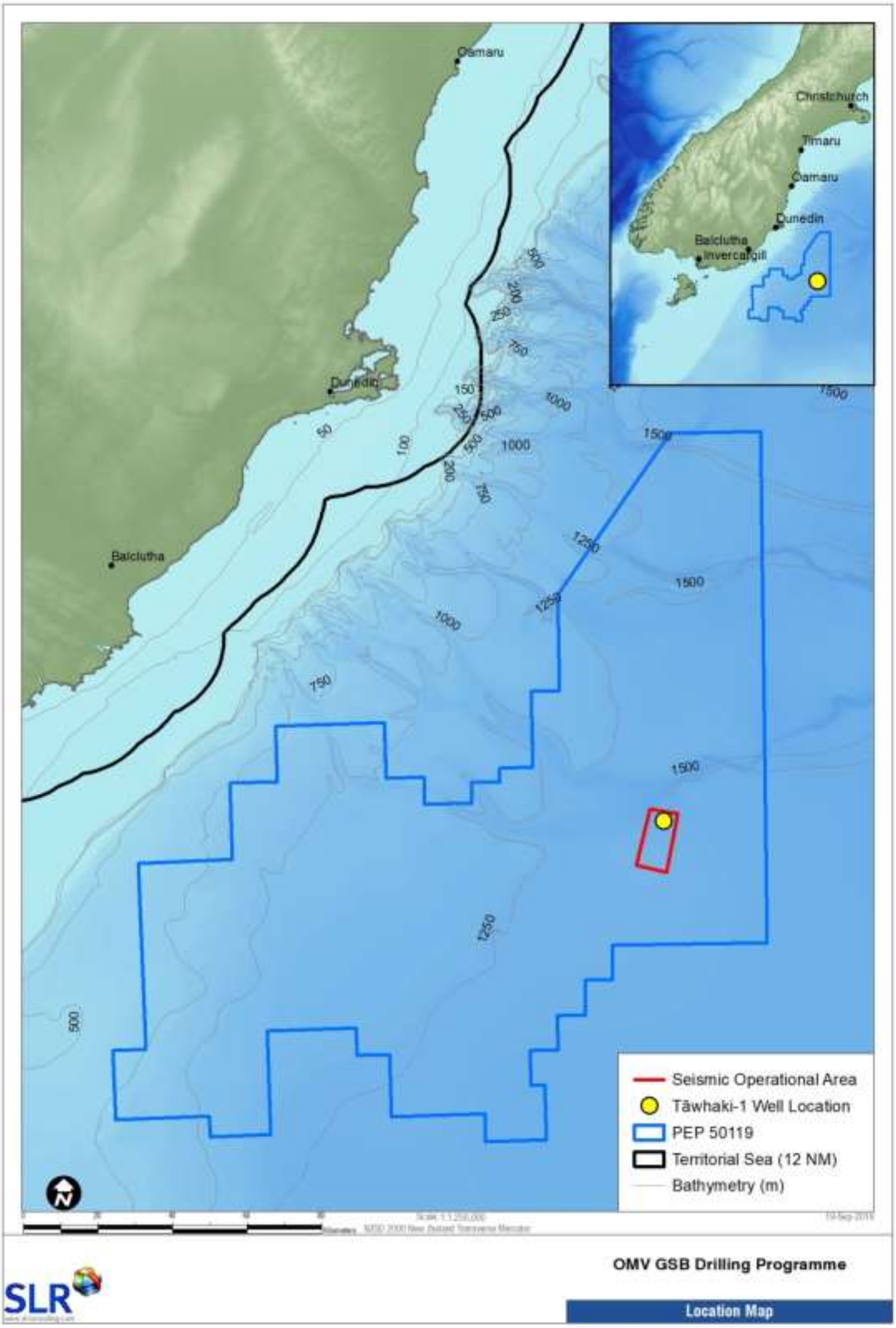
During a checkshot survey the acoustic source is lowered into the water column from a crane on the Mobile Offshore Drilling Unit (**MODU**). A downhole receiver is lowered into the recently completed well bore to receive the sound. The acoustic source emits the first signal with the receiver at the deepest point in the well, after which the receiver is raised at pre-determined distance intervals within the wellbore and the process is repeated. This process continues until the receiver reaches a point within the subsurface where the signal received is too weak to be recorded accurately (typically due to the acoustic signal having to penetrate through multiple casing strings to reach the receiver inside the wellbore). The survey could take up to 5.5 hours to complete, depending on the particular well characteristics and required information.

The acoustic source proposed for the potential survey is comprised of three 150 in^3 sub-sources, with an effective volume of 450 in^3. According to the Code of Conduct, the proposed checkshot survey is classified as a Level 1 seismic survey on account of the acoustic source being greater than 427 in^3.

During the checkshot survey a support vessel will be present close to the MODU (circling at approximately 1 km). The Marine Mammal Observers (**MMO**) will be onboard the MODU; however, due to the interfering noise source that is emitted from the MODU, the Passive Acoustic Monitoring (**PAM**) system and PAM Operators will be stationed onboard the support vessel.

As the drilling schedule for the Tāwhaki-1 well is currently unknown it is not possible to provide a detailed timeframe for when the checkshot surveys might occur. Unlike traditional 2D or 3D seismic surveys, checkshot surveys are not constrained by weather conditions or season, unless weather conditions are so severe that the MODU cranes cannot be operated.

Figure 1 Location of Operational Area



2 Procedures for Seismic Operations

2.1 Standard Procedures

The procedures outlined below are stipulated by the Code of Conduct and represent the standard mitigations that operators implement for compliance with the Code of Conduct during a Level 1 seismic survey. **Section 2.2** describes the variations that are specific to the GSB EAD Checkshot Survey.

2.1.1 Notification

The notification requirements of the Code of Conduct have been adhered to. OMV notified the Director General of Conservation at DOC on 26 June 2019 of their intention to undertake the checkshot survey as part of the wider GSB EAD Programme.

2.1.2 Marine Mammal Impact Assessment

Under normal circumstances, a Marine Mammal Impact Assessment (**MMIA**) must be submitted to the Director-General of Conservation not less than one month prior to the start of a checkshot survey. To fulfil this requirement, the MMIA for the GSB Checkshot Survey was submitted to DOC in December 2019. This MMMP forms part of the MMIA. Note that the term 'Species of Concern' is used both in the MMIA and the Code of Conduct, **Appendix 1** lists these species.

2.1.3 Observer Requirements

All Level 1 seismic surveys require the use of MMOs in conjunction with PAM. MMOs visually detect marine mammals while the PAM system detects marine mammal vocalisations with hydrophones and is overseen by PAM Operators. MMOs and PAM Operators must be qualified according to the criteria outlined in the Code of Conduct.

The minimum qualified observer requirements for a Level 1 survey are:

- There will be at least two qualified MMOs on-board at all times;
- There will be at least two qualified PAM Operators on-board at all times;
- The roles of MMOs and PAM Operators are strictly limited to the detection and collection of marine mammal sighting data, and the instruction of crew on the Code of Conduct and the crew's requirements when a marine mammal is detected within mitigation zones (including pre-start, soft start and operating at full acquisition capacity requirements). A summary of MMO and PAM Operator duties are presented in **Table 2**;
- At all times when the acoustic source is in the water, at least one qualified MMO (during daylight hours) and at least one qualified PAM Operator will maintain 'watch' for marine mammals; and
- The maximum on-duty shift for an MMO or PAM Operator must not exceed 12 hours per day.

Note that in the event that qualified MMO and PAM Operator personnel are unable to be engaged for the GSB Checkshot Surveys, the Code of Conduct provides for a qualified MMO or PAM Operator to act as a supervisor/mentor to a trained MMO or PAM Operator. Therefore, one qualified observer and one trained observed may be engaged in each observation role (i.e. MMO or PAM Operator); however, at least one of the engaged MMOs will be qualified as there are no provisions under the Code of Conduct for a suitable trained MMO to undertake the same role as a qualified MMO. Given the unknowns around the duration and timing of the GSB EAD Programme and associated checkshot survey, details of the observers engaged for the GSB Checkshot Survey are not known as part of this MMMP process. Prior to the commencement of the GSB Checkshot Survey, the names, qualifications, and experience of each observer will be provided to DOC and the EPA for approval/acceptance.

MMOs and PAM Operators must schedule their shifts and breaks in such a way as to manage their fatigue levels appropriately so that focus on the required monitoring can be maintained.

Marine mammal observations by crew members are accommodated under the Code of Conduct through the following prescribed process:

1. Crew member to promptly report sighting to MMO;
2. If marine mammal remains visible, MMO to identify marine mammal and distance from acoustic source; and
3. If marine mammal is not observed by the MMO, the crew member will be asked to complete a sighting form and the implementation of any resulting mitigation action will be at the discretion of the MMO.

Table 2 Operational Duties of Qualified Observers

MMO Duties	PAM Operator Duties
Provide effective briefings to crew members, and establish clear lines of communication and procedures for on-board operations.	Provide effective briefings to crew members, and establish clear lines of communication and procedures for on-board operations.
Continually scan the water surface in all directions around the acoustic source for presence of marine mammals, using a combination of naked eye and high-quality binoculars from optimum vantage points for unimpaired visual observations.	Deploy, retrieve, test and optimise PAM hydrophone arrays.
Determine distance/bearing and plot positions of marine mammals whenever possible during sightings using GPS, sextant, reticle binoculars, compass, measuring sticks, angle boards or other appropriate tools.	When on duty, concentrate on continually listening to received signals and/or monitor PAM display screens in order to detect vocalising cetaceans, except when required to attend to PAM equipment.
Record/report all marine mammal sightings, including species, group size, behaviour/activity, presence of calves, distance and direction of travel (if discernible).	Use appropriate sample analysis and filtering techniques.
Record sighting conditions (Beaufort sea state, swell height, visibility, fog/rain and glare) at the beginning and end of the observation period, and whenever there is a significant change in weather conditions.	Record and report all cetacean detections, including, if discernible, identification of species or cetacean group, position, distance and bearing from vessel and acoustic source. Record the type and nature of sound, time and duration over which it was heard.

MMO Duties	PAM Operator Duties
Record acoustic source power output while in operation, and any mitigation measures taken.	Record general environmental conditions, acoustic source power output while in operation, and any mitigation measures taken.
Communicate with DOC to clarify any uncertainty or ambiguity in application of the Code of Conduct.	Communicate with DOC to clarify any uncertainty or ambiguity in application of the Code of Conduct.
Record/report to DOC any instances of non-compliance with the Code of Conduct.	Record/report to DOC any instances of non-compliance with the Code of Conduct.

2.1.4 PAM Operations

Due to the limited detection range of current PAM technology, any ultra-high frequency detections will require an immediate shutdown of an active source or will delay the start of operations, regardless of signal strength or whether distance or bearing from the acoustic source has been determined. It is not necessary to determine whether the marine mammal is within a mitigation zone. However, shutdown of an activated source will not be required if visual observations by a MMO confirm the acoustic detection was of a species falling into the category of 'Other Marine Mammals' (i.e. not a Species of Concern).

If the PAM system malfunctions[1] or becomes damaged, seismic operations may continue for 20 minutes without PAM while the PAM operator diagnoses the problem. If it is found that the PAM system needs to be repaired, seismic operations may continue for an additional two hours without PAM as long as the following conditions are met:

- It is during daylight hours and the sea state is less than or equal to Beaufort 4;
- No marine mammals were detected solely by PAM in the relevant mitigation zones in the previous two hours;
- Two MMOs maintain watch at all times during seismic operations when PAM is not operational;
- DOC is notified via email as soon as practicable, stating time and location in which seismic operations began without an active PAM system; and
- Seismic operations with an active source, but without an active PAM system, do not exceed a cumulative total of four hours in any 24 hour period.

2.1.5 Reporting Requirements

Qualified observers are required under the Code of Conduct to record and report all marine mammal sightings during the survey (regardless of where they occur in relation to a mitigation zone). The following standardised excel datasheets must be used:

- On-survey Excel Reporting Form: http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/seismic-surveys-code-of-conduct/on-survey-seismic-mmo-reporting-form.xls
- Off-survey Excel Reporting Form: http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/seismic-surveys-code-of-conduct/off-survey-seismic-mmo-reporting-form.xls

[1] PAM malfunction can relate to the towed PAM equipment, or the software used to receive, process and display acoustic detections.

All raw datasheets must be submitted directly to DOC at the earliest opportunity, but no longer than 14 days after the completion of each deployment. A written final report must also be provided to DOC at the earliest opportunity, but no later than 60 days after the completion of the survey.

If qualified observers consider that there are higher than expected numbers of marine mammals encountered during seismic survey operations, they are required to immediately notify the Director General of Conservation. Adaptive management procedures will be agreed following a discussion between DOC and the Operator. The MMO/PAM team will then implement any required adaptive management actions.

Incidents of non-compliance with the Code of Conduct must be reported immediately to DOC and the Environmental Protection Authority (**EPA**). Within 48 hours of the initial notification of non-compliance a short summary of the incident should be sent by email to DOC and the EPA to provide a written record that outlines the nature of the non-compliance, where it occurred, when it occurred, why it occurred, how it occurred and any steps that have been taken to prevent reoccurrence.

2.1.6 Pre-Start Observations

A Level 1 acoustic source can only be activated if it is within the specified Operational Area and adheres to the following protocol:

- The acoustic source cannot be activated during daylight hours unless:
  - At least one qualified MMO has made continuous visual observations around the source for the presence of marine mammals, using both binoculars and the naked eye, and no marine mammals (other than New Zealand fur seals) have been observed in the relevant mitigation zone for at least 30 minutes, and no New Zealand fur seals have been observed in the relevant mitigation zones for at least 10 minutes; and
  - Passive acoustic monitoring for the presence of marine mammals has been carried out by a qualified PAM Operator for at least 30 minutes before activation and no vocalising cetaceans have been detected in the relevant mitigation zones.
- The acoustic source cannot be activated during night-time hours or poor sighting conditions (visibility of 1.5 km or less or in a sea state greater than or equal to Beaufort 4) unless:
  - Passive acoustic monitoring for the presence of marine mammals has been carried out by a qualified PAM Operator for at least 30 minutes before activation; and
  - The qualified PAM Operator has not detected any vocalising cetaceans in the relevant mitigation zones.

As the commencement of the checkshot survey meets the requirement of a ‘new location’, the following additional requirements for start-up at night or in poor sightings conditions will be applied:

- MMOs will have undertaken observations within 20 NM of the planned start-up position for at least the last two hours of good sighting conditions preceding proposed operations, and no marine mammals have been detected; or
- Where there have been less than two hours of good sighting conditions preceding proposed operations (within 20 NM of the planned start-up position), the source may be activated if:
  - PAM monitoring has been conducted for two hours immediately preceding proposed operations;
  - Two MMOs have conducted visual monitoring in the two hours immediately preceding proposed operations;

- No Species of Concern have been sighted during visual monitoring or detected during acoustic monitoring in the relevant mitigation zones in the two hours immediately preceding proposed operations;
- No fur seals have been sighted during visual monitoring in the relevant mitigation zone in the 10 minutes immediately preceding proposed operations; and
- No other marine mammals have been sighted during visual monitoring or detected during acoustic monitoring in the relevant mitigation zones in the 30 minutes immediately preceding proposed operations.

2.1.7 Soft Starts

A soft start consists of gradually increasing the source's power, starting with the lowest capacity acoustic source, over a period of at least 20 minutes and no more than 40 minutes. With regard to soft starts, the following points are critical:

- **The operational source capacity is not to be exceeded during the soft start period; and**
- **The observer team must draw this to the attention of the seismic staff on-board the MODU.**

Where possible, initial activation of the acoustic source must be by soft start, unless the source is being reactivated after a break in firing less than 10 minutes before that time (not in response to a marine mammal observation within a mitigation zone). In the case of checkshot seismic surveying, activation of the acoustic source at least once within sequential 10 minute periods shall be regarded as continuous operation.

2.1.8 Mitigation Zones for Delayed Starts and Shutdowns

Species of Concern with calves within a mitigation zone of 1.5 km

If, during pre-start observations or while the acoustic source is activated (including during soft starts), a qualified observer detects at least one Species of Concern with a calf within 1.5 km of the source, start-up will be delayed or the source will be shut down and not reactivated until:

- A qualified observer confirms the group has moved to a point that is more than 1.5 km from the source; or
- Despite continuous observation, 30 minutes has elapsed since the last detection of the group within 1.5 km of the source, and the mitigation zone remains clear.

Where marine mammal detection occurs via PAM it shall be recognised that calves and adults cannot be differentiated, therefore calf presence must be assumed and the 1.5 km mitigation zone will apply to all Species of Concern.

Species of Concern within a mitigation zone of 1 km

If during pre-start observations or while the acoustic source is activated (including during soft starts), a qualified observer detects a Species of Concern within 1 km of the source, start-up will be delayed or the source will be shut down and not reactivated until:

- A qualified observer confirms the Species of Concern has moved to a point that is more than 1 km from the source; or

- Despite continuous observation, 30 minutes has elapsed since the last detection of a Species of Concern within 1 km of the source, and the mitigation zone remains clear.

Other Marine Mammals within a mitigation zone of 200 m

If during pre-start observations prior to initiation of the acoustic source soft-start procedures, a qualified observer detects a marine mammal other than a Species of Concern within 200 m of the source, start-up will be delayed until:

- A qualified observer confirms the marine mammal has moved to a point that is more than 200 m from the source; or
- Despite continuous observation, 10 minutes has elapsed since the last detection of a New Zealand fur seal within 200 m of the source and 30 minutes has elapsed since the last detection of any other marine mammal within 200 m of the source, and the mitigation zone remains clear.

Once all marine mammals that were detected within the relevant mitigation zones have been observed to move beyond the respective mitigation zones, there will be no further delays to the initiation of soft start procedures.

2.1.9 Acoustic Source Testing

Acoustic source testing will be subject to the relevant soft start procedure, although for testing, the 20 minute minimum duration does not apply. The power of the acoustic source should be built up gradually to the required test level at a rate not exceeding that of a normal soft start.

Acoustic source tests shall not be used for mitigation purposes, or to avoid implementation of soft start procedures.

2.1.10 Key Contacts and Communication Protocols

The key contact for DOC is Dave Lundquist who can be contacted by phone on [redacted] or email at [redacted]t@doc.govt.nz. Dave is the point of contact for all DOC enquiries or notifications.

Any correspondence with the EPA should be directed to seismic.compliance@epa.govt.nz.

Note that OMV must be kept informed of any correspondence with DOC or the EPA; in this regard please copy all emails to [redacted]:[redacted]@omv.com. Any phone calls made to DOC should be followed up with an email to confirm the message; please cc these emails to [redacted] [redacted] at [redacted]@omv.com.

2.2 Additions to the Code of Conduct

The procedures outlined in this section are further to those required by the Code of Conduct. These additional procedures have been adopted by OMV for the purpose of the GSB Checkshot Survey and have been agreed with DOC as part of the MMIA process. Based on this it is imperative that these procedures are considered as strict requirements of the survey and therefore constitute additional responsibilities of qualified observers during the GSB Checkshot Survey.

2.2.1 Reporting Requirements

In addition to the reporting requirements outlined in **Section 2.1.5**, the following additional reporting components are required:

- Marine mammal sightings will be collected whilst in transit to the Operational Area. These records will be collated onto the DOC standardised 'Off-survey Excel Reporting Forms' (http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/seismic-surveys-code-of-conduct/off-survey-seismic-mmo-reporting-form.xls) and will be provided to DOC no later than 14 days after the completion of each deployment;
- MMOs will be vigilant for dead marine mammals observed at sea and will report details of these incidences to DOC in the final trip report; and
- MMOs to notify DOC immediately of any Hector's/Maui's dolphin sightings. These sightings will be made via telephone to [redacted] on [redacted], with a follow up email sent to [redacted]@doc.govt.nz.

2.2.2 Other

In the event that a marine mammal stranding event occurs inshore of the Operational Area during the checkshot survey, or up to two weeks following the completion of the survey, OMV will on a case-by-case basis consider covering the cost of a necropsy in an attempt to determine the cause of death. This will be considered following discussions with DOC. DOC would be responsible for all logistical aspects associated with the necropsy such as coordination with Massey University pathologists to undertake the work.

APPENDIX 1

Species of Concern

LATIN NAME	COMMON NAME
Megaptera novaengliae	Humpback Whale
Balaenoptera borealis	Sei Whale
Balaenoptera edeni	Bryde's Whale
Balaenoptera bonaerensis	Antarctic Minke Whale
Balaenoptera acutorostrata subsp.	Dwarf Minke Whale
Balaenoptera musculus	Blue Whale
Balaenoptera physalus	Fin Whale
Balaenoptera musculus brevicauda	Pygmy Blue Whale
Eubalaena australis	Southern Right Whale
Caperea marginata	Pygmy Right Whale
Lissodelphis peronii	Southern Right-whale Dolphin
Globicephala melas	Long-finned Pilot Whale
Globicephala macrorhynchus	Short-finned Pilot Whale
Peponcephala electra	Melon-headed Whale
Physeter macrocephalus	Sperm Whale
Kogia sima	Dwarf Sperm Whale
Kogia breviceps	Pygmy Sperm Whale
Mesoplodon grayi	Gray's Beaked Whale
Berardius arnuxii	Arnoux's Beaked Whale
Ziphius cavirostris	Cuvier's Beaked Whale
Mesoplodon layardii	Strap-toothed Whale
Hyperoodon planifrons	Southern Bottlenose Whale
Mesoplodon bowdoini	Andrew's Beaked Whale
Mesoplodon mirus	True's Beaked Whale
Mesoplodon densirostris	Blainville's Beaked Whale
Mesoplodon gingkodens	Ginkgo-toothed Whale
Mesoplodon hectori	Hector's Beaked Whale
Mesoplodon peruvianus	Pygmy/Peruvian Beaked Whale
Tasmacetus shepherdi	Shepherd's Beaked Whale
Orcinus orca	Killer Whale
Pseudorca crassidens	False Killer Whale
Feresa attenuata	Pygmy Killer Whale
Cephalorhynchus hectori	Hector's Dolphin
Cephalorhynchus hectori maui	Maui's Dolphin
Phocarctos hookeri	New Zealand Sea Lion
Tursops truncatus	Bottlenose Dolphin

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