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Māui 4D Seismic Survey

Marine Mammal Impact Assessment

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Shell Taranaki Limited

167 Devon Street West

New Plymouth

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Māui 4D Seismic Survey

Marine Mammal Impact Assessment

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Executive Summary

Shell Taranaki Limited proposes to undertake a marine seismic survey, the 'Māui 4D Seismic Survey', in the Taranaki Basin. The objective of this survey is to monitor changes in the Māui Field hydrocarbon reservoir since the last seismic survey in 2002.

Seismic operations are predicted to take place over a period of approximately 40 days; with the start of the survey planned for February 2018. The Operational Area for this survey is located off Cape Egmont and in waters to the southwest. Seismic operations will not occur in any waters within 21 km of shore, and the majority of operations will occur in water depths greater than 100 m. No seismic operations will occur within 6.5 km of the boundary to the West Coast North Island Marine Mammal Sanctuary. The nearest major settlement to the Operational Area is the coastal city of New Plymouth, located approximately 55 km to the northeast.

The seismic survey would be undertaken using a specialised 3D seismic survey vessel, the *MV Amazon Warrior*, which will tow eight streamers, each measuring 3 km in length separated by 100 m spacings. The acoustic source of the proposed survey will also be towed by the *MV Amazon Warrior* and will consist of two 3,147 in^3 arrays at a water depth of 6 m, which will be activated alternatively at an operating pressure of 2,000 psi. The acoustic sources are typically set off so that the shot-point interval is 18.75 m apart, and with an average vessel speed of 4.5 knots, this equates to activation every eight seconds. One support vessel and one chase vessel will accompany the *MV Amazon Warrior* to provide supplies, scout the area ahead for obstructions and to ensure other vessels are aware of the presence and extent of the streamers behind the seismic vessel.

The Department of Conservation's 2013 *Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* (the 'Code of Conduct') defines three levels of marine seismic surveys based on acoustic source capacity. Based on this classification, the Māui 4D Seismic Survey is considered a 'Level 1' seismic survey and requires a Marine Mammal Impact Assessment (MMIA) to be assessed as sufficient to meet the requirements of the Code of Conduct by the Department of Conservation (DOC) before the survey commences.

An important part of the MMIA development is consultation with interested parties and technical experts, and in preparation for the Māui 4D Seismic Survey, Shell Taranaki Limited is undertaking consultation with a wide range of stakeholders whose concerns will be taken into account.

In assessing the potential impacts of the seismic survey on marine mammals the following steps were undertaken:

- all potential environmental sensitivities which could be vulnerable to seismic operations were identified;
- all potential environmental effects of the seismic operations were identified;
- mitigation actions were developed to avoid, remedy or mitigate each potential effect; and
- an assessment of the significance of each potential effect (based on likelihood, magnitude, geographical scale, and mitigation actions) was conducted.

A thorough understanding of the existing environmental sensitivities in the offshore Taranaki region provides a fundamental basis for this MMIA. Environmental sensitivities include marine mammals, seabirds, fish species, benthic marine fauna and plankton.

The MMIA process has identified that up to thirteen species of marine mammal could be present in the Operational Area; of these species only two, killer whales (Nationally Critical) and bottlenose dolphins (Nationally Endangered) are considered to be threatened under the New Zealand Threat Classification System.

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Other species of marine mammals could also be utilising habitat in the vicinity, including a number of 'Species of Concern' as defined by the Code of Conduct. Pygmy blue whales in particular use the South Taranaki Bight for foraging and recent evidence suggests that this area may also support a nursery ground for this species.

Numerous seabird species are likely to be present in the Operational Area; however, Antipodean albatross, back-billed gull, fairy tern, Gibson's albatross, Salvin's mollymawk, black-fronted tern, black petrel, caspian tern, flesh-footed shearwater, grey-headed albatross, pied shag, red-billed gull, and Hutton's shearwater have a DOC threat listing of nationally vulnerable or greater so are of greatest significance.

The most commonly caught commercial fish species in this area are jack mackerel and barracouta, accounting for about 95% of the total catch in offshore Taranaki waters.

As part of this MMIA, a range of potential effects on the environment have been assessed. To address these potential effects Shell Taranaki Limited will implement mitigation measures which aim to eliminate or minimise any negative environmental consequences as far as practicable.

The introduction of sound into the marine environment is considered to be the most significant potential effect from the Māui 4D Seismic Survey. The primary mitigation tool to address these effects is compliance with the Code of Conduct which Shell Taranaki Limited commits to do for the duration of the survey, both in the EEZ and in the territorial sea. The Code of Conduct is highly regarded internationally, and is often cited as one of the most comprehensive management regimes in the world with regard to mitigating the effects of seismic operations on marine mammals (e.g. Wright & Cosentino, 2015).

In accordance with the Code of Conduct, the measures that will be employed include:

- The use of pre-start observations by Marine Mammal Observers (MMOs) and Passive Acoustic Monitoring (PAM) to detect marine mammals (both visually and acoustically) prior to the commencement of seismic operations;
- The delay of operations in the event that marine mammals are detected;
- The use of 'soft starts' whereby the acoustic source volume is gradually increased over 20–40 minutes at the start of the survey to give any marine mammals the opportunity to leave the survey area before full power is reached; and
- The shutdown of the acoustic source if 'Species of Concern' are detected.

Sound transmission loss modelling was conducted as part of this MMIA whereby acoustic propagation is modelled to predict the received sound levels at various underwater distances from the acoustic source. This modelling indicated that the proposed acoustic source was compliant with the standard mitigation zones and associated thresholds defined in the Code of Conduct. Hence no tailored mitigation zones are required during the Māui 4D Seismic Survey.

In addition to full compliance with the Code of Conduct, Shell Taranaki Limited commits to the following management actions over and above those required:

- Whilst transiting to and from the Operational Area, and during daylight hours and good sighting conditions, a MMO will be on watch and recording marine mammal sightings;
- Weekly MMO reports will be provided to DOC and the Environmental Protection Authority (EPA);
- DOC will be notified immediately of any sightings of Māui or Hector's dolphins; and

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- If any stranding's occur that result in mortality during the Māui 4D Seismic Survey or within 14 days of the survey completion date, Shell Taranaki Limited will, on a case-by-case basis, consider covering the costs of undertaking a necropsy in an attempt to determine the cause of death.

Other potential environmental effects (outside those directly relating to marine mammals and noise) are addressed by adherence to the International Convention for the Prevention of Pollution from Ships 1978 (MARPOL), and the International Regulations for the Prevention of Collisions at Sea 1972 (COLREGS).

In summary, the environmental effects associated with the Māui 4D Seismic Survey, when assessed in light of the proposed mitigation measures, are considered to be mostly minor or moderate whereby recovery is predicted within 24 hours. Moderate effects include 1) potential temporary behavioural changes for marine mammals; 2) a reduction in zooplankton abundance within 2.5 km from the source; 3) the potential masking of low frequency baleen whale calls; and 4) indirect effects associated with changes in prey availability. More significant effects (major or severe) could potentially occur for other marine mammal species (i.e. those not considered to be Species of Concern) that make close approaches to the acoustic source during full seismic operations or for Species of Concern that go undetected within the designated Mitigation Zones. However, it is envisaged that the use of delayed starts and soft starts will minimise the direct effects on marine mammals which is indeed their intended purpose under the Code of Conduct.

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ABBREVIATIONS AND DEFINITIONS

AEI	Areas of Ecological Importance
Acoustic Array	An acoustic source system in which airgun elements are arranged to produce desired directional characteristics
Acoustic Source	A source of acoustic pressure waves used, or intended to be used, for the purpose of an acoustic seismic survey, and in relation to a source vessel, means an acoustic source on or controlled from the vessel.
Code of Conduct	The 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
DOC	Department of Conservation
EEZ	Exclusive Economic Zone
EEZ Act	Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012
Energetic costs	The metabolic costs of various forms of biological activity
EPA	Environmental Protection Authority
Flip-Flop	Alternating activation of two parallel seismic source arrays
Full-fold	Full power operations to achieve maximum offset acquisition data
Good sighting conditions	In daylight hours, during visibility of more than 1.5 km, and in a sea state of less than or equal to Beaufort 3.
Level 1 survey	Any marine seismic survey using an acoustic source with a total combined operational capacity exceeding 7 litres/427 cubic inches.
MARPOL	International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978
MMIA	Marine Mammal Impact Assessment
MMO	Marine Mammal Observer
MMS	Marine Mammal Sanctuary
MPI	Ministry for Primary Industries
MSL	MetOcean Solutions Limited
NABIS	National Aquatic Biodiversity Information System
NIWA	National Institute of Water and Atmospheric Research
NZ	New Zealand
Operational Area	The entire geographical area potentially used for acoustic source activation throughout the marine seismic survey, including seismic data acquisition lines, acoustic source testing and soft start initiation
PAM	Passive Acoustic Monitoring
PEP	Petroleum Exploration Permit
PML	Petroleum Mining Licence
PSI	Pounds per square inch
RMA	Resource Management Act 1991
SEL	Sound Exposure Level
Shutdown	Stopping an active marine seismic survey by immediately turning off power to the acoustic source.
SLIMPA	Sugar Loaf Island Marine Protected Area

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SLR	SLR Consulting New Zealand Ltd
Soft Starts	The gradual increase in the source's power to the operational power requirement over a period of at least 20 minutes and no more than 40 minutes, starting with the lowest capacity/power acoustic source.
Sound exposure level	A measure of the received energy in the sound source pulse and represents the sound pressure level that would be measured if the pulse energy were spread evenly across a 1 second period.
Sound transmission loss modelling	The process carried out during the environmental impact assessment stage, in advance of a marine seismic survey in an Area of Ecological Importance, where acoustic propagation is modelled to predict the received sound levels at various distances, based on the specific configuration of the acoustic source and environmental conditions in the Operations Area.

1 INTRODUCTION

1.1 Background

SLR Consulting New Zealand Limited (SLR) has been engaged by Shell Taranaki Limited to finalise this Marine Mammal Impact Assessment (MMIA) for the Māui 4D Seismic Survey within the Taranaki Basin. This marine seismic survey will replicate the seismic programme which occurred in the Māui Field in 2002 to monitor changes in the Māui Field hydrocarbon reservoir since this time.

The 'Survey Area' outlined in **Figure 1**, represents the area for which full-fold seismic data will be acquired. The Survey Area lies primarily within Petroleum Mining Licence (PML) 381012, with extensions into Petroleum Exploration Permit (PEP) 51906. Surrounding the Survey Areas is a larger Operational Area which is all encompassing and provides a buffer for run in/out, line turns, acoustic source testing and soft start source initiation. The Operational Area covers approximately 3,000 km^2.

It is anticipated that to complete this survey a timeframe of approximately 40 days will be required. The survey is proposed to take place in early 2018 (February - April).

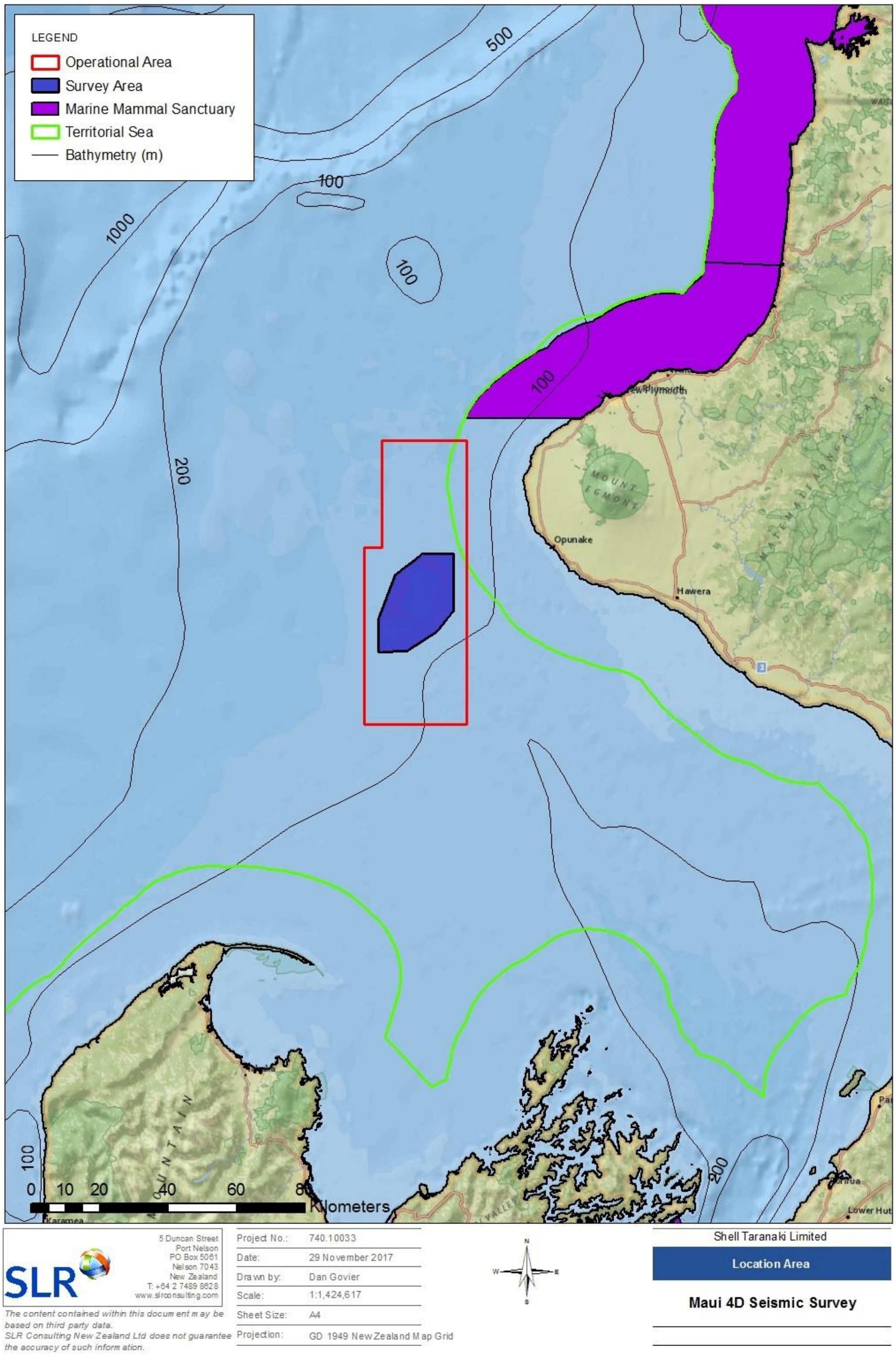
The Exclusive Economic Zone and Continental Shelf (Environmental Effects – Permitted Activities) Regulations 2013 (Permitted Activities Regulations) under the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (EEZ Act) classify seismic surveys as 'Permitted Activities' as long as they comply with the '2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations' (the 'Code of Conduct') (DOC, 2013).

Throughout the Māui 4D Seismic Survey, Shell Taranaki Limited will adhere to the Code of Conduct which was developed by DOC in consultation with a broad range of stakeholders in marine seismic survey operations in New Zealand. This MMIA has been prepared in accordance with the EEZ Act and the Code of Conduct to:

- Describe baseline environmental sensitivities in relation to the seismic survey;
- Identify potential environmental effects on marine species and the surrounding environment; and
- Describe measures to avoid or minimise any adverse effects to the surrounding environment and marine mammals.

Shell Taranaki Limited operates the Māui field on behalf of a joint venture including Shell Petroleum Mining Ltd (83.75%), OMV New Zealand Ltd (10%) and Todd Petroleum Mining Ltd (6.25%). The Māui Joint Venture contracts Shell Taranaki Limited as an independent Operator under a Contract of Employment.

Figure 1: Location Map of the Survey Area and Operational Area



1.2 New Zealand Legislation

Activities associated with the offshore oil and gas sector; including maritime activities, environmental protection, biosecurity, industrial safety, and cultural and archaeological heritage is covered under a range of different statutes.

The jurisdictions of these different statutes can vary, for example, the Resource Management Act 1991 (RMA) and the Biosecurity Act 1993 only apply within New Zealand's territorial sea (12 Nm from the statutory baseline), whereas the EEZ Act applies within the EEZ (12 - 200 Nm from shore) and Continental Shelf, and the Marine Mammals Protection Act 1978 applies to New Zealand's 'fisheries waters' (including inshore waters, the territorial sea, and the EEZ).

The Operational Area of the Māui 4D Seismic Survey occurs mainly in the EEZ, but does overlap with the territorial sea (**Figure 1**). The primary legislation, with which Shell Taranaki Limited will comply for the upcoming seismic survey, is the EEZ Act (including the Code of Conduct) which relates to waters beyond 12 Nm from shore, and the RMA which relates to waters inside the 12 Nm territorial sea.

1.2.1 Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012

The EEZ Act came into force on 28 June 2013, when the first regulations (Permitted Activities) were promulgated. The EEZ Act is considered as landmark legislation as it establishes the first comprehensive environmental consenting regime for activities in New Zealand's EEZ and Continental Shelf. The purpose of the EEZ Act is to manage and protect the natural resources of the EEZ whilst concurrently enabling use of resources on or within the seabed and sub-surface.

The EEZ Act allows the Minister for the Environment to classify activities within the EEZ and Continental Shelf, depending on the considerations outlined in s33 of the EEZ Act. These considerations include; environmental effects of the activity, the importance of protecting rare and vulnerable ecosystems and the economic benefit to New Zealand of the activity. The classifications for activities within the EEZ Act are either:

- **Permitted** – the activity can be undertaken provided the operator meets the conditions specified within the regulations. Marine 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** – where activities can be undertaken if applicants obtain a marine consent from the EPA, who may grant or decline consent and place conditions on the consent. The consent application is not publically notified and has statutory timeframes adding up to 70 working days in which the EPA must assess the consent application, although the EPA has discretion to extend the timeframes by up to double;
- **Discretionary** – activities may be undertaken if applicants obtain a marine consent from the EPA. The consent application will be notified, submissions will be invited and hearings will be held if requested by any party, including submitters. The process has a statutory timeframe of 150 working days in which the EPA must assess the consent application; and
- **Prohibited** – the activity may not be undertaken.

1.2.2 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations

The Code of Conduct was developed to establish a comprehensive regime to manage the potential impacts of seismic survey activities. Under the EEZ Act – *Permitted Activities Regulations*, seismic surveys within the EEZ must now comply with the Code of Conduct, which 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 observation 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 cubic inches) are typically large scale geophysical investigations, Level 2 surveys (151 – 426 cubic inches) are lower scale seismic investigations often associated with scientific research, and Level 3 surveys (<150 cubic inches) include all small scale, low impact surveys. The Māui 4D Seismic Survey is classified as a Level 1 survey which features the most stringent requirements for marine mammal protection (see **Section 1.2.2**).

Shell Taranaki Limited is a formal signatory to the Code of Conduct and as such agrees to commit to the provisions of the Code of Conduct in full for all marine seismic survey activities in New Zealand continental waters, including voluntary adherence to these provisions throughout the territorial sea. The notification requirements of the Code of Conduct have been adhered to and followed with the formulation of this MMIA. A letter was submitted to the Director-General of Conservation on 18 September 2017 informing DOC of the proposed survey and intention to submit an MMIA as per the requirements of the EEZ Act.

1.2.3 Resource Management Act 1991

The purpose of the RMA is to promote the sustainable management of natural and physical resources in New Zealand. The RMA applies to all terrestrial land, all lakes and rivers, and the territorial sea. Territorial Authorities are responsible for implementing the RMA: which in the case of the Māui 4D Seismic Survey is the Taranaki Regional Council.

Section 16 of the RMA states that "every occupier of land (including any premises and any coastal marine area), and every person carrying out an activity in, on or under a body of water or the coastal marine area, shall adopt the best practicable option to ensure that the emission of noise from that land or water does not exceed a reasonable level". In the territorial sea (coastal marine area), seismic surveying is considered to be a permitted activity as long as operations comply with the Code of Conduct (as specified in the draft Taranaki Regional Coastal Plan which is due to be notified in early February 2018). Compliance with the Code of Conduct and managing operational noise to acceptable pre-defined levels; presumably also satisfies s16 of the RMA. The Taranaki Regional Council has been supplied with a copy of this MMIA.

Under the existing Taranaki Regional Coastal Plan (2007), seismic surveys are a permitted activity in Taranaki coastal waters (the territorial sea) provided the following conditions are met:

- The survey does not involve placement of explosives or does not otherwise directly involve disturbance of the foreshore or seabed; and
- The survey is not conducted in an area that is used by marine wildlife for breeding purposes during the time that those animals are breeding.

The Māui 4D Seismic Survey will not directly disturb the seabed and does not involve the use of explosives. The potential for overlap between seismic survey operations and the breeding habitat of coastal marine wildlife (within 12 Nm of the shore) has also been assessed. In regard to this, breeding behaviour has been interpreted to mean 'mating' and 'parturition' (calving or pupping) and the following points of consideration have been made:

- Southern right whales calve in shallow coastal waters around the New Zealand mainland during winter months. Cow/calf pairs have been seen in Taranaki coastal waters in winter. The Māui 4D Seismic Survey is planned for late summer/early autumn 2018; hence no temporal overlap is predicted between the survey operations and southern right whale breeding activities (also see **Section 4.3.5**);

- Māui dolphins calve from November to mid-February in shallow coastal waters (less than 100 m). The population concentration for this species is north of the Operational Area with very low densities of dolphins occurring south of New Plymouth (Currey et al., 2012; see **Figure 19, Section 4.3.5**). Therefore, no significant spatial overlap is predicted between the survey operations and Māui dolphin breeding activities (also see **Section 4.3.5**);
- New Zealand fur seals breed on the Sugar Loaf Islands, which represent the closest breeding colony to the Operational Area. This species gives birth ashore with peak pupping occurring in mid-December. Pups remain at the breeding colony from birth until weaning which occurs when pups are 8 – 12 months old (Baird, 2011). Therefore, no significant spatial overlap is predicted between the survey operations and New Zealand fur seal breeding activities (also see **Section 4.3.5**);
- Mother and calf pairs of pygmy blue whales have been observed in the South Taranaki Bight; however to date no actual mating or calving has been documented. It is possible that mothers with young calves could from time to time enter the area of the territorial sea within the proposed Operational Area, but the effect of such spatial overlap is expected to be no more than minor as:
  - The area of overlap (territorial sea within the proposed Operational Area) is small (see **Figure 1**);
  - All mother/calf sightings have to date occurred beyond 12 Nm from shore (Torres et al., 2017): and
  - The DOC Marine Mammal Sighting Database includes no mother/calf sightings within the Operational Area (also see **Section 4.3.5**); and
- There is no information to suggest that Taranaki coastal waters are of particular importance as breeding habitat for any other marine mammal species. Some species (e.g. common dolphins) may mate and give birth anywhere throughout the South Taranaki Bight including in the territorial sea.

1.3 International Conventions

The following international regulations and conventions will be adhered to during the Māui 4D Seismic Survey.

International Regulations for the Prevention of Collisions at Sea 1972

These regulations are commonly referred to as the COLREGS and provide an international set of operational expectations and navigation procedures to prevent collisions at sea. New Zealand ratified the convention in 1972, and the COLREGS are implemented in New Zealand under the Maritime Transport Act 1994.

The International Convention for the Prevention of Pollution from Ships 1973

This convention is commonly referred to as the MARPOL Convention and addresses the prevention of ship-based marine pollution from both operational and accidental causes. The original MARPOL Convention has been updated through time by a number of amendments and associated protocol. Specific provisions of relevance relate to the discharge of oily water from machinery spaces, sewage and garbage. Discharge requirements and allowances vary with proximity to the shore and are further discussed in **Section 5.3.3**.

1.4 MMIA Objectives

This MMIA forms part of the overall planning process for the Māui 4D Seismic Survey. In accordance with the Code of Conduct the objectives of this MMIA are to:

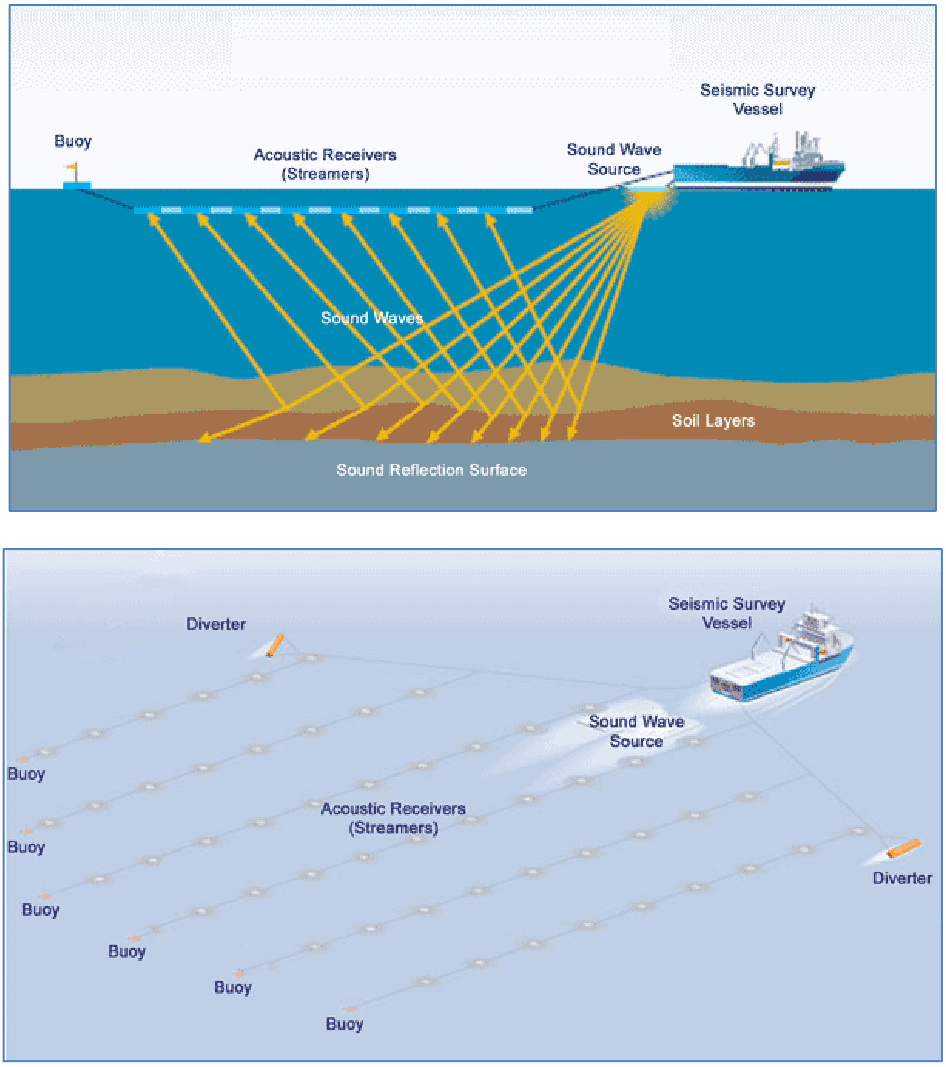
- Describe the activities related to the proposed marine seismic survey (**Section 2**);
- Describe the state of the local environment in relation to marine species and habitats, with particular focus on marine mammals, prior to the activities being undertaken (**Section 4.3**);
- Identify the actual and potential effects of the activities on the environment and existing interests, including any conflicts with existing interests (**Section 5**);
- Identify the significance (in terms of risk and consequence) of any potential negative impacts and define the criteria used in making each determination (**Section 5**);
- Identify persons, organisations or tangata whenua with specific interests or expertise relevant to the potential impacts on the environment, describe any consultation undertaken and specify those who have provided written submissions on the proposed activities (**Section 7**);
- Include copies of any written submissions from the consultation process (**Appendix A**);
- Specify any possible alternative methods for undertaking the activities to avoid, remedy, or mitigate any adverse effects (**Section 3**);
- Specify the measures that the operator intends to take to avoid, remedy, or mitigate the potential adverse effects identified (**Section 5**); and
- Specify a monitoring and reporting plan, and a means of coordinating research opportunities, plans, and activities relating to reducing and evaluating environment effects (**Section 6**).

2 PROJECT DESCRIPTION

2.1 Seismic Survey Overview

Marine seismic surveys are used to identify geological features below the seafloor, by relying on the differing reflective properties of sound waves to various subsurface rock strata. During a survey the sound wave energy source (airgun array), which is towed behind the seismic vessel, transmits a downward pulse of sound generated by the release of compressed air from an acoustic source array. This pulse travels through the water column and into the earth. At each point where different geological strata exist, different densities and velocity discontinuities cause a portion of the energy to be reflected back to the sea surface. The reflected sound waves are picked up by a series of acoustic receivers (hydrophones) which are located along the 'streamers' towed behind the vessel. Data received by the hydrophones are amplified and digitised to facilitate interpretation. The seismic data profiles provide an 'image' of the rocks beneath the seafloor, commonly to depths of 10 km (McCauley et al. 2000). The configuration of a marine seismic survey is illustrated in **Figure 2**.

Figure 2: Schematic of an Operational Marine Seismic Survey



(Source: www.fishsafe.eu)

Streamers consist of neutrally buoyant tubular sections containing the hydrophones and electrical conductors which transmit seismic data to the vessel. Streamers commonly consist of two types, either fluid-filled or solid streamers. The fluid used in fluid-filled streamers is typically an oil-based fluid; whereas solid streamers are typically filled with a water-based gel or foam. In recent years the industry has moved towards to use of solid streamers for the following reasons:

- They produce lower secondary noise profiles, hence higher quality seismic data;
- They are relatively fast to deploy and steerable once deployed;
- They are more resistant to shark damage;
- They require less frequent repairs which in turn reduces operational risk; and
- When damaged there is no hydrocarbon pollutant emitted.

Marine seismic surveys can be 2-dimensional (2D), 3-dimensional (3D) or 4-dimensional (4D). 2D surveys tow only one streamer (with acquired data representing a 2D slice of the subsurface structure), 3D surveys tow multiple streamers (with acquired data representing a 3D image of the subsurface structure), and 4D surveys (also known as time-lapse surveys) which involve repeated 3D seismic surveys through time in order to introduce a fourth dimension (time).

2.2 Overview of Māui field

The Māui natural gas field is operated by Shell Taranaki Limited. The field was discovered in 1969 and production began in 1979. Existing offshore facilities within the Māui Field include the following:

- Māui Platform Alpha (Māui A) situated approximately 35 km offshore Taranaki in 108 m of water;
- Māui Platform Bravo (Māui B) is situated approximately 50 km offshore at a water depth of 108 m. The distance between the two platforms is approximately 15 km;
- A single 500 mm multi-phase pipeline that transports both liquid and gas from Māui B to Māui A for initial process separation; and
- Hydrocarbon gas is transported from Māui A to Māui Production Station by a 610 mm diameter subsea pipeline and condensate liquid is dewatered on Māui A and is transported by a 250 mm diameter subsea pipeline to the Māui Production Station.

2.3 Māui 4D Seismic Survey

The proposed Māui 4D Seismic Survey is being undertaken by Shell Taranaki Limited and will acquire seismic data over the Survey Area outlined in **Figure 1**. Full-fold data acquisition will occur within the Survey Area, which is buffered by a larger Operational Area that provides for run in/out, line turns, acoustic source testing and soft start initiation.

The objective of the Māui 4D Seismic Survey is to continue the existing time-lapse series of seismic datasets to monitor changes in the reservoir over time. The 4D acquisition represents a repeat of two previous surveys (1991 and 2002). Data from all three surveys will be collated into a time-lapse series to assess changes in the Māui Field hydrocarbon reservoir through time. In order to maximise sensitivity to small changes in the acoustic properties of the reservoir through time, the survey parameters (acoustic source size, streamer configuration etc) are repeated as closely as possible between time-lapse surveys. It is for this reason that recently collected 3D data over the Operational Area is inappropriate to gauge fine scale reservoir changes through time.

2.3.1 Survey Parameters

The acoustic parameters and configuration of the proposed Māui 4D Seismic Survey are outlined in **Table 1**.

Table 1: Survey Parameters for the Māui 4D Seismic Survey

Survey line direction	north-south
Source size	3,147 cubic inches
Source depth	6 m
No. of sources	2
No. of sub-arrays per source	3
Sub-array separation	8 m
Shot point interval	18.75 m flip-flop
Source pressure	2,000 psi
No. of streamers	8
Streamer separation	100 m
Streamer length	3 km
Streamer type	Solid (single sensor)
Streamer depth	8 m

During seismic operations the arrays will be activated alternatively with a shot point interval of 18.75 m. At an average vessel speed of 4.5 knots (2.3 $m.s^{-1}$), this relates to a shot every 8 seconds. The acoustic output for marine seismic surveys is typically broad band, emitting most of their energy at low frequencies, typically 20-50 Hz with declining energy at frequencies above 200 Hz (Popper et al., 2014). Source levels range from ~222 – 264 dB when measured relative to a reference pressure of one micro-pascal (re $1\mu Pa\text{-}m_{p\text{-}p}$) (Richardson et al., 1995). Pre-determined survey lines will be acquired in a north-south direction.

Acoustic source arrays are designed to direct the majority of energy vertically towards the seabed. However, some energy is also lost horizontally into the water column, and can be detected at different distances from the source (see **Section 5.3.2**).

2.3.2 Location and Timing of Survey

The Survey Area lies primarily within PML 381012, with extensions into surrounding PEP 51906. As specified in the Code of Conduct, the Operational Area encompasses normal seismic operations (i.e. run in's and run out's from each survey line, soft starts, line turns, and acoustic source testing). For the most part the source will only be operating at full power within the full fold Survey Area and up to 1.5 km beyond the Survey Area (half the streamer length). However, there may be cause to test individual guns or sub-arrays outside the Survey Area, but within the Operational Area. Any such testing is also subject to the controls specified in the Code of Conduct and covered under this MMIA.

Although the Shell Taranaki Limited production facilities MPA and MPB are located in the Survey Areas, no seismic equipment (including streamers) will come within 100 m of the platforms.

Shell Taranaki Limited is planning to undertake the Māui 4D Seismic Survey in the period of February to April 2018. Seismic operations will be conducted 24 hours per day, 7 days per week, subject to suitable weather conditions and marine mammal encounter protocols (see **Section 2.4**), and it is envisaged that the survey will take approximately 40 days to complete.

2.3.3 Survey Vessels

Shell Taranaki Limited will conduct the seismic survey from a specialist 3D seismic vessel which will be supported by a support/supply vessel and chase vessel. Details of the seismic vessel and the support/survey vessels are summarised in **Table 2** and **Table 3** below.

Table 2: *MV Amazon Warrior* Technical Specifications

General Specifications	
Vessel Name	*MV Amazon Warrior*
Vessel Owner	GecoShip AS
Maritime Operator	WesternGeco
Engine Details	2 x Wartsila W9L32 each 4500kW, 2 x PTI each 2500kw/690V
Fuel Capacity	3,941 t (MGO)
Dimensions and capacities	
Vessel Length	126 m
Vessel Beam	32 m
Max Draft	7.6 m
Gross Tonnage	21,195 gross tonnes
Cruising Speed	14 knots

Table 3: Support Vessel Technical Specifications

General Specifications	**Mermaid Searcher**	**MV Sea Ranger**
Vessel Owner	MMA Offshore	Seaworks
Maritime Operator	MMA Offshore	Seaworks
Engine Details	Cummins KTA50-M42 1600 bhp	2 x Cummins KTA50M2, total 3244 HP
Fuel Capacity	926 m^3	275 m^3
Dimensions and capacities		
Vessel Length	54 m	32 m
Vessel Beam	13.8 m	9.15 m
Max Draft	3.6 m	3.68 m
Gross Tonnage	1,079 tonnes	336 tonnes
Max Speed	12.5 knots	12 knots
Transit Speed	9 knots	9 knots

Figure 3: Seismic Vessel – *MV Amazon Warrior*

Figure 4: Support Vessels – *Mermaid Searcher* (Left) and *MV Sea Ranger* (Right)

All survey vessels will operate nominally from the closest port, Port Taranaki, New Plymouth. Crew changes during the survey will occur from New Plymouth either by helicopter or port call. Port calls may be required during adverse weather conditions. Refuelling of the survey vessel will be preferentially conducted in port before the survey commences, but may be conducted at sea during the survey if required. At-sea refuelling is routine during seismic surveys and will take place in daylight hours within permissible weather conditions. The support vessels will refuel at Port Taranaki.

At the outset of the survey the towed gear (streamers and acoustic source arrays) will be deployed. This gear will remain in the water for the duration of the survey, except when on-board repairs are necessary or inclement weather dictates the need to bring gear aboard.

2.4 Operational Protocols

Shell Taranaki Limited will adhere to the operational protocols outlined below. These protocols are in accordance with the requirements of the Code of Conduct for a Level 1 Marine Seismic Survey.

A Level 1 survey requires at least two qualified Marine Mammal Observers (MMOs) and two qualified Passive Acoustic Monitoring (PAM) operators on-board for the duration of the survey.

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

- The qualified observers will be dedicated in that their roles on the vessel are strictly for the detection and data collection of marine mammal sightings and instructing crew on their requirements when a marine mammal is detected within the relevant mitigation zone; and
- At all times while the acoustic source is in the water, at least one qualified MMO (during daylight hours) and one qualified PAM operator will maintain a watch for marine mammals.

Two MMOs and two PAM operators will be procured from a specialist independent consultancy company to meet Shell Taranaki's obligations under under the Code of Conduct. There is a strong preference for the use of New Zealanders to carry out these roles. The MMOs and PAM operators will be qualified and trained in accordance with the Code of Conduct.

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

Pre-Start Observations

The normal requirements for pre-start observations are as follows:

A Level 1 acoustic source can only be activated if it is within the specified operational area and no marine mammals have been observed or detected in the relevant mitigation zones.

The Level 1 source cannot be activated during daylight hours unless:

- At least one qualified MMO has continuously made visual observations all around the source for the presence of marine mammals, from the bridge (or preferably an even higher vantage point) using both binoculars and the naked eye, and no marine mammals (other than fur seals) have been observed in the relevant mitigation zones for at least 30 minutes and no fur seals have been observed in the relevant mitigation zone for at least 10 minutes; and
- Passive acoustic monitoring for the presence of cetaceans 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 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 vocalising cetaceans in the relevant mitigation zones.

In addition to the normal pre-start observation requirements outlined above, when arriving at a new location in the survey programme for the first time the initial acoustic source activation must not be undertaken at night or during poor sighting conditions unless either:

- MMOs 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; and
    - Two MMOs have conducted visual monitoring in the two hours immediately preceding proposed operations; and
    - 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; and
    - 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.

Delayed Starts & Shut-downs

Delayed starts and shut downs will occur in accordance with the standard mitigation zones outlined in the Code of Conduct; whereby if during pre-start observations or while a Level 1 acoustic source is activated (which includes soft starts), a qualified observer detects a Species of Concern within 1 km or a Species of Concern with a calf within 1.5 km of the acoustic 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 (for a Species of Concern without a calf) or 1.5 km for a Species of Concern with a calf from the acoustic source; or
- Despite continuous observation, 30 minutes has elapsed since the last detection of a Species of Concern, and the relevant mitigation zone remains clear.

Or, if during pre-start observations prior to initiation of a Level 1 acoustic source soft start, a qualified observer detects any other marine mammal 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 acoustic source; or
- Despite continuous observation, 10 minutes has passed since the last detection of a New Zealand fur seal within 200 m of the acoustic 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.

If all mammals detected within the relevant mitigation zones are observed moving beyond the respective areas, there will be no further delays to initiation of a soft start.

Soft Start Protocol

Typically Level 1 acoustic sources will not be activated at any time except by soft start, unless the acoustic 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. Soft start means a gradual increase of the acoustic source's power, starting with the lowest capacity source, over a period of at least 20 minutes and no more than 40 minutes (unless the source is being reactivated after a break in firing less than 10 minutes before that time).

3 SURVEY DESIGN – MITIGATIONS AND ALTERNATIVES

This section of the MMIA outlines considerations that were given to the survey design in order to minimise adverse effects on the marine environment. In particular, the Code of Conduct requires that any possible alternative methods for undertaking the activities to avoid, remedy or mitigate adverse effects are specified.

The survey design was developed with an awareness of the need to minimise potential effects in the coastal zone and the West Coast North Island Marine Mammal Sanctuary (Māui dolphin habitat) and blue whale habitat in the greater South Taranaki Bight. This awareness has guided survey design outcomes as described below.

3.1 Survey Location

The location of the Operational Area has largely been driven by the location of the Māui Field and the boundaries of previous survey efforts. Care has been taken to ensure that the Operational Area is minimised to restrict the area affected by seismic operations. In particular, a buffer of 6.7 km has been established between the West Coast North Island Marine Mammal Sanctuary in an attempt to minimise the effects of underwater noise into this sensitive area. Based on the sound transmission loss modelling (see **Section 5.3.2**), it is concluded that marine mammals within the sanctuary will suffer no behavioural or physiological effects from the Māui 4D Seismic Survey.

3.2 Acoustic Parameters

A variety of seismic sources are available for marine applications, including water guns (20-1500 Hz), airguns (100 – 1500 Hz), sparkers (50-4000 Hz), boomers (300-3000 Hz), and chirp systems (500 Hz – 200 kHz). The greatest resolution of near surface structure is generally obtained from the higher frequency sources such as the chirp systems, while the lower frequencies characterise structure at depth.

The acoustic source size to be used is dependent on the source design offered by the seismic contractor. However, in accordance with the Code of Conduct, Shell Taranaki Limited recognises the importance of minimising the source size whilst still achieving the geophysical objectives of the survey.

During the Māui 4D Seismic Survey, the source will be 3,147 in^3 and is an approximate match for the previous 2002 Māui 4D survey (3,090 in^3) to provide for best possible 4D repeatability. By contemporary standards this source level is comparable to the source level used for most seismic surveys undertaken in the industry.

3.3 Project Alternatives

The 4D survey is required to support further development of the Māui Field. To do nothing would hinder further development of the Māui Field and may result in the field being shut-in before the gas resource has been fully extracted.

A wide tow multi-client 3D survey is currently being acquired over the Maui Field (Dec 2017 to Feb-2018) however, the data from this survey cannot meet the 4D project objectives. In line with the survey objective to monitor changes in the Māui Natural Gas Field reservoir through time, and in order to maximise sensitivity to small changes in the reservoir, the survey parameters (acoustic source size, source depth, streamer configuration, sail line spacing and source point locations) are repeated as closely as possible between time-lapse surveys. It is for this reason that the recently collected 3D data over the Operational Area is inappropriate to gauge fine scale reservoir changes through time; hence the use of the multi-client 3D data is incompatible with the 4D survey objective.

4 BASELINE ENVIRONMENT

4.1 Methodology

The aim of this section is to describe the state of the local environment in relation to the marine species, habitats and existing users of the Operational Area. In keeping with the requirements of the Code of Conduct, emphasis has been placed on marine mammals.

A review of information from regional, national and international sources was undertaken in order to thoroughly describe the following environmental receptors:

- Physical environment – geology, climate, and oceanography;
- Biological environment – sensitive sites, benthic and pelagic (plankton and fish) ecosystems, marine mammals, seabirds, and marine reptiles ; and
- Existing interests – cultural, recreational and commercial values.

In accordance with the agreed scope of work, this MMIA was prepared on the basis of existing information sources held within the public domain or Shell Taranaki Limited file records. There is a large amount of baseline data available for Taranaki waters and this information is considered sufficient for the purposes of this MMIA, hence baseline field studies were not necessary. The following sources are considered to be of primary importance; however a complete bibliography can be found in **Section 9**:

- Summaries of metocean conditions as produced by MetOcean Solutions Limited (MSL)[1];
- Various research reports from the National Institute of Water and Atmospheric Research (NIWA);
- The National Aquatic Biodiversity Information System (NABIS) as hosted by The Ministry for Primary Industries;
- Past benthic monitoring reports from Cawthron Institute and SLR;
- DOC sightings and stranding records for marine mammals;
- The DOC Threat Classification System;
- The International Union for the Conservation of Nature (IUCN) Red List of Threatened species;
- The Draft Taranaki Regional Coastal Plan;
- Fisheries effort reports from the Ministry for Primary Industries;
- Ruru-2 and Māui-8 Exploration Well Impact Assessments; and
- Māui Impact Assessment, December 2014.

Baseline environment information has been provided based on the best information sources possible. In some instances abundance data, precise distributions and seasonal variations are relatively unknown as pelagic communities are inherently difficult to study due to their typically large distributional ranges, observational limitations at sea and the high costs of conducting systematic marine surveys.

[1] Note that data associated with Māui-8 locations have been used to represent the Operational Area

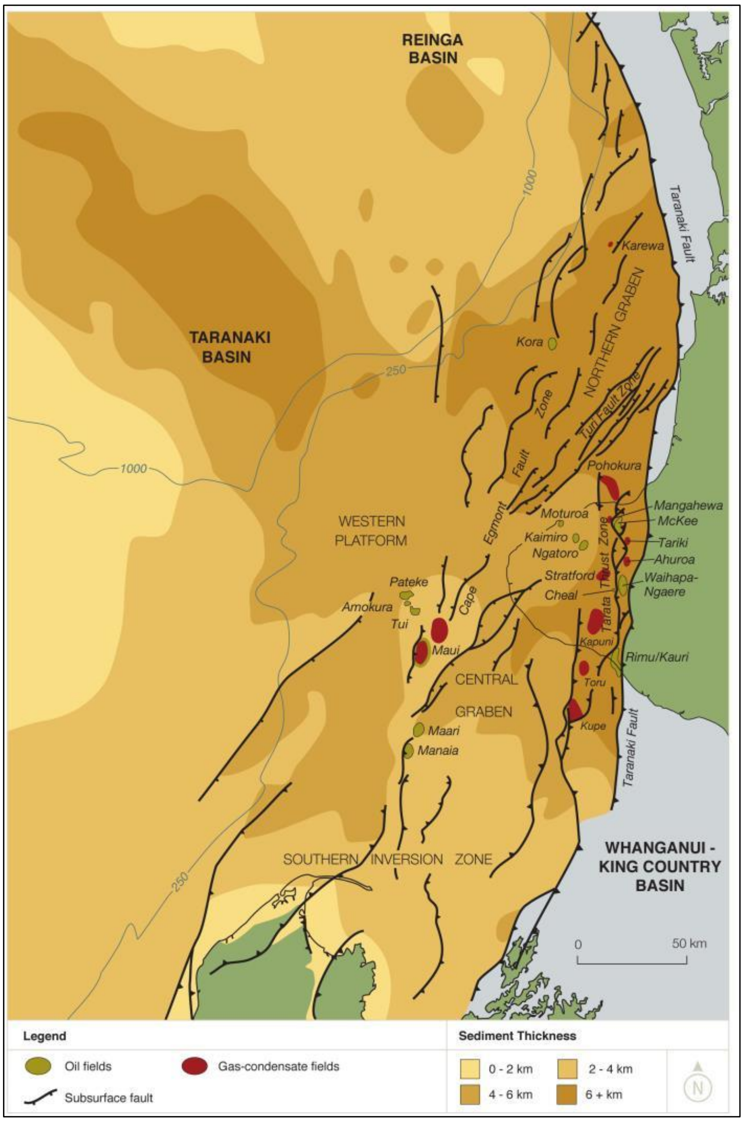
4.2 Physical Environment

4.2.1 Geology

The Taranaki Basin is located along the western side of the North Island; covering an area of about 330,000 km^2 and occupying the site of a late mesozoic extension of the landward side of the Gondwana margin. This basin lies at the southern end of a rift which now separates Australia and New Zealand, with movement along the Taranaki, Cape Egmont and Turi fault zones influencing the structure of the basin over time (**Figure 5**).

The Taranaki Basin is a sedimentary basin with jurassic and earliest cretaceous Murihiku rocks generally being regarded as basement or early basin-fill. Exploration for oil and gas reserves within the offshore area of the basin has occurred since the early 1900's, and it is currently the only oil and gas producing basin in New Zealand.

Figure 5: Taranaki Basin Map



(Source: NZP&M, 2015)

Surficial marine sediment across the Taranaki shelf follows a gradient from the coastal zone to the continental shelf, with fine to medium sand typical of coastal sediments and silt and muds prevailing further offshore. Mechanisms for sediment transportation in the region are the waves and currents generated by prevailing southwest – westerly storms.

The seabed in the Operational Area is mainly composed of silt, clay and fine sand fractions (Johnston, 2011; Johnston & Forrest, 2012; Johnston et al., 2012; SLR, 2015; SLR, 2016).

4.2.2 Climate

The New Zealand climate is underpinned by a succession of eastward migrating anticyclones, which pass through on a 6 - 7 day cycle. The centres of these anticyclones generally track across the North Island, with more northerly paths being followed in spring, and southerly paths in autumn and winter. Anticyclones are high pressure systems comprised of descending air. These bring settled weather, with clear skies or low cloud/fog and little or no rain.

Troughs of low pressure are present between the anticyclones. These troughs often contain cold northwest to southeast orientated fronts, which initially bring cloudy skies and north-westerly winds followed by a period of rain before a change to cold showery south-westerly winds.

The South Taranaki Bight is directly exposed to intense weather systems from the Tasman Sea and is subject to high winds and seas. The strongest and most frequent winds and swells are generally from the west to southwest. Weather in the South Taranaki Bight can be extremely changeable but climatic extremes are infrequent.

In New Plymouth, the closest city to the proposed seismic survey, summer daytime temperatures range from 19˚C to 24˚C but seldom exceed 30˚C. Winters are relatively mild and are the most unsettled time of the year, with daytime maximum temperatures ranging from 10˚C to 14˚C (NIWA, 2013). **Table 4** outlines basic weather parameters at New Plymouth (MyWeather2, 2017).

Table 4: Mean Monthly Weather Parameters at New Plymouth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	54	83	68	104	112	123	110	101	105	117	102	106
Temperature – avg. daytime (˚C)	21	22	20	18	16	14	13	13	14	16	17	19
Temperature – avg. night time (˚C)	14	14	13	11	10	8	7	7	8	10	10	13
Avg. wind speed (kts)	17	17	17	16	18	19	18	18	20	22	20	18
Max wind speed – (kts)	56	70	56	61	65	69	67	57	87	107	57	69

4.2.3 Oceanography

Environmental conditions at the Māui 8 prospect location, which is centrally located in PML 381012 and considered to be representative of the survey areas, have been used in this MMIA to provide background information on the oceanography conditions likely to be encountered.

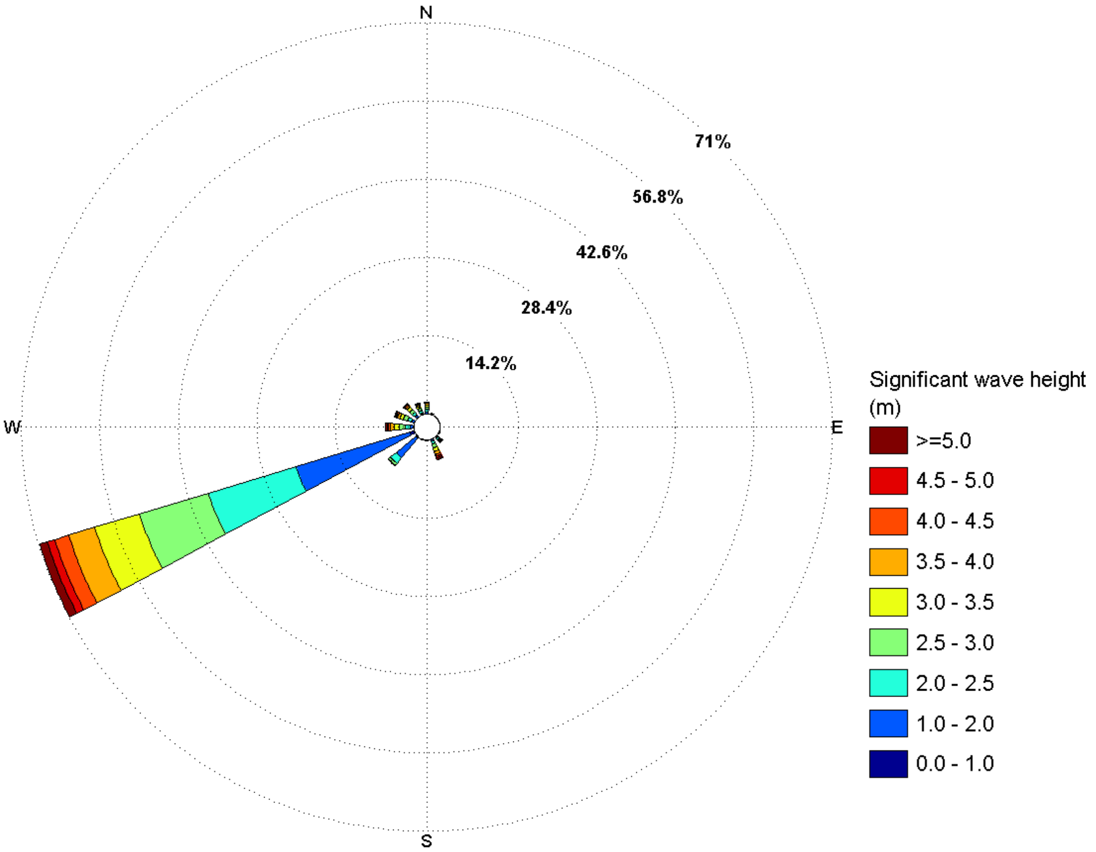
Wave Height

The Operational Area is situated in a high energy wave climate on account of its exposure to long period swells originating from the southern ocean, and locally generated waves. The majority of this wave energy originates from the southwest (**Figure 6**); however, energetic wave conditions can arrive suddenly from other directions.

Wave height data from MetOcean Solutions, based on numerical hind-casting and validated with wave buoy data from offshore Taranaki are summarised in **Figure 6**. The largest significant wave height at Māui 8 over the period 1979 – 2011 was 9.10 m, with a mean wave height at this location of 2.60 m.

The most energetic month at Māui 8 is September (mean wave height of 2.89 m), while the calmest month is February (mean wave height of 2.20 m).

Figure 6: Annual Wave Rose for Māui-8



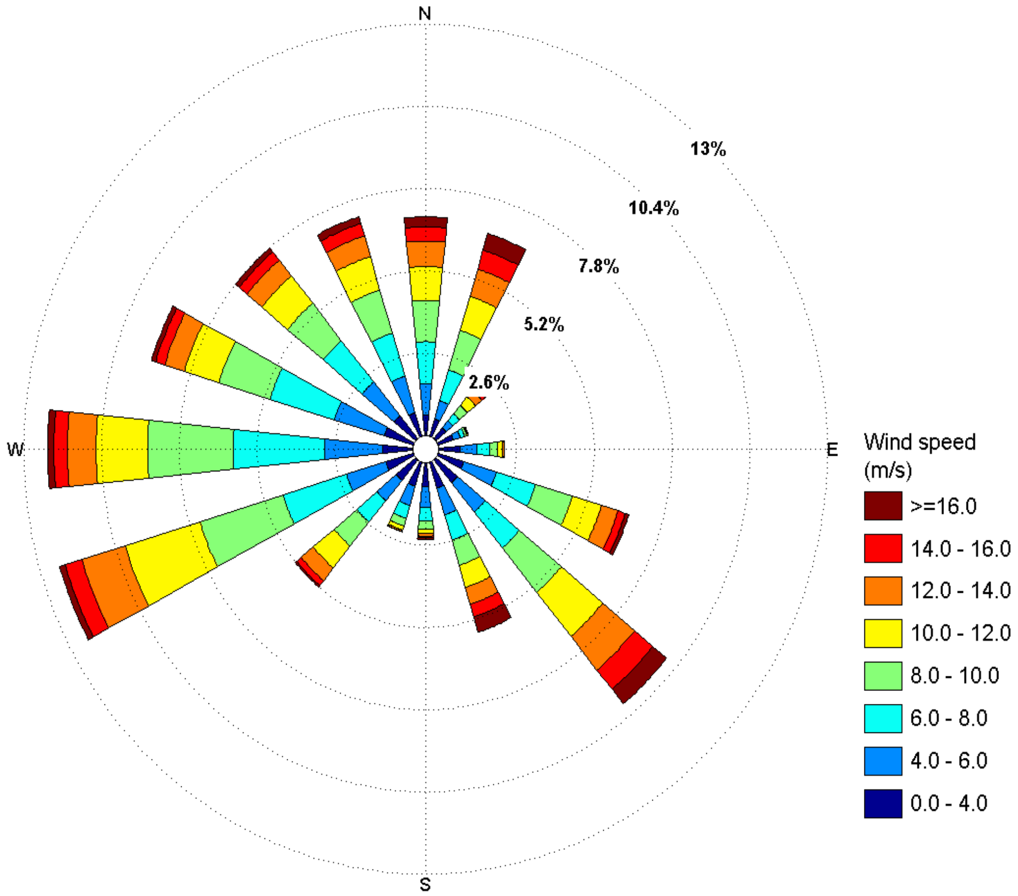
(Source: MSL data supplied by Shell Taranaki Limited)

Wind Climate

Wind climate modelling carried out at Māui 8 indicates that the windiest month is June (average wind speed of 9.14 $m.s^{-1}$), while the month with the least wind is February (average wind speed of 7.52 m/second).

The predominant wind at Māui 8 is from the westerly to south-westerly sectors; however, strong winds are also possible from all quarters (**Figure 7**).

Figure 7: Annual Wind Rose for Māui 8



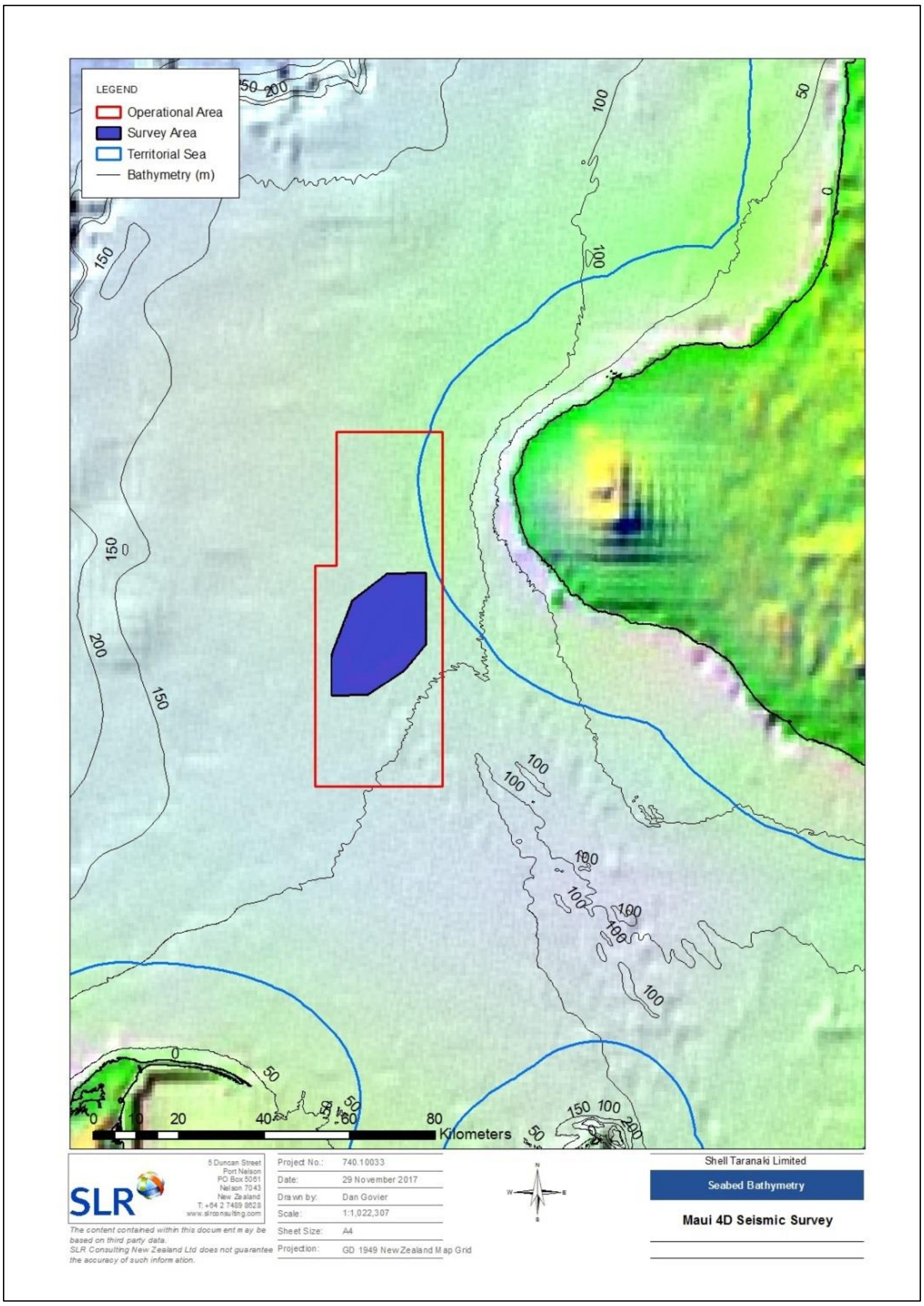
(Source: MSL data supplied by Shell Taranaki Limited)

Bathymetry

The continental shelf is broad in the Taranaki region and occupies approximately 30,000 km^2. The shelf slopes gently towards the west with an overall gradient of less than 0.1˚ and locally less than 0.5˚ (Nodder, 1995).

A gridded bathymetry for the Operational Area was provided by Shell Taranaki Limited for the purpose of this project based on actual sounding data for locations where this was available and using the LINZ sounding data from hydrographic charts for the remainder of the Operational Area. Through the Operational Area the seabed slopes towards the west from 80-100 m water depths on the eastern boundary to depths of 120-150 m on the western boundary, with the steepest gradient occurring in the northern portion (**Figure 8**).

Figure 8: Bathymetry of the Survey Area



Currents

New Zealand sits within the subtropical gyre. This gyre is driven by winds – the southeast trade winds to the north, and the westerly 'Roaring Forties' to the south. Together these winds set up the anti-clockwise circulation within the gyre.

The currents occurring along New Zealand's west coast are weaker and more variable than those on the east coast (Brodie, 1960). The primary ocean currents are illustrated in **Figure 10**. Oceanic currents towards the south of the Operational Area are predominately influenced by the D'Urville and Westland Currents (RPS, 2014), with the West Auckland Current replacing the D'Urville Current to the north.

The eastward flow out of the Tasman Sea splits into two currents across the top of the North Island; the West Auckland Current flowing from Cape Reinga towards Kaipara, and the East Auckland Current flowing from North Cape towards the Bay of Plenty (Brodie, 1960; Heath, 1985; Stanton, 1973). As the West Auckland Current progresses south, it is met in the North Taranaki Bight by the north-flowing Westland Current. This current flows from the west coast of the South Island up to the west coast of the North Island, where it weakens and becomes subject to seasonal variability. The convergence zone of the two currents is highly variable (Brodie, 1960; Ridgway, 1980; Stanton, 1973). The D'Urville Current flows from the South Island's Farewell Spit into the South Taranaki Bight where it travels south-east through Cook Strait (Brodie, 1960).

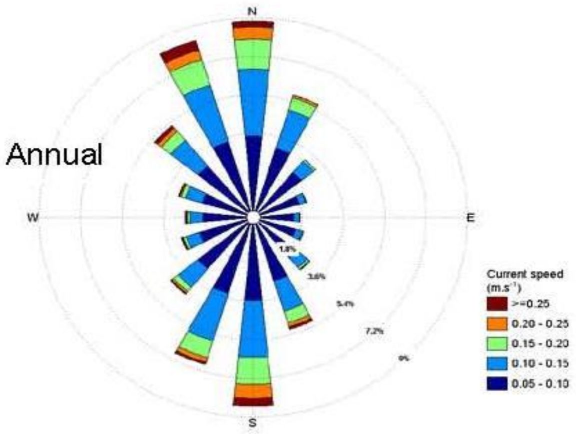
Seasonal variation in the West Auckland Current and Westland Current results in varying temperatures and salinity off the west coast of central New Zealand. During winter, the West Auckland Current extends further south, bringing with it warmer waters. In contrast, the West Auckland Current is weaker in the summer months and the Westland Current dominates, bringing with it colder waters (Ridgway, 1980; Stanton, 1973). Additional areas of cold surface water can also be found off the Taranaki coastline: however these are thought to be caused by terrestrial run-off (Ridgway, 1980).

The current regime around New Zealand is dominated by three main processes; wind-driven flows, low frequency flows and tidal currents (MSL, 2014). The net flows are a combination of all three of these processes, and can be further influenced by bathymetric effects.

At Māui 8, the depth-averaged currents showed a bimodal distribution with a clear north to south orientation and a slight predominance directed towards the north (**Figure 9**). At this site there is very little seasonal variation in flow patterns (MSL, 2014a).

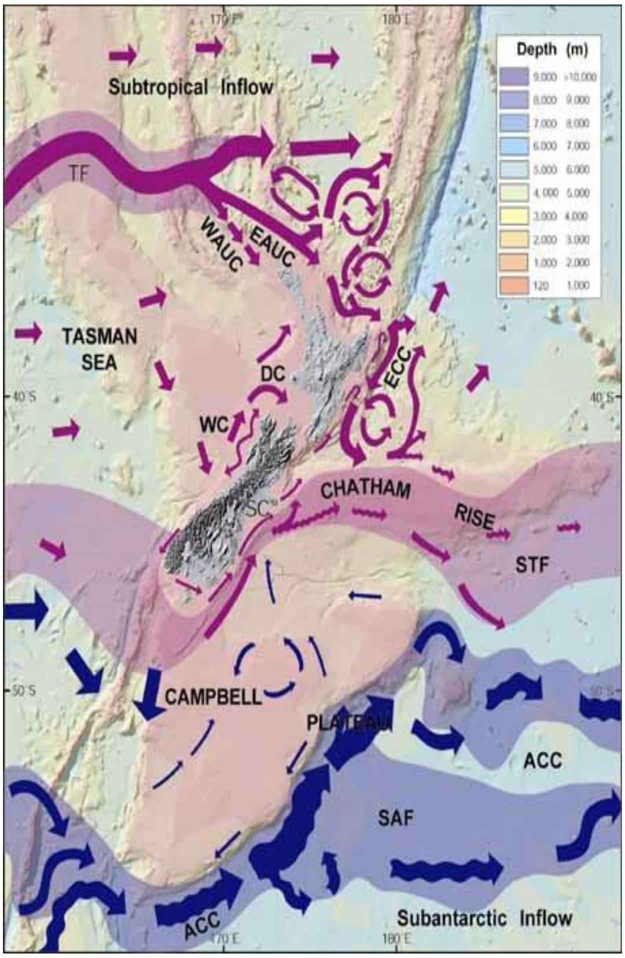
There are few direct measurements of currents around New Zealand, and long-term current measurements are even rarer. Tides around New Zealand are moderate compared to world standards, with a tidal range of 1–2 m and tidal currents which travel about 2 km/hour (~1 knot). The exception is Cook Strait where the tidal currents can be much stronger.

Figure 9: Annual Current Rose for Māui 8



Note: Currents are shown in the ‘going to’ direction

Figure 10: Ocean Circulation around New Zealand



(Source: The Encyclopaedia of New Zealand)

Water Column and Water Temperature

During spring and summer months, thermal stratification of the water column occurs over a large portion of the Greater Cook Strait and the offshore Taranaki. This seasonal stratification is a result of the solar heating of the upper water column. During late autumn this stratification usually breaks down due to mixing of the water column and reduced levels of solar radiation. The degree of stratification is strongly influenced by weather conditions, where rough weather in summer can quickly result in vertical mixing; hence, the summer thermocline is not a consistently present.

The water column properties within the Taranaki Bight are largely driven by the upwelling plumes originating from the Kahurangi Shoal off the west coast of the South Island. This upwelling leads to the formation of cyclonic plumes that are episodically shed off Cape Farewell. These intermittent upwelling events generate cold nutrient rich water that move to the northeast towards the Taranaki coast, promoting high nutrient concentrations and associated biological activity on a temporally variable basis (ASR, 2003).

Water Temperature

Satellite records from 1999 – 2009 provide information on monthly average sea surface water temperatures at Māui 8 (MSL, 2013). The seasonal average temperatures were: Summer 17.3 °C, Autumn 18.0 °C, Winter 15.0 °C, and Spring 14.0 °C.

4.3 Biological Environment

4.3.1 Overview of Marine Ecosystem

New Zealand is home to approximately 16,000 marine species, with the New Zealand Threat Classification listing 3% of these as being under treat on account of their small population size, restricted range, and/or declining populations. The New Zealand Threat Classification Database can be accessed via the following link:

http://www.doc.govt.nz/publications/conservation/nz-threat-classification-system/nz-threat-classification-system-lists-2012-14/

The list of threatened marine species includes 38 seaweeds (Hitchmough et al. 2005), 11 marine invertebrates (Freeman et al. 2014), 71 seabirds (Robertson et al., 2017), and 8 marine mammals (Baker et al. 2016). No assessment has yet been conducted for New Zealand marine fish.

New Zealand Marine Environmental Classification

The Marine Environmental Classification was developed to provide a spatial framework for the systematic management or marine biogeographic regions. This classification system uses physical (depth, solar radiation, sea surface temperatures, waves, tidal current, sediment type, and seabed slope and curvature) and biological parameters (such as characteristic species present and primary productivity) to map marine areas that have a similar environmental character. The Ministry for the Environment, Ministry of Fisheries and DOC jointly commissioned NIWA to develop the classification (Snelder et al., 2005).

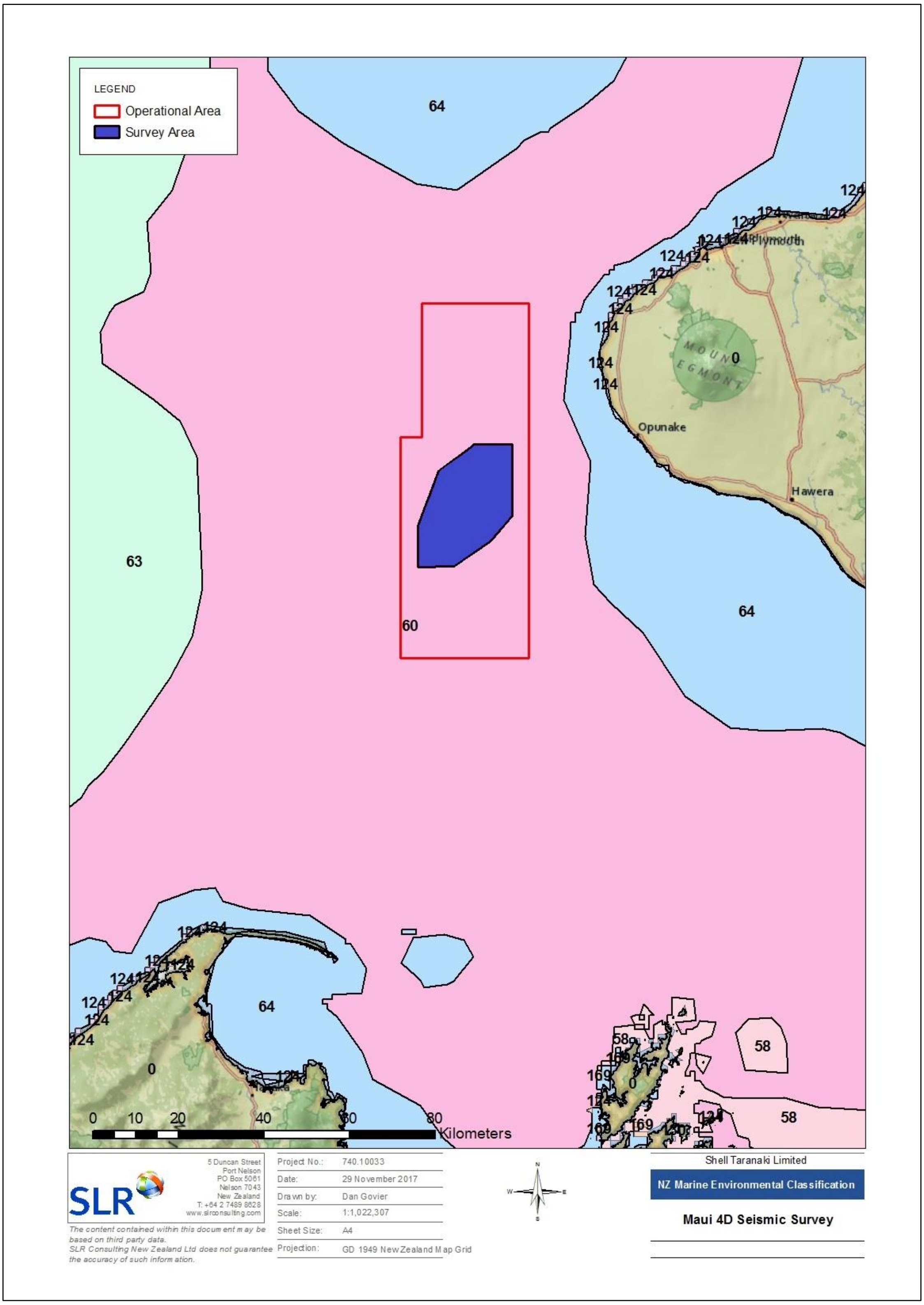
The classification system is accessible via the following link:

https://www.mfe.govt.nz/publications/ser/marine-environment-classification-jun05/

Under the New Zealand Marine Environmental Classification 20-class level, all of the Operational Area falls within 'class 60' representing the moderately shallow waters on the continental shelf (**Figure 11**); as described below following definitions provided by Snelder et al. (2005).

- **Class 60:** occupies moderately shallow waters (mean = 112 m) on the continental shelf. It experiences moderate annular solar radiation and wintertime sea surface temperatures and has moderately high average chlorophyll-α concentrations. Some of the most commonly occurring fish species are jack mackerel, barracouta, red gurnard, john dory, spiny dogfish, snapper and sea perch, while arrow squid are also frequently caught in trawls. The most commonly represented benthic invertebrate families are tusk shells (Dentaliidae), cockles (Cardiidae), clams (Carditidae, Veneridae and Nuculanidae), brittle stars (Amphiuridae) and scallops (Pectinidae).

Figure 11: The Marine Environmental Classification at the 20-Class Level.



4.3.2 Sensitive Sites

Sensitive sites are locations that receive special mention due to their recognised natural ecological values, and/or established protection regimes.

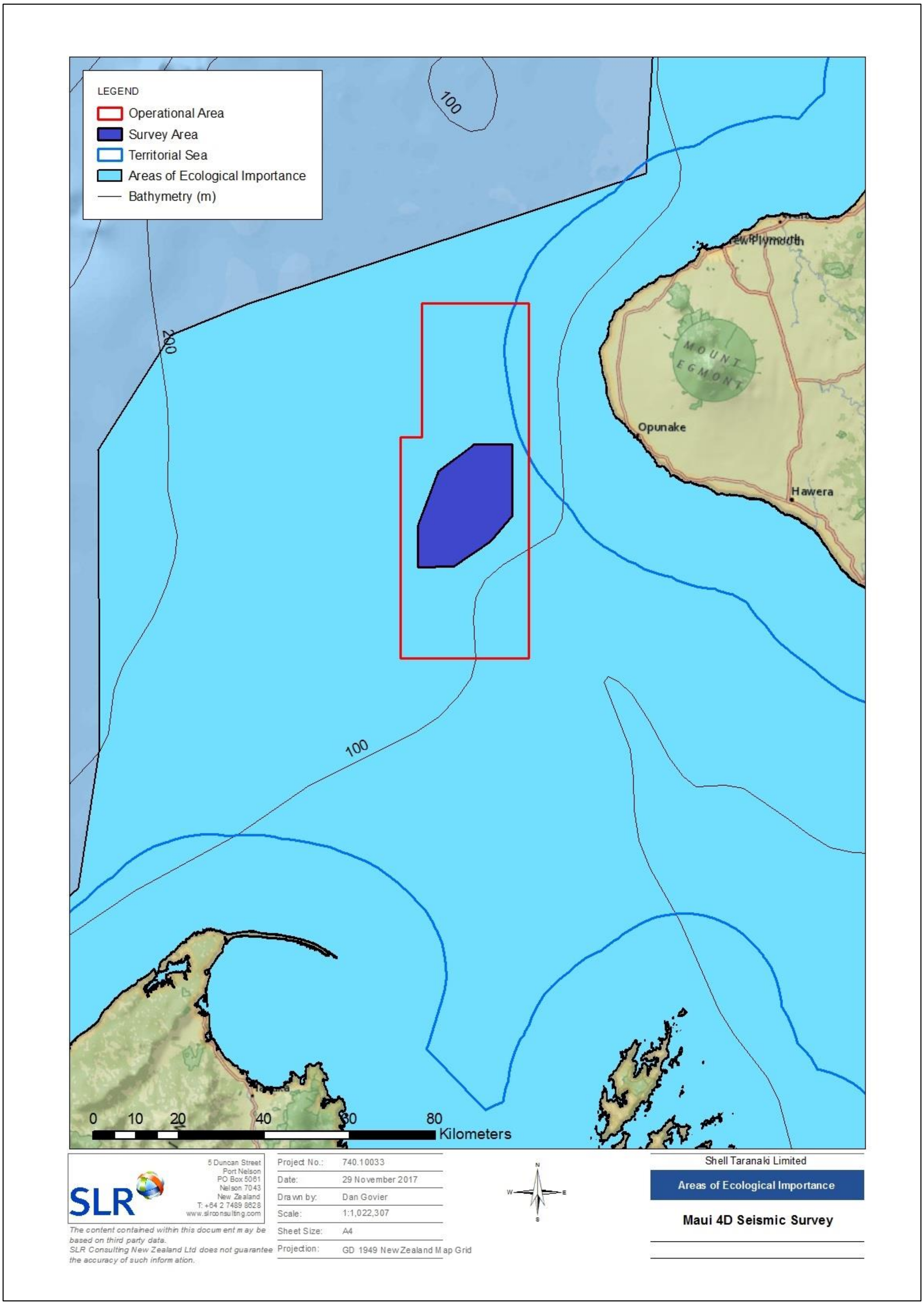
Areas of Ecological Importance

The Code of Conduct identifies Areas of Ecological Importance (as illustrated in **Figure 12**). The locations and extent of the Area of Ecological Importance in New Zealand continental waters have been determined from DOC marine mammal sighting and stranding records, fisheries related data from the Ministry of Primary Industries and species distributional information from a range of data sources. Where data was incomplete or absent, technical experts have helped refine the Area of Ecological Importance maps.

When seismic surveys are operating within these areas, as is the case with the Māui 4D Seismic Survey, the Code of Conduct states that additional measures to avoid, remedy or mitigate adverse effects on marine mammals may be required and that increased planning is therefore necessary for such surveys.

The Māui 4D Seismic Survey will be undertaken in accordance with the requirements of the Code of Conduct; this MMIA incorporates sound transmission loss modelling, ground-truthing of modelled results and additional management actions over and above those required in the Code of Conduct.

Figure 12: Area of Ecological Importance



Marine Protected Areas

Marine Protected Areas are put in place for the conservation of biodiversity and receive varying degrees of protection as a result of their recognised natural values. Marine Protected Areas are managed under six main pieces of legislation; the Conservation Act 1987, National Parks Act 1980, Reserves Act 1977, Wildlife Act 1953, Marine Reserves Act 1971, and the Marine Mammals Protection Act 1978.

There are three levels of marine protection in New Zealand; Type 1 and Type 2 Marine Protected Areas and ‘Other’ Marine Protection Tools. Type 1 Marine Protected Areas are the Marine Reserves. They are established under the Marine Reserves Act 1971 and provide the highest level of marine protection. Type 2 Marine Protected Areas are established outside of the Marine Reserves Act and provide protection from adverse effects of fishing. They include Marine Protected Areas, Marine Parks, Marine Management Areas, Mātaitai, and fisheries closures. ‘Other’ Marine Protection Tools are similar to Type 1 and Type 2 Marine Protected Areas but don’t protect sufficient biodiversity to meet the protection standard. Examples include Benthic Protection Areas, Seamount Closures, Marine Mammal Sanctuaries and customary management areas (DOC, 2017).

Marine Reserves

Of relevance to the Māui 4D Seismic Survey is the Tapuae Marine Reserve (**Figure 13**). The Tapuae Marine Reserve covers 1,404 ha and has a diverse range of habitats from canyons to boulder fields. It adjoins the Sugar Loaf Islands Marine Protected Area in the north, and extends south of New Plymouth to Tapuae Stream. The northwest part of the reserve is sheltered and characterised by islands, caves, canyons, and boulder fields, while the south-western part of the reserve is more exposed. Within the reserve, the waters contain a diverse range of fish, invertebrate and algal species. Tapuae Reserve is an important breeding and haul out site for New Zealand fur seals. Within this area other marine mammals have also been observed such as common dolphins, pilot whales, orca, humpback whales and southern right whales (DOC, 2017a).

Further afield, is Paraninihi Marine Reserve to the north, Tonga Island and Horoirangi Marine Reserves to the south, and Kapiti Marine Reserve to the southeast of the Operational Area (**Figure 13**).

Marine Protected Areas

The Ngā Motu/Sugar Loaf Islands Marine Protected Area lies offshore from the city of New Plymouth. It covers a group of low sea stacks and seven islands which provide a semi-sheltered environment amongst an otherwise exposed coast. A range of subtidal habitats are found within the Marine Protected Area including canyons, caves, rock faces with crevices and overhangs, large pinnacles, boulder fields and sand flats. At least 89 species of fish, 33 species of sponges, 28 species of bryozoans, and nine species of nudibranch have been observed. This area is also important for a number of seabirds, with 10,000 nesting annually and also supports a fur seal breeding colony. Within the Marine Protected Area commercial fishing is prohibited with the exception of trolling for kingfish and kahawai. Spoil dumping and activities that may cause disturbance to the foreshore and seabed are also restricted (DOC, 2017b).

Marine Mammal Sanctuaries

Marine Mammal Sanctuaries are designed to protect marine mammals from harmful human activities. There are currently six Marine Mammal Sanctuaries around New Zealand that have been established under the Marine Mammal Protection Act 1978. Two additional sanctuaries for whales and fur seals have been established under the Kaikoura Marine Management Act 2014.

The only Marine Mammal Sanctuary of relevance to the Māui 4D Seismic Survey is the West Coast North Island Marine Mammal Sanctuary (**Figure 14**). This sanctuary extends along 2,164 km of coastline along the North Island's west coast from Maunganui Bluff in the north, down to Oakura Beach in the south. Its offshore boundary extends from mean high water spring out to the 12 Nm CMA limit. In total, the sanctuary covers an area of 1,200,086 ha. The sanctuary was established in 2008 as part of the Hector's and Maui's Dolphin Threat Management Plan and places restrictions on seabed mining activities and acoustic seismic surveys. Further restrictions were implemented in 2013; set-netting for recreational and commercial purposes 2 – 7 Nm offshore is prohibited between Pariokariwa Point and the Waiwhakaiho River (DOC, 2015)

The Operational Area of the Māui 4D Seismic Survey lies outside, to the sound and west of the West Coast North Island Marine Mammal Sanctuary, separated by 6.7 km from the southern boundary of the sanctuary (see **Figure 14**).

Taranaki Areas of Outstanding Coastal Value

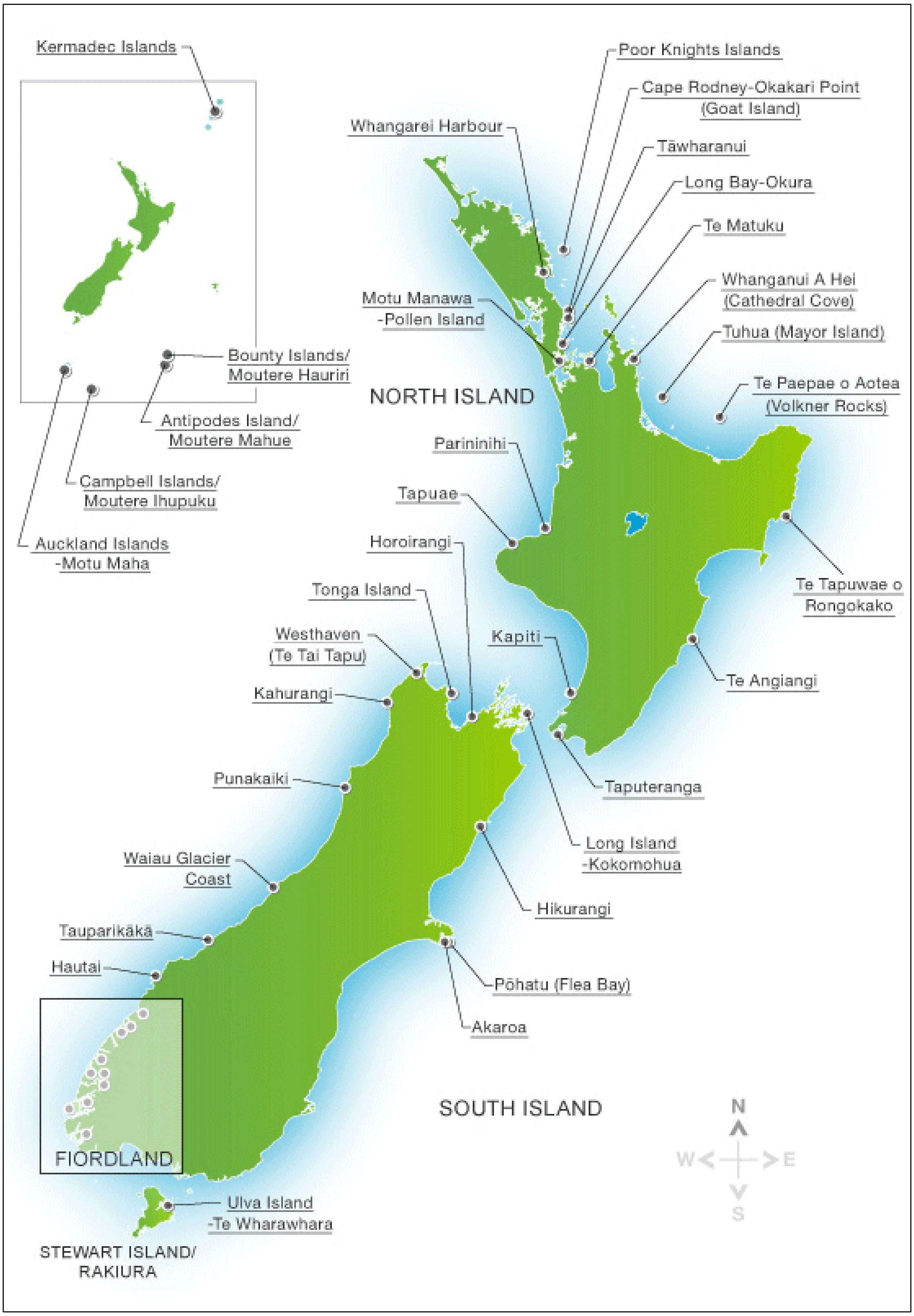
Within their Draft Coastal Plan, Taranaki Regional Council has divided the Taranaki coastline into five Coastal Management Areas. These areas recognise that some sites have values, characteristics, or uses that are vulnerable or sensitive or that require different management styles (Taranaki Regional Council, 2016). The Draft Coastal Plan outlines the activities that are permitted to occur within each management area (Note: the Draft Coastal Plan is not yet operative, but has been used here in place of the still operative 1997 Coastal Plan). The Coastal Management Areas are:

- Outstanding Value Areas: areas that have outstanding natural character and areas identified as outstanding natural features and landscapes. They contain values and attributes (such as landforms, cultural and historic associations, and visual qualities) that are exceptional;
- Estuaries Unmodified: estuaries that have not been significantly modified, including the surrounding area and environment;
- Estuaries Modified: estuaries that are highly modified and are surrounded by urban and extensively modified environments. These estuaries include Patea, Waiwhakakaiho and Waitara. Although modified they retain indigenous biodiversity values, amenity values, and contain significant habitats;
- Ports: covers Port Taranaki which contains regionally and nationally important infrastructure; and
- Open Coast: the area within the CMA that is not covered by other management areas.

Outstanding Value Areas have been identified within Schedule 2 of the Draft Coastal Plan (Taranaki Regional Council, 2016). These areas are further defined as Areas of Outstanding Natural Value or Areas that are Outstanding Natural Features or Landscapes. Details of the relevant coastal features are provided in **Table 5** and **Table 6** respectively. Areas of Outstanding Natural Character are mapped in **Figure 15**.

Also included in the Taranaki Draft Coastal Plan are Sites with Significant Amenity Values based on the natural or physical qualities and characteristics that contribute to the pleasantness, aesthetic coherence, and cultural and recreational attributes. These sites are in addition to the Areas of Outstanding Natural Character and Areas that are Outstanding Natural Features or Landscapes and include 22 beaches, 48 reefs, and 10 estuaries and river mouths. 103 Significant Surf Breaks and Nationally Significant Surfing Areas, and 29 Sites of Geological Significance have also been identified within the Draft Coastal Plan (Taranaki Regional Council, 2016).

Figure 13: Locations of Marine Reserves around New Zealand



(Source: http://www.doc.govt.nz/nature/habitats/marine/marine-reserves-a-z/marine-reserves-map/)

Figure 14 Location of Marine Mammal Sanctuaries around mainland New Zealand

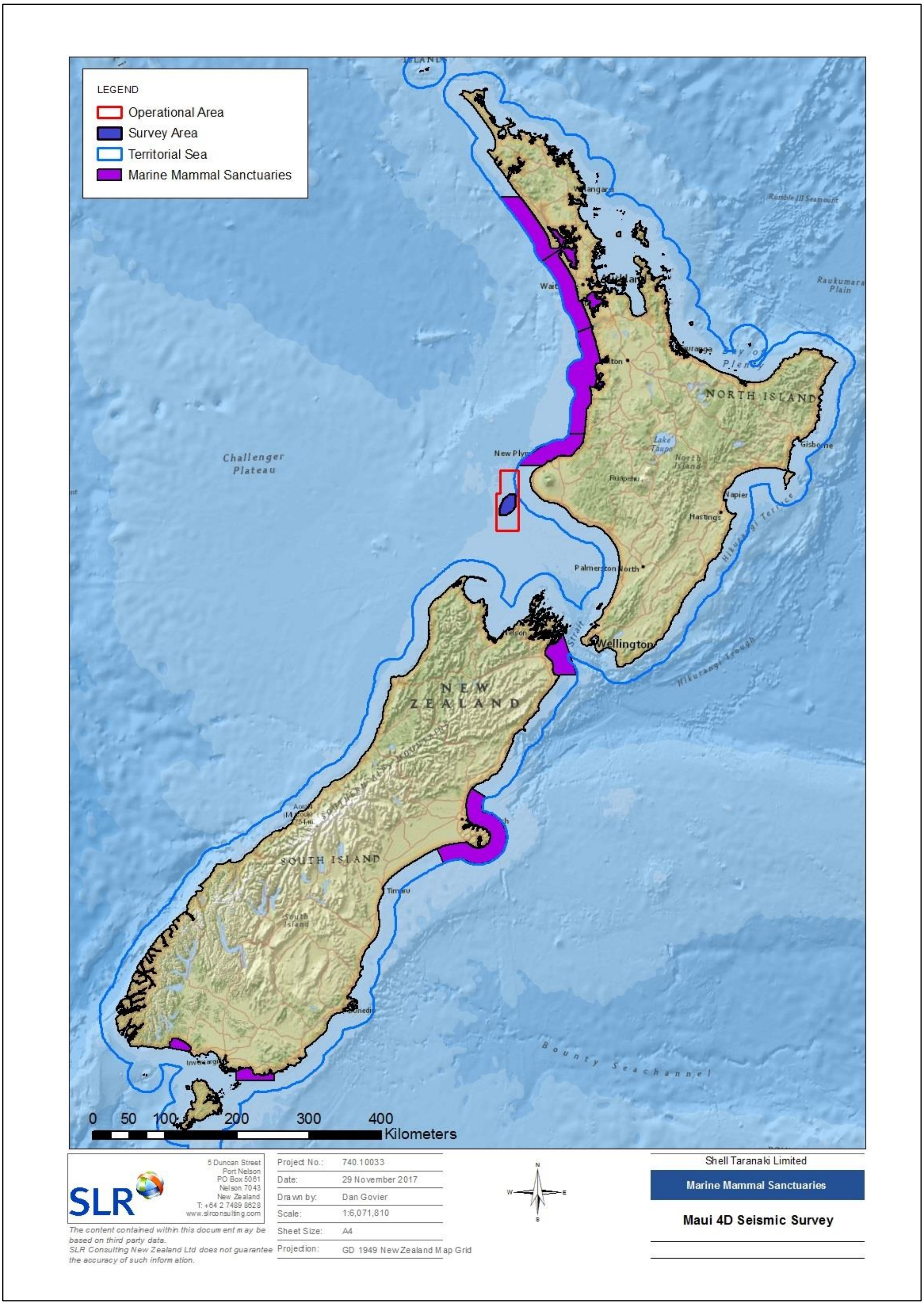


Table 5: Areas of Outstanding Natural Character

Area	Value
Parininihi	Contains unmodified and diverse habitats; coastal forest, dune systems, offshore reefs. White Cliffs are identified as a well-defined landform of scenic value. The extensive offshore reef is unique for North Taranaki. The marine reserve contains internationally important sponge gardens, high fish diversity and important crayfish and paua habitat. Human activity here is minimal giving an experience with a high sense of wilderness and remoteness.
Mimi Estuary*	Provides a diverse range of habitat types; riverine estuary, small tidal bays, estuary margins, and sandy foreshore. Supports unmodified natural processes including sand spit and dune processes and river mouth oscillation. Provides important habitats for a range of resident and migratory birds, including threatened species. The estuary contains diverse and regionally distinctive native fish. Human activity is minimal giving a sense of remoteness and high scenic associations.
Paritutu, Ngā Motu (Sugar Loaf Islands) and Tapuae*	Contains a diverse range of habitats including islands and stacks, subtidal canyons, caves, large pinnacles, boulder fields, rocky reefs, and sand flats. The islands have significant scientific and educational value, and support a diverse range and significant number of nesting birds, including threatened species. The marine protected area and marine reserve contain a diverse range of fish, sponges, and bryozoans as well as important crayfish and paua habitat. Supports the largest fur seal breeding colony on the North Island's west coast and other marine mammals may be observed at times. Human activity is minimal. The expansive seascape with minimal apparent modification retains wild scenic associations.
Waikirikiri (Komene Lagoon)	Contains active and uninterrupted natural processes; dune systems, a wide sandy beach that contains an ephemeral wetland and nationally rare coastal habitats. The coastline is accreting (unique for Taranaki). The dune system is unmodified and supports a range of native plants. The wetland and foreshore contains a range of resident and migratory birds including threatened and at risk species. Human activity is minimal, maintaining a high sense of wilderness and remoteness.
Whenuakura Estuary*	Relatively unmodified with diverse habitats; extensive mudflats, tidal lagoons, a freshwater lagoon, unmodified mudstone coastal cliffs, and a sand bar with an island forming intermittently. Flora is predominantly native including coastal swamp and wetland species. Several threatened and at risk flora and fauna species are present. It is the migratory route of several bird species. There is minimal modification maintaining strong wild and scenic associations.
Waipipi Dunes*	Consist of a highly dynamic complex of low (<4 m) dunes and small wet sand flats and depressions extending from the coast inland 200 – 300 m to taller (15 m) more stable relic foredunes. It is the only sizeable area in the Foxton Ecological Area with no artificially induced erosion and includes a Significant Natural Area and Regionally Significant Wetland. The vegetation is predominately native. The unmodified dune landforms retain a strong sense of wildness and isolation.
North and South Traps*	Two large adjoining pinnacle reefs which are unusual features on the sand dominated shelf. Contains important kelp beds, a diverse range of fish and encrusting sponges, and valuable crayfish habitat. The experience maintains a high sense of wilderness and remoteness.
Waitotara*	An actively eroding broken foredune and extensive series of undulating dunes with hollows and relic foredunes further inland parallel to the beach. Contains a system of wetlands which provide habitat for threatened and at risk flora and fauna, including coastal and migratory birds. Human activity is minimal and the experience maintains a high sense of wilderness and remoteness.

** indicates sites that are also considered to be 'coastal areas of local or regional significance'*

Table 6: Areas that are Outstanding Natural Features or Landscapes

Area	Value
Waihi Stream to Pariokariwa Point	The area extends out 1 Nm and contains a sequence of elevated marine terraces dissected by two estuaries, towering coastal cliffs, and a diverse range of coastal stacks, islands, caves and arches. Contains several geopreservation sites and the only reef and shore platform north of New Plymouth. There are offshore fish breeding grounds within the open coastal waters and the marine reserve contains significant scientific and ecological values including internationally important sponge assemblages. The estuaries along this coastline contain important breeding areas for native fish and abundant and diverse shellfish communities. The only mainland nesting site for grey-faced petrel occurs here and the offshore stacks and cliff edges also support breeding colonies of a number of other seabirds. Blue penguin nest in the area. A variety of threatened and at risk flora and fauna species are present. Aesthetic, scenic and recreational values are very high. The area is important to tangata whenua and contains significant pā sites and mahinga kai. There are historic and archaeological sites present such as ship wrecks and carvings.
Paritutu, Ngā Motu (Sugar Loaf Islands) and Tapuae*	An area of cultural, historic and spiritual importance to Te Atiawa and Te Kahui o Taranaki Trust due to tangata whenua occupation and use of the area. See **Table 5** for further information.
Hangatahuna (Stony River)*	The only braided river within the Taranaki region and largest and most prominent river carrying water from Mount Taranaki to the sea.
Oaonui (Sandy Bay)*	Largely unmodified and forms the only significant remaining area of coastal sand dunes within the volcanic ring plain. A geopreservation site. Provides important bird feeding, breeding, and resting areas. Provides habitat for a range of threatened and rare flora and fauna. Very high recreational, historic and cultural values.
Kaupokonui	A steep enclosing terrace scarp that reaches ~40 m above the coastal edge. Contains significant scientific values and has threatened, at risk, and regionally distinctive flora species. Is a whitebait spawning site. Retains a high level of naturalness. Considered the 'Jewel of South Taranaki' and is valued by locals and tourists. Significant to Ngā Ruahine Iwi and contains important cultural and archaeological sites.
Kapuni Stream Mouth	A naturally formed peninsula and flat topped island that supports threatened, at risk, and regionally distinctive flora and fauna. Retains a strong level of naturalness. Contains important historic (site of first clash between Māori and British troops) and cultural sites; pā, kāinga, tauranga waka, and pūkāwa
North and South Traps*	Popular recreational fishing and diving area and known by local iwi and hapu as a rich fishing ground. See **Table 5** for further information.
Waverly Beach*	Part of the South Taranaki uplifted marine terraces. Contains a range of coastal stacks, caverns, ravines, and blow holes carved into the cliffs and is recognised as a geopreservation site. Threatened and at risk flora and fauna are present. Has high scenic and recreational value, as well as significance for mahinga kai to tangata whenua. Contains significant pā and kainga including Tauranga waka and kai moana reefs.
Waitotara	Contains several geopreservation sites, seabird feeding, breeding, and resting areas, and several threatened and at risk species. Is a popular fishing area and contains significant pā and kainga, including tauranga waka and mahinga kai reefs.

** indicates sites that are also considered to be 'coastal areas of local or regional significance'*

In addition to the areas identified in **Table 5** and **Table 6**, Taranaki Regional Council, New Plymouth District Council, South Taranaki District Council and DOC have developed a list of coastal areas of local or regional significance in the Taranaki region. These areas are considered significant due to their amenity, recreational, cultural/historical and/or ecological/scientific values (Taranaki Regional Council, 2004). **Table 7** provides a summary of local and regionally significant sites that have not already been mentioned in **Table 5** and **Table 6** (indicated by an asterisk), and which have a marine component.

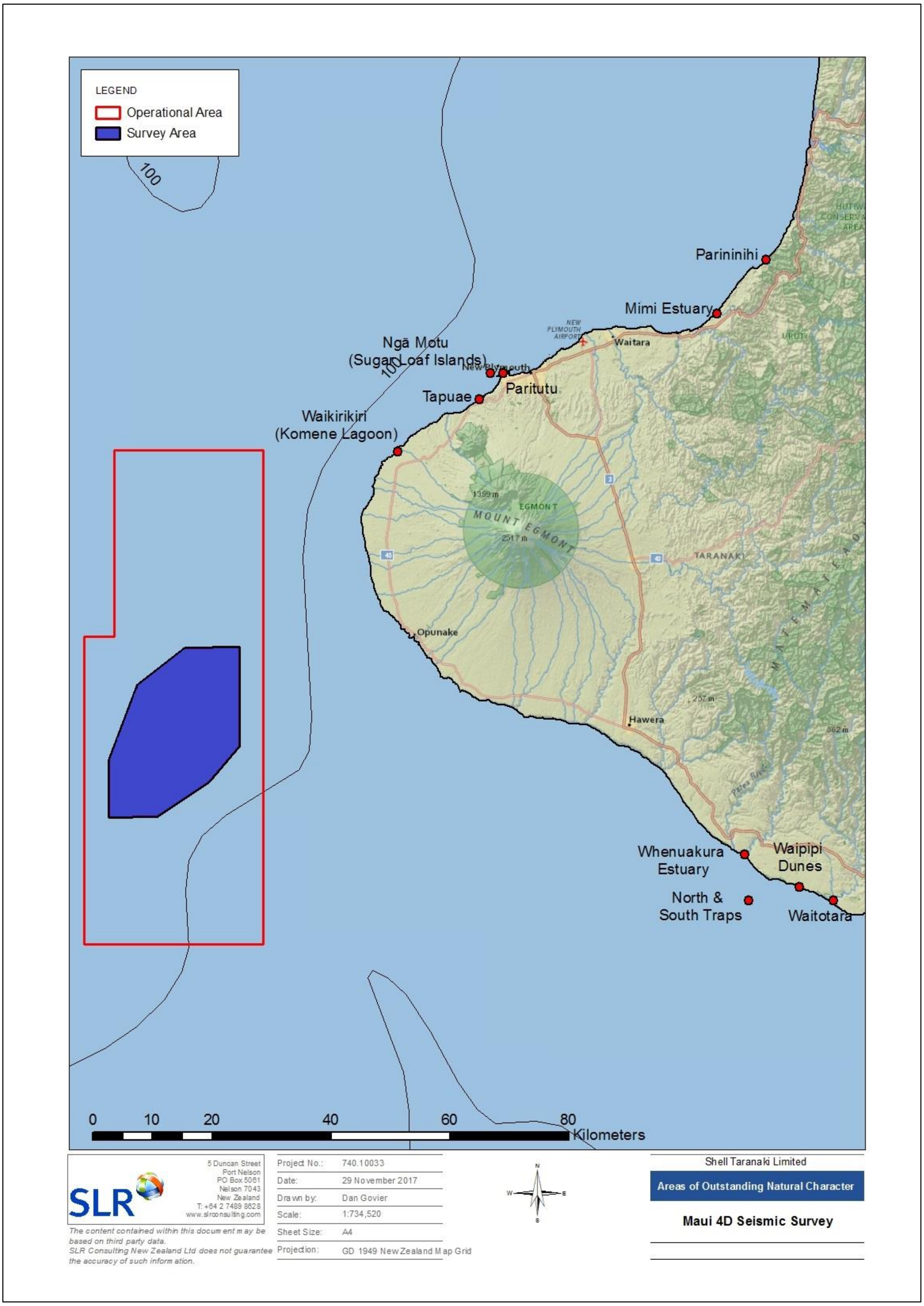
Table 7: Coastal Areas of Local or Regional Significance Taranaki

Site	Values			
	Amenity	Recreational	Cultural/ historic	Ecological/ scientific
Mokau-Mohakatino (Epiha Reef)	High	Moderate	High	High
Mohakatino Estuary	High	Moderate	High	High
Te Kawau Pa	High	Low	High	Moderate
Te Puia	Moderate	Moderate	High	High
Rapanui	High	Moderate	High	High
Tongaporutu Estuary	High	High	High	High
Tongaporutu Coast	High	Moderate	High	High
Whitecliffs (Parininihi)	High	Moderate	High	High
Pariokariwa Reef and Opourapa Island	High	Moderate	High	Moderate
Pukearuhe	Moderate	Moderate	High	Not known
Waiiti Beach	High	High	High	High
Urenui Estuary and Beach	High	High	High	High
Onaeroa Estuary and Beach	High	High	High	Moderate
Buchanans Bay	Moderate	Moderate	High	High
Motunui Beach	Moderate	Moderate	High	Not known
Waitara Estuary	High	Moderate	High	Moderate
Waitara, Waiongana and Airedale Reefs	High	High	Moderate	Moderate
Waiongana Estuary	High	Moderate	High	High
Bell Block and Waipu Lagoons	High	High	High	High
Waiwhakaiho Estuary	High	High	High	Moderate
Fitzroy Beach	High	High	Not known	Not known
East End Beach	High	High	High	Not known
New Plymouth Foreshore	High	High	Not known	Not known
Kaweroa Park	High	High	Moderate	Not known
Ngamotu Beach	High	High	High	Moderate
Paritutu/Back Beach	High	High	Not known	Not known
Tapuae Stream Mouth	High	Moderate	High	Moderate
Oakura Beach	High	High	High	Moderate
AhuAhu, Weld and Timaru Road Beaches	High	High	High	Moderate
Tataraimaka	High	Moderate	High	Moderate
Leith/Perth Road Beaches	High	Moderate	High	High
Komene Road Beach	High	High	High	High

Puniho Road Beach	High	Moderate	Not known	Not known
Paora Road Coast	High	High	High	Not known
Stent Road Coast	High	High	High	High
Bayly Road	Moderate	High	High	High
Cape Egmont	Moderate	Moderate	High	High
Arawhata Road Beach	High	Moderate	Not known	High
Middletons Bay	High	Moderate	High	Moderate
Opunake Beach	High	High	High	High
Mangahume Beach	High	Moderate	Moderate	Not known
Puketapu Road End	Moderate	Moderate	High	High
Oeo Cliffs	Moderate	Moderate	High	Moderate
Rawa Stream Mouth	Moderate	Moderate	High	Moderate
Otakeho Beach	High	Moderate	Not known	High
Kaupokonui Stream	High	High	High	High
Inaha Beach	High	Moderate	Not known	Not known
Waingogoro River, Ohawe Beach and Four Mile Reef	High	High	High	High
Waihi Beach	Moderate	High	High	Moderate
Kakaramea Beach	Moderate	Moderate	High	Moderate
Patea Beach and River Mouth	Moderate	High	High	High
Waiinu Beach and Reef	High	High	High	High

From the table above it is noteworthy that there is a snapper and trevally spawning ground off Buchanans Bay, Epiha Reef is the most extensive intertidal reef system in north Taranaki, Mohakatino Estuary is one of the least modified estuaries in north Taranaki, Te Puia is one of the few remaining natural areas of uplifted marine terrace, the Waitara River is the largest river in the Taranaki region and has extensive offshore reefs (Waitara, Waiongana, and Airedale reefs), and Waiinu Beach is the southernmost Taranaki beach.

Figure 15: Taranaki Areas of Outstanding Natural Character



Sensitive Environments defined by the EEZ & Continental Shelf Regulations

Schedule 6 of the EEZ and Continental Shelf (Environmental Effects – Permitted Activities) Regulations 2013 (the EEZ Regs) describes 13 sensitive biogenic and geological environments that have been identified by the Ministry for the Environment (in consultation with NIWA). ‘Sensitivity’ is defined as the tolerance of a species or habitat to damage from an external factor and the time taken for its subsequent recovery from damage sustained as a result of an external factor (MacDiarmid et al., 2013). The rarity of a habitat was taken into account when considering the tolerance, as an external factor is more likely to damage a higher proportion of a population or habitat as rarity increases (i.e. a rare habitat has a lower tolerance rating).

The environments considered sensitive under Schedule 6 of the EEZ Regs and the indicators used to identify their existence are provided in **Table 8**.

Table 8: Schedule 6 Sensitive Environment Definitions

Sensitive Environment	Indicator of existence of sensitive environment
Stony coral thickets or reefs	A stony coral reef or thicket exists if – • A colony of a structure-forming species covers 15% or more of the seabed in a visual imaging survey of 100 m² or more; or • A specimen of a thicket-forming species is found in two successive point samples; or • A specimen of a structure-forming species is found in a sample collected using towed gear.
Xenophyophore beds	A xenophyophore bed exists if average densities of all species of xenophyophore found (including fragments) equal or exceed one specimen per m² sampled.
Bryozoan thickets	A bryozoan thicket exists if – • Colonies of large frame-building bryozoan species cover at least 50% of an area between 10 m² and 100 m²; or • Colonies of large frame-building bryozoan species cover at least 40% of an area that exceeds 10 km²; or • A specimen of a large frame-building bryozoan species is found in a sample collected using towed gear; or • One or more large frame-building bryozoan species is found in successive point samples.
Calcareous tube worm thickets	A tube worm thicket exists if – • One or more tube worm mounds per 250 m² are visible in a seabed imaging survey; or • Two or more specimens of a mound-forming species of tube worm are found in a point sample; or • Mound-forming species of tube worm comprise 10% or more by weight or volume of a towed sample.
Chaetopteridae worm fields	A chaetopteridae worm field exists if worm tubes or epifaunal species – • Cover 25% or more of the seabed in a visual imaging survey of 500 m² or more; or • Make up 25% or more of the volume of a sample collected using towed gear; or • Are found in two successive point samples.
Sea pen fields	A sea pen field exists if - • A specimen of sea pen is found in successive point samples; or

	• Two or more specimens of sea pen per m² are found in a visual imaging survey or a survey collected using towed gear.
Rhodolith (maerl) beds	A rhodolith bed – • Exists if living coralline thalli are found to cover more than 10% of an area in a visual imaging survey; • Is to be taken to exist if a single specimen of a rhodolith species if found in any sample.
Sponges gardens	A sponge garden exists if metazoans of classes Demospongiae, Hexactinellida, Calcerea, or Homoscleromorpha – • Comprise 25% or more by volume or successive point samples; or • Comprise 20% or more by volume of any sample collected using towed gear; or • Cover 25% or more of the seabed over an area of 100 m² or more in a visual imaging survey.
Beds of large bivalve molluscs	A bed of large bivalve molluscs exists if living and dead specimens – • Cover 30% or more of the seabed in a visual imaging survey; or • Comprise 30% or more by weight or volume of the catch in a sample collected using towed gear; or • Comprise 30% or more by weight or volume in successive point samples.
Macro-algae beds	A macro-algae bed exists if a specimen of a red, green, or brown macro-algae is found in a visual imaging survey or any sample.
Brachiopods	A brachiopod bed exists if one or more live brachiopods – • Are found per m² sampled using towed gear; or • Are found in successive point samples.
Deep-sea hydrothermal vents	A sensitive hydrothermal vent exists if a live specimen of a known vent species is found in visual imaging survey or any sample. See Schedule 6 for a list of known vent species.
Methane or cold seeps	A methane or cold seep exists if a single occurrence of one of the taxa listed in Schedule 6 is found in a visual imaging survey or any sample.

Complex biogenic structures in otherwise homogenic habitats may be created by the presence of bivalve beds, resulting in modification of the surrounding habitat and the communities present. Bivalve beds in New Zealand are mainly found on the continental shelf in water depths less than 250 m. Common species include horse mussels, scallops, and dredge oysters. Bivalves have been reported to be particularly well represented off the west coast of the North Island to mid-shelf depths where surface sediments consist mainly of modern terrigenous clean sands and coarser-grained relict terrigenous or biogenic sediment (as referenced in MacDiarmid et al., 2013). Due to their preferred water depth and the known presence of bivalves in the Taranaki Bight, as reported by Johnston (2016), it is likely that this sensitive habitat type will be present in the Operational Area.

As with bivalves, the presence of brachiopod shells (including shells of live and dead individuals) increases habitat complexity. Brachiopods occur throughout New Zealand predominately on hard substrates in areas that experience significant water movement and are free of fine sediments. They are found at all depths but mainly less than 500 m, although a large number of species have also been recorded in depths over 1,000 m (as referenced in MacDiarmid et al., 2013). The North Taranaki Bight is not known to have diverse or abundant brachiopod assemblages; however, Johnston (2016) has reported brachiopods to present within, or in close proximity to, the Operational Area.

Habitat forming bryozoans are most commonly found in temperate continental shelf environments where there is suitable stable substrate and fast consistent water movement. New Zealand has a particularly abundant and diverse assemblage of bryozoans (MacDiarmid et al., 2013). Bryozoan thickets have been reported by Johnston (2016) within and in close proximity to the Operational Area.

Calcareous tube worm thickets/mounds can form dense three-dimensional mosaics across the seabed. The mound forming species *Galeolaria hystrix* is the best described example of mounds in New Zealand, and can be found from the Taranaki Coast down to Stewart Island (as referenced in MacDiarmid et al., 2013). The distribution of calcareous tube worm thickets in Taranaki as described in Johnston (2016) appears to be restricted to shallow coastal waters. Furthermore, the Taranaki Bight was not included in MacDiarmid et al. (2013) as a particularly important area for calcareous tube worms. Based on the above reports, calcareous tube worms are unlikely to be present within the Operational Area.

Little is known on the role of chaetopteridae tube worms in New Zealand. They belong to a family of filter-feeding polychaetes that form burrows in soft sediments (Johnston, 2016). Although not reported by MacDiarmid et al. (2013) to be present in the Taranaki Bight, Johnston (2016) has reported chaetopteridae worms to be present off Cape Egmont. As a result there is potential for chaetopteridae tube worms to be present within, or in close proximity to, the Operational Area.

The distribution of deep-sea hydrothermal vents is related to plate boundaries; New Zealand's deep-sea hydrothermal vents are associated with the subduction zone of the Pacific Plate under the Australian Plate (MacDiarmid et al., 2013). This occurs to the north of New Zealand well away from the Operational Area.

Macro-algae beds grow on hard rocky substrates in the photic zone (where light reaches) down to depths of 200 m. They include species of small foliose brown, red, and green algae as well as large brown algae/kelp and are important components of reef ecosystems (MacDiarmid et al., 2013). MacDiarmid et al. (2013) reports macro-algae beds to be present throughout New Zealand's EEZ; however, no specific Taranaki sites are mentioned. There are no reports of brown, green, or red macro-algae beds within the Operational Area (Johnston, 2016) and it is likely that the survey will be operating too far offshore for any to be present.

Methane or cold seeps occur where methane-rich fluids escape into the water column from underlying sediments. Active seeps are usually associated with gas hydrates in the Gas Hydrate Stability Zone which typically occurs in the upper 500 m of sediments beneath the seabed in water depths of at least 500 m (MacDiarmid et al., 2013). Active and relict cold seeps have been confirmed at the Hikurangi Margin on the North Island's east coast (MacDiarmid et al., 2013) but have not been recorded in the Taranaki Basin (Johnston, 2016). Furthermore, it is unlikely that cold seeps will be present within the Operational Area due to the relatively shallow nature of the Operational Area (100–200 m).

Rhodolith beds form structurally and functionally complex habitats (MacDiarmid et al., 2013). Little is known on the location of rhodolith beds in New Zealand; however, known locations are typically coastal in nature (MacDiarmid et al., 2013). It is suggested that rhodoliths prefer areas characterised by strong currents within the photic zone particularly around the margins of reefs or elevated banks (MacDiarmid et al., 2013). Rhodolith beds and their preferred habitat have not been reported as present within the Operational Area (Johnston, 2016) therefore this sensitive habitat is unlikely to be present within the Operational Area.

Sea pens occur on fine gravels, soft sand, mud, or the abyssal ooze. They occur in areas where turbulence is unlikely to dislodge their anchoring peduncle but where a current exists to ensure a continuous flow of food (MacDiarmid et al., 2013). Johnston (2016) has reported sea pens to be present in the Operational Area; however, based on benthic sampling around the Māui Field (SLR, 2015), the density of sea pens in the Operational Area is not enough to reach the definition of a sensitive environment under the EEZ Regs.

Sponges are dominant in many environments such as shallow coastal rocky reefs, seamounts, hydrothermal vents and oceanic ridges. In New Zealand demosponges dominate the shelf and coast in water depths down to 250 m, while deeper waters are dominated by the glass sponges. Examples of known sponge gardens in New Zealand include the North Taranaki Bight (MacDiarmid et al., 2013). The Sugar Loaf Islands Marine Protection Area is well known for its high diversity and abundance of sponges and this area has also been identified by Johnston (2016). Sponge gardens could be present within the Operational Area although they are more likely to be found inshore of the Operational Area.

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 reefs or thickets (MacDiarmid et al., 2013). See **Figure 16** for distribution maps of corals in the Operational Area. Although reported as present within the Operational Area (Johnston, 2016), densities have not been significant.

Xenophyophore beds are often mistakenly identified as broken and decaying parts of other animals. Seven species have been recorded in New Zealand, three of which are endemic (MacDiarmid et al., 2013). Xenophyophores are particularly abundant below areas of high surface productivity. 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 (as referenced in MacDiarmid et al., 2013). There have been no xenophyophore beds reported in the Operational Area (Johnston, 2016).

4.3.3 Benthic Ecosystem

The offshore benthic ecosystems in the North and South Taranaki Bight are generally characterised by soft sand/mud substrates. The habitat is considered to be relatively homogenous with low levels of diversity (Asher, 2014; Skilton, 2014) compared to that of other coastal areas in New Zealand (MacDiarmid et al., 2015). Over 200 invertebrate taxa have been recorded in the offshore area, where polychaetes (bristle worms) account for 45-65%, molluscs (mainly bivalves) account for 10-20% and crustaceans (such as shrimps, amphipods and cumaceans) account for 15-35% of the benthic communities (pers. obs. C. Dufour). Similarly, Handley (2006) found that soft bottom sediments offshore of Tasman and Golden Bays were also dominated by polychaetes, bivalves and small crustaceans, as well as echinoderms and bryozoans.

Species numbers and diversity tends to increase towards the shore, where highest numbers occur in the near-shore area (MacDiarmid et al., 2015). Over 370 species of invertebrates are known to inhabit the subtidal and intertidal shores adjacent to the Operational area, where the highest species diversity (172-180 species) and abundance have been recorded in the partially sheltered rocky shores of New Plymouth (Hayward et al., 1999; Hayward & Morley, 2002). In comparison, species diversity and abundance decrease to the north and south of New Plymouth, coinciding with increased exposure and the presence of sand/mud habitats (Hayward et al., 1999; MacDiarmid et al., 2015). This difference arises as invertebrate communities of soft sand/mud environments are characterised by fewer mobile organisms (like that of offshore benthic communities), whereas the hard substrate communities are dominated by higher densities of sessile invertebrates such as ascidians, sponges and hydroids (Hayward et al., 1999).

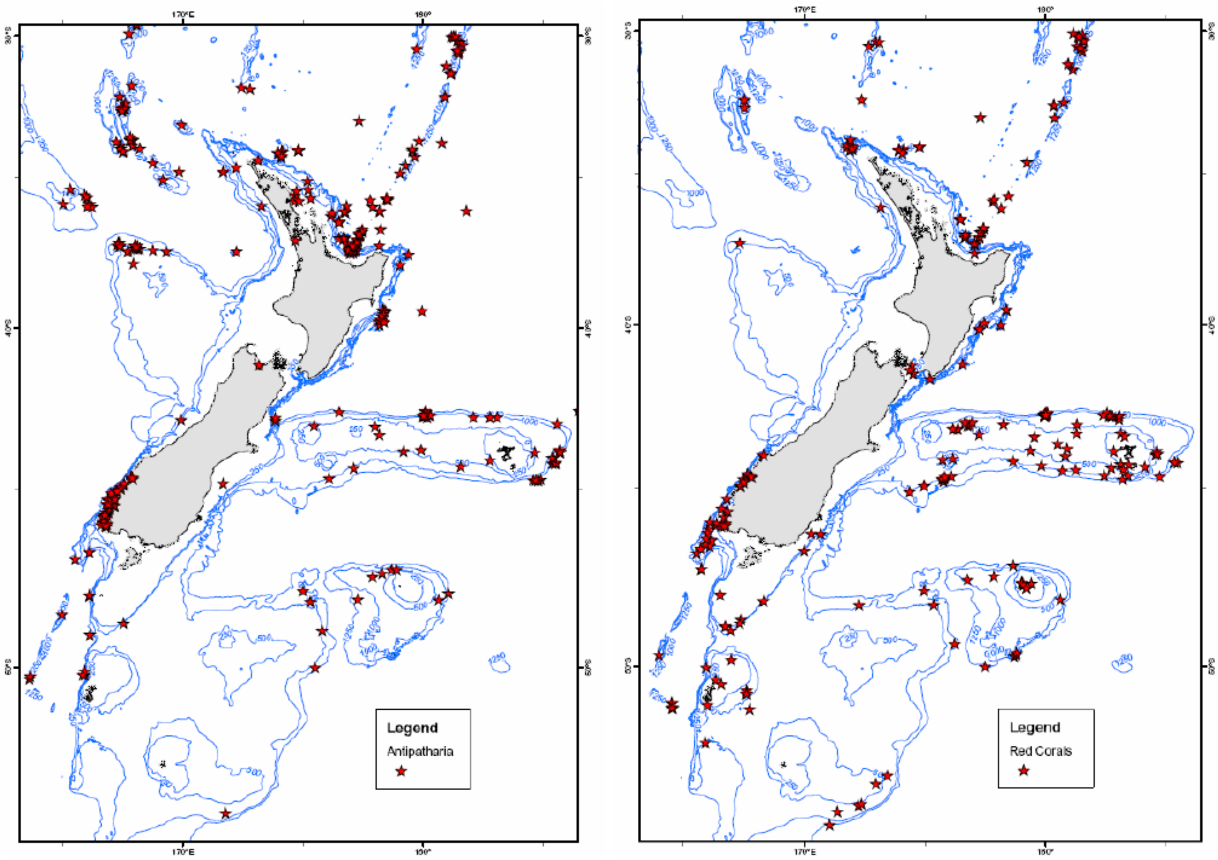
Invertebrate species (other than corals – see below) considered to be ‘at risk’ or ‘threatened’, under the New Zealand Threat Classification System have not been found in previous studies that have investigated the benthic communities in coastal and offshore Taranaki (MacDiarmid et al., 2015). In 2016, however, the Taranaki Regional Council identified the following within their Draft Coastal Plan as indigenous species that are regionally significant for their coastal indigenous biodiversity values: the hydrozoan *Nemertesia elongate*; the whelk *Cominella quoyana griseicalx*; the spider crab *Leptomithrax tuberculatus mortenseni*; the cushion star *Eurygonias hyalacanthus* and the stony coral *Maldrepora oculata* (Taranaki Regional Council, 2016). It must be noted that this report remains a draft, and none of these invertebrates have been recorded in the offshore habitats associated with the Operational Area (pers. obs. C. Dufour, SLR).

Deep Sea Corals

New Zealand has a rich and diverse range of corals that are present from the intertidal zone down to 5,000 m (Consalvey et al., 2006). Of the protected marine invertebrate species, the deep sea corals, such as black coral and stylasterid hydrocoral (formerly known as red coral), are the most relevant to the Māui 4D Seismic Survey as both groups are protected under the Wildlife Act 1953. These long-lived sessile invertebrates are fragile, slow-growing, restricted to certain habitats and have limited larval dispersal. Within New Zealand waters there have been 58 species of black coral identified, and although their depth and geographical distributions have not been analysed in detail, it appears most tend to live in deep water on seamounts or other hard substrate in depths ranging from 200 to 1,000 m deep.

NIWA have developed a database of coral distribution around New Zealand based on records from commercial fishing by-catch. From this data the presence of black and stylasterid coral appears to be greatest in the north and east of New Zealand; there are no significant densities of black coral or stylasterid coral in, or near, the Operational Area (**Figure 16**).

Figure 16 Records of Black Corals (left) and Stylasterid Corals (right)



(Source: Consalvey et al., 2006)

4.3.4 Pelagic Ecosystem

Plankton

'Plankton' is the collective term for drifting organisms that inhabit the pelagic zone (water column) of the World's oceans. Plankton fills the role of primary producers of the ocean and forms the basis of the marine food web. In general, planktonic organisms have such limited powers of locomotion that they are at the mercy of prevailing water movements; however, diurnal vertical migrations have been observed in some planktonic species (Nybakken & Bertness, 2005).

'Plankton' encompasses a broad taxonomic range, including animals, algae, protists, archaea and bacteria, which can be split into four functional groups (Nybakken & Bertness, 2005):

- Phytoplankton – free floating organisms capable of photosynthesis. Includes diatoms and dionflagellates;
- Zooplankton – free floating animals. Includes jellyfish, copepods, and the larval stages of larger animals such as fish, corals and crustaceans;
- Bacterioplankton – bacteria that are free floating within the plankton and usually of a size range from 0.2 – 2.0 µm; and
- Viroplankton – organisms in the size range of 0.02 – 0.2 µm that cannot survive without infecting a host.

Plankton are also characterised by size classes ranging from the largest megaplankton (above 20 cm) down to the smallest femtoplankton (0.02 – 0.2 µm). Standard plankton nets are only capable of sampling down to the microplankton (20 – 200 µm), which excludes the small bacterioplankton and viroplankton which as a result are poorly studied (Nybakken & Bertness, 2005).

The abundance of zooplankton and phytoplankton is influenced by large-scale physical processes such as upwelling systems, tidal mixing, and river plumes. These systems renew nutrients in depleted areas which in turn enhance primary productivity. The resulting enhanced primary productivity has a knock-on effect, influencing zooplankton communities (Bradford-Grieve & Stevens, 2013). An upwelling system occurs on the upper West Coast of the South Island (i.e. the Kahurangi Shoals), bringing pulses of nutrient rich cold water into the South Taranaki Bight. These upwelling events are considered ecosystem drivers, whereby an initial increase of phytoplankton occurs, followed by consequential increases in zooplankton and higher trophic levels as the upwelling eddies move northeast across the South Taranaki Bight (Bradford & Chapman, 1988).

The abundance of phytoplankton in marine environments can be quantified and mapped using chlorophyll-α concentration as a proxy (Pinkerton et al., 2013); with high chlorophyll-α concentration suggesting high phytoplankton abundance. Field work studies carried out by Pinkerton et al. (2013) reported the highest chlorophyll-α concentration in the South Taranaki Bight occurred during winter months. Large phytoplankton blooms characterise the offshore South Taranaki Bight, with such blooms sometimes covering much of the offshore area (Pinkerton et al., 2013).

Zooplankton biomass in the Western Cook Strait region (including within the South Taranaki Bight) is higher than that of the general west coast, suggesting enhanced productivity (Foster & Battaerd, 1985). Field surveys carried out in the South Taranaki Bight during the 1970s and 1980s observed a high degree of variation in the annual and seasonal distribution and biomass patterns of zooplankton, with highest biomass recorded during summer months. Zooplankton communities in these surveys were dominated by copepods. South Taranaki Bight zooplankton communities are considered to be typical of nearshore communities around New Zealand's North Island (Bradford-Grieve & Stevens, 2013; MacDiarmid et al., 2015a). It is also worth noting that many of the survey sites were inshore of the Operational Area, however, some sites were located within the Operational Area around the Māui Natural Gas Field (Bradford-Grieve & Stevens, 2013).

Phytoplankton blooms in the offshore South Taranaki Bight lead to seasonal aggregations of *Nyctiphanes australis* (a species of krill) (Bradford & Chapman, 1988). This species, being a favoured prey item of blue whales (see **Section 4.3.5**) leads to aggregations of pygmy blue whales in the area (Torres et al., 2014).

Fish Species

Fish populations around the Operational Area are comprised of various demersal and pelagic species, most of which are widely distributed from north to south and from shallow water to beyond the shelf edge. Species richness in New Zealand waters is strongly correlated with water depth, with the highest level of species richness typically associated with waters between 900 and 1,100 m deep (Leathwick et al, 2006). The Operational Area is substantially shallower, hence the anticipated diversity of fish species is not predicted to be particularly high.

In offshore Taranaki waters the diversity of fish species has an element of seasonality, with some pelagic species (such as sunfish, flying fish, marlin, albacore tuna, skipjack tuna, mako sharks and blue sharks) having a greater presence in summer months when they follow warm currents and prey species down from the north. The fish species richness of Taranaki has been reported to be moderate on a national scale, with no nationally rare or threatened species present (MacDiarmid et al., 2015).

A general summary of the fish species potentially present within the Operational Area is presented in **Table 9**. The information for this summary table was collated from the NABIS database, the Ministry of Fisheries New Zealand fish guides (McMillan et al., 2011; 2011a) and more than 35 years of trawl surveys as reported in Anderson et al. (1998), Bagley et al. (2000), Hurst et al. (2000), and O'Driscoll et al. (2003). Over 1,000 species of fish occur in New Zealand waters (Te Ara, 2017), therefore it is worth noting that **Table 9** is not intended as an exhaustive list of all species that could be present, but rather an indication of the species that are likely to have reasonable numbers present.

Fish spawning and pupping areas may be disproportionately important to fish populations, with any disruption to spawning or pupping activity potentially resulting in a reduction in recruitment (Morrison et al., 2014). Spawning activity may range from large spawning aggregations, localised groups of spawning fish, or single pairs of individuals. Large aggregations may involve large scale migrations (transient aggregations) or short distance migrations of local fish (resident aggregations) (Morrison et al., 2014). Information on the spawning and pupping of New Zealand's fish is very limited. While the spawning activity of some species is well known, for example commercially important species such as orange roughy and hoki, insufficient data exists for the majority of species. Data on the presence of spawning/pupping locations usually relies on reported catch of spent or ripe running females in research trawl tows. Species potentially spawning/pupping within the Operational Area and the approximate timing of such events have been provided in **Table 10** based on Morrison et al. (2014) and trawl data reported in Hurst et al. (2000) and O'Driscoll et al. (2003). Large harbours along the west coast of the North Island such as Kawhia are also important nursery grounds for a number of fish species (e.g. snapper and school shark) (Hurst et al., 2000). Adults migrate in to these sheltered bays to spawn/pup; therefore they may use the Operational Area during such movements.

Table 9 Fish Species Potentially Present in the Operational Area

Common Name		
Trawl surveys (Anderson *et al.,* 1998; Bagley *et al*., 2000, Hurst *et al*., 2000; O'Driscoll *et al*., 2003) [1] NABIS Database [2] McMillan *et al*. (2011) [3]		
Albacore tuna [2]	Greenback jack mackerel [3]	Rough skate [1,2,3]
Barracouta [1,2,3]	Gurnard [1,2,3]	Rubyfish [1,2,3]
Basking shark [2]	Hake [2,3]	Sand flounder [2]
Bass [2]	Hapuku [1,2,3]	Scaly gurnard [1,3]
Black marlin [2]	Hoki [1,2,3]	School shark [1,2,3]

Blue cod [1,2,3]	Horse mackerel [2]	Seal shark [2]
Black mackerel [1,2,3]	Jack mackerel [1]	Sepiolid squid [1]
Blue marlin [2]	John dory [1,2,3]	Short tail stingray [1]
Blue moki [2]	Kahawai [1,2,3]	Short-tailed black ray [3]
Blue shark [2,3]	Kingfish [2,3]	Silver conger [3]
Blue warehou [1,2]	Koheru [2]	Silver dory [1,2,3]
Bluenose [2]	Leatherjacket [1,2,3]	Silver warehou [1,2,3]
Brill [2]	Lemon sole [1,2]	Silverside [1,3]
Broadbill swordfish [2]	Ling [1,2,3]	Skipjack tuna [1,2]
Broadnose sevengill shark [3]	Longfinned beryx [2]	Slender jack mackerel [3]
Bronze whaler shark [2,3]	Mako shark [1,2,3]	Slender tuna [1]
Brown stargazer [3]	Moonfish [2]	Sloan's arrow squid [1,2]
Butterfly perch [1,3]	Murphy's mackerel [1,2]	Smooth skate [1,2,3]
Capro dory [1,3]	New Zealand sole [2]	Snapper [1,2,3]
Carpet shark [1,3]	Northern spiny dogfish [1,2,3]	Snipefish [3]
Common roughy [3]	Oblique banded rattail [3]	Southern conger [3]
Common warehou [3]	Opalfish [3]	Spiny dogfish [1,2,3]
Cucumberfish [1,3]	Pacific Bluefin tuna [2]	Spotted gurnard [3]
Dark ghost shark [1,2,3]	Pilchard [1,2,3]	Spotted stargazer [1,2,3]
Eagle ray [1,3]	Porae [2]	Striped marlin [2]
Electric ray [3]	Porbeagle shark [2,3]	Tarakihi [1,2,3]
Escolar [2]	Porcupine fish [1,3]	Thresher shark [1,2,3]
Frostfish [1,2,3]	Ray's bream [2,3]	Trevally [1,2,3]
Gemfish [1,2,3]	Red cod [1,2,3]	Turbot [2]
Giant stargazer [1,2,3]	Red perch/Jock Stewart [1,2,3]	Two saddle rattail [2,3]
Golden mackerel [2]	Red snapper [2]	Yellowtail jack mackerel [3]
Gould's arrow squid [1,2]	Redbait [1,2,3]	White warehou [2]
Great white shark [2]	Rig [1,2,3]	

Table 10 Fish Species Potentially Spawning in the Operational Area

Species common name	Spawning season
Barracouta	July – October then January – March
Blue mackerel	Summer
Blue warehou	October
Jack mackerel	July, September, and December – February
John dory	December – March
Red cod	July - September
Red gurnard	December – February
Rig	Spring/Summer
Rubyfish	November, January and February
School shark	Spring/Summer
Snapper	October – March (November – December peak)
Tarakihi	March – May

There are eight species of fish protected under Schedule 7A of the Wildlife Act 1953, including the basking shark, deepwater nurse shark, great white shark, manta ray, oceanic white-tip shark, spiny-tailed devil ray, spotted black grouper, and whale shark. Great white, basking, and oceanic white-tip sharks are also protected under the Fisheries Act 1996, prohibiting New Zealand flagged vessels from taking these species from all waters, including beyond New Zealand's EEZ. Of these protected species, the great white shark and basking shark have the greatest potential to occur in the Operational Area.

Two species of freshwater eel occur in New Zealand; the endemic long-finned eel (*Anguila dieffenbachii*) and the short-finned eel (*A. australis schmidtii*) which is found throughout New Zealand and Australia. Under the New Zealand Threat Classification System (Goodman et al., 2013) long-finned eels are classified as 'declining' and short-finned eels as 'not threatened'. Both species are managed under the Quota Management System, with separate stocks for each species in the North Island (Jellyman, 2012). Although considered a freshwater species, these eels have a catadromous life history; whereby they carry out oceanic spawning at great distances from their typical freshwater habitat (Jellyman, 2012). Although little is known of the marine component of the life cycle of these eels, four migration phases are known to occur in New Zealand as described below.

- From October to December the elvers (two year old eels) move into freshwater habitat. The elvers move at night or during floods, where 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);
- Following the influx of elvers, an upstream migration occurs of the four to five year old eels. This migration further upstream occurs annually in January (Cairns, 1950);
- Adult eels (known as tuna heke) move to marine spawning grounds in February and March, with the majority of adults having migrated by April. This seaward migration 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 with males migrating before females following the migration by short-finned eels (Cairns, 1950). The adults move to the sub-tropical Pacific Ocean and although the exact location and migration route for spawning is not known (eel spawning has never been observed), deep ocean trenches (DOC, 2017c) near Fiji and New Caledonia are thought to be important for spawning (NIWA, 2017). Short-finned and long-finned eels are semelparous; they breed only once at the end of their life (DOC, 2017c), therefore adults do not return to New Zealand after spawning; and
- The leptocephalii (transparent leaf-shaped eel larvae) reach New Zealand waters by drifting on ocean currents. Once in New Zealand coastal waters they morph into eel-shaped 'glass eels' and move into river mouths and estuaries (Te Ara, 2017a) before commencing their freshwater life-cycle as elvers.

4.3.5 Marine Mammals

New Zealand waters support a diverse community of marine mammals, with forty-eight species of cetacean (whales and dolphins) and nine species of pinniped (seals and sea lions) are known to inhabit New Zealand waters (Baker et al., 2016). Understanding the distribution of these species is fundamental with regard to understanding the potential impacts that seismic surveys may have on them. The information contained in this section therefore largely focusses on species distribution with the aim of identifying any spatial overlap between marine mammal distributions and the Operational Area. The key information sources which underpin this section are:

- Published literature on individual species (individually referenced); and
- The DOC marine mammal sighting and stranding database records.

The DOC marine mammal sighting and stranding records contain presence-only data, and it is important to recognise that the observer effort behind this data is not consistent across space and time.

Figure 17 provides a summary of all sightings from the DOC marine mammal sightings database in the vicinity of the Operational Area, while **Figure 18** provides a summary of the DOC stranding records in the vicinity of the Operational Area.

Figure 17 Cetacean Sightings in the Vicinity of the Operational Area

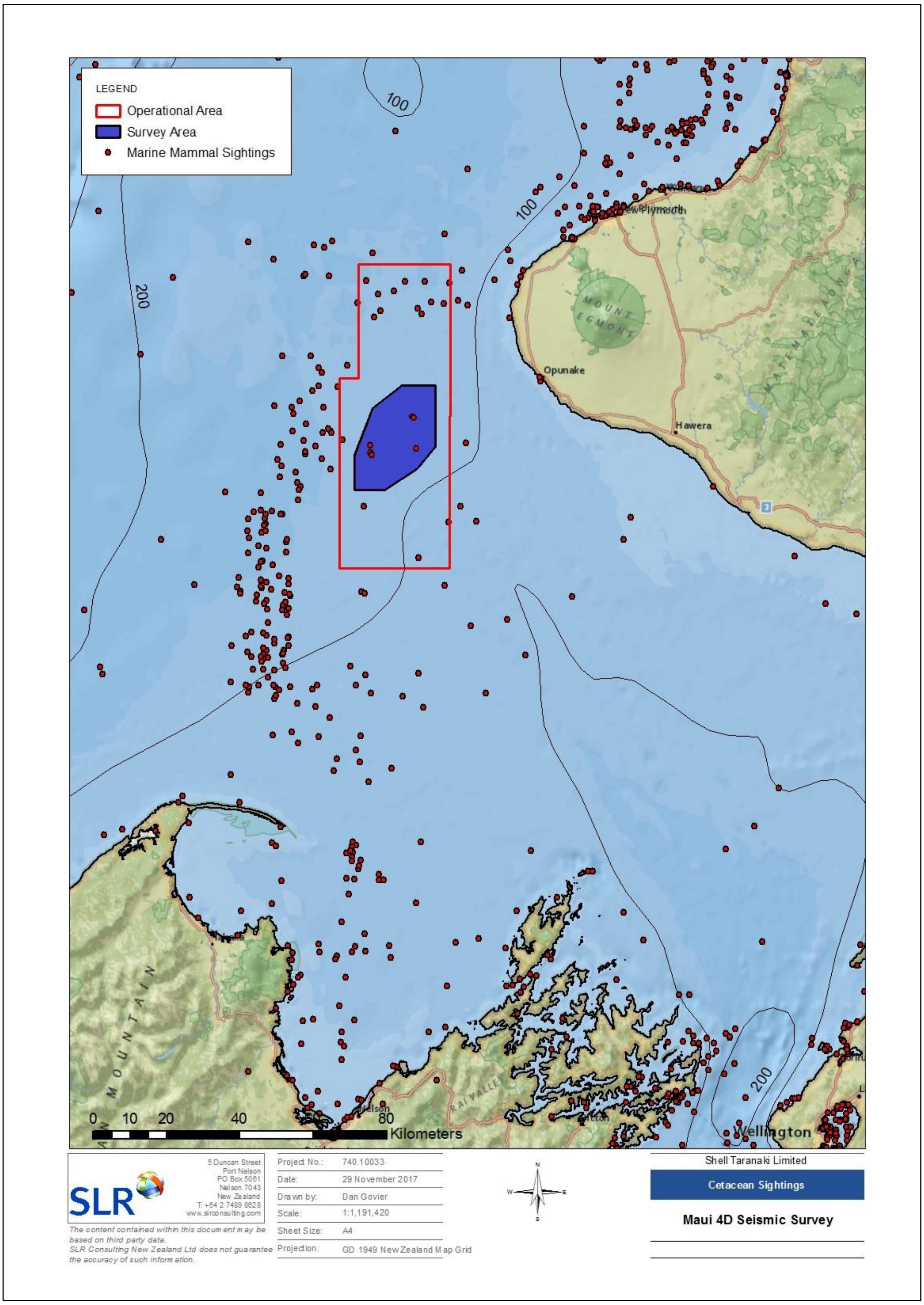
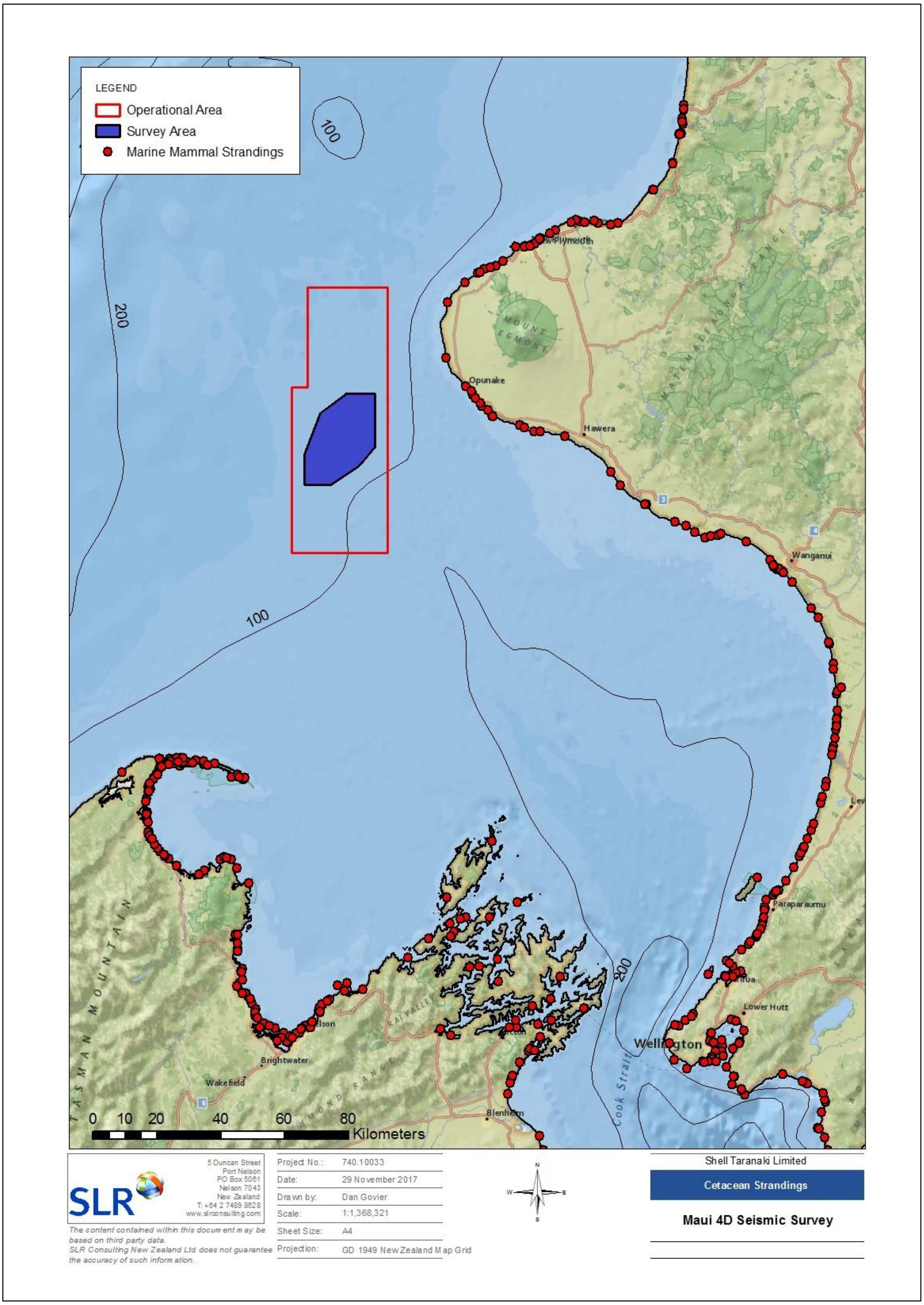


Figure 18 Cetacean Strandings in the Vicinity of the Operational Area



Not only is it important to identify spatial overlap between marine mammal distributions and the Operational Area, but it is also useful to assess the likelihood of each species being present in the vicinity of the Operational Area. To facilitate such an assessment, criteria have been developed against which the likelihood of a species being present in the Operational Area are assessed. These criteria are presented in **Table 11**.

Table 11 Criteria used to assess the likelihood of cetacean species being present

Likely	Species that are represented in the DOC sightings and/or stranding record from the Operational Area and which are not classified as 'Vagrant', or 'Data Deficient' in the New Zealand Threat Classification System (Baker et al., 2016).
Possible	Species that are represented in the DOC sightings and/or stranding record from the Operational Area and which are classified as 'Data Deficient' in the New Zealand Threat Classification System (Baker et al., 2016).
Occasional Visitor	Species that are represented in the DOC sightings and/or stranding record from the Operational Area, but are listed as 'Migrant' in the New Zealand Threat Classification System (Baker et al., 2016). Note that this criterion does not preclude some 'Migrant' species from being assessed as being 'likely' to occur in the Operational Area.
Rare Visitor	Species that are present in the DOC sightings and/or stranding record from the Operational Area, or reportedly occur in the Operational Area, or whose known range is directly adjacent to the Operational Area, but are listed as 'Vagrant' in the New Zealand Threat Classification System (Baker et al., 2016).
Unlikely	Those species not represented in the DOC sightings and/or stranding record from the Operational Area.
Note	*Where only very small numbers of sightings or strandings are present in the DOC Strandings and Sighting Databases, likelihood determination has been adjusted to take any additional information into consideration.*

The findings of our assessment are summarised in **Table 12**, and a basic ecological summary for those more commonly occurring species is provided in the sections below. Note that stranding data from Taranaki, Manawatu/Whanganui, Kapiti Coast, the outer Marlborough Sounds, Tasman Bay and Golden Bay have been analysed as part of the assessment, based on these regions being in the vicinity of the Operational Area. Although stranding data gives a broad indication of species occurrence, the following caveats should be noted 1) dead animals can wash ashore a long way from where they died; and 2) prior to death, sick or diseased animals may be well outside their normal distribution range.

Based on the distributional information available and in accordance with the criteria in **Table 11** and the New Zealand Threat Classification System (as summarised in **Appendix C**), thirteen species are likely to occur in the Operational Area as follows:

- Bottlenose dolphin (Nationally Endangered);
- Common dolphin (Not Threatened);
- Dusky dolphin (Not Threatened);
- Dwarf minke whale (Not Threatened);
- False Killer whale (Not Threatened);
- Gray's beaked whale (Not Threatened);
- Cuvier's beaked whale (Data Deficient)

- Killer whale (Nationally Critical);
- Long-finned pilot whale (Not Threatened);
- New Zealand fur seal (Not Threatened);
- Pygmy blue whale (Migrant);
- Pygmy sperm whale (Not Threatened); and
- Sperm whale (Not Threatened).

Each spring most of the large baleen whales living in the Southern Hemisphere undertake extensive migrations: from the Pacific Islands to the Antarctic Ocean to feed, and return each Autumn-Winter back to the Pacific Islands for the breeding season (May – July) (DOC, 2007). On account of their migratory habits, most species of baleen whales are considered unlikely to be present in the Operational Area; instead these species are typically considered occasional visitors. There are however exceptions, for example Bryde’s whales and pygmy blue whales which do not exhibit clear migratory patterns and instead are resident or semi-resident to particular habitats. Greater detail about migration patterns, or lack thereof, is discussed in the species-specific accounts throughout the remainder of this section.

The Māui 4D Seismic Survey will commence in late summer 2018 and may extend into early autumn. At this time of the year most baleen whales will still be concentrated at the Antarctic feeding grounds. On this basis there is only limited potential for overlap between the migratory behaviours of baleen whales and survey operations.

Table 12: Likelihood of Occurrence of Marine Mammals in the Operational Area

Common Name	**Scientific Name**	**NZ Conservation Status** (Baker et al., 2016)	**Qualifier ***	**IUCN Conservation Status** www.redlist.org (July 2017)	**Species of Concern** (DOC, 2013)	**DOC Stranding database** (No. of events near Operational Area**)	**DOC Sightings database** (No. of reports in Operational Area)	**Presence in the Operational Area**
Andrew's beaked whale	*Mesoplodon bowdoini*	Data deficient	SO	Data deficient	Yes	✓ (4)	×	Possible
Antarctic blue whale	*Balaenoptera musculus intermedia*	Migrant	TO	Critically endangered	Yes	✓ (5)	✓ (****)	Occasional visitor
Antarctic fur seal	*Arctocephalus gazella*	Vagrant	SO	Least concern	No	×	×	Unlikely
Antarctic minke whale	*Balaenoptera bonaerensis*	Not threatened	DP, SO	Data deficient	Yes	✓ (4)	×	Possible ***
Arnoux's beaked whale	*Berardius arnuxii*	Migrant	SO	Data deficient	Yes	✓ (10)	×	Occasional visitor
Blainville's/Dense beaked whale	*Mesoplodon densirostris*	Data deficient	SO	Data deficient	Yes	×	×	Unlikely
Bottlenose dolphin	*Tursiops truncatus*	Nationally endangered	CD, Sp, SO	Least concern	Yes	✓ (17)	×	**Likely**
Bryde's whale	*Balaenoptera edeni*	Nationally critical	SO	Data deficient	Yes	✓ (2)	×	Possible ***
Common dolphin	*Delphinus delphis*	Not threatened	DP,SO	Least concern	No	✓ (68)	✓ (2)	**Likely**
Crab eater seal	*Lobodon carcinophaga*	Vagrant	SO	Least concern	No	×	×	Unlikely
Cuvier's beaked whale	*Ziphius cavirostris*	Data deficient	SO	Least concern	Yes	✓ (24)	✓ (1)	**Likely *** **
Dusky dolphin	*Lagenorhynchus obscurus*	Not threatened	SO	Data deficient	No	✓ (41)	×	**Likely**
Dwarf minke whale	*Balaenoptera acutorostrata*	Not threatened	DP, SO	Least concern	Yes	✓ (12)	×	**Likely**
Dwarf sperm whale	*Kogia sima*	Vagrant	SO	Data deficient	Yes	×	×	Unlikely
False killer whale	*Pseudorca crassidens*	Not threatened	DP, SO	Data deficient	Yes	✓ (2)	✓ (1)	**Likely**
Fin whale	*Balaenoptera physalus*	Migrant	TO	Endangered	Yes	✓ (4)	×	Occasional visitor
Fraser's dolphin	*Lagenodelphis hosei*	Vagrant	SO	Least concern	No	×	×	Unlikely
Gingko-toothed whale	*Mesoplodon ginkgodens*	Vagrant	SO	Data deficient	Yes	✓ (3)	×	Rare visitor
Gray's beaked whale	*Mesoplodon grayi*	Not threatened	DP, SO	Data deficient	Yes	✓ (40)	×	**Likely**
Hector's beaked whale	*Mesoplodon hectori*	Data deficient	SO	Data deficient	Yes	×	×	Unlikely
Hector's dolphin	*Cephalorhynchus hectori hectori*	Nationally endangered	CD	Endangered	Yes	✓ (16)	✓ (1)	Possible ***
Hourglass dolphin	*Lagenorhynchus cruciger*	Data deficient	SO	Least concern	No	×	×	Unlikely
Humpback whale	*Megaptera novaeangliae*	Migrant	SO	Least concern	Yes	✓ (6)	✓ (1)	Possible ***
Killer whale	*Orcinus orca*	Nationally critical	DP, SO, Sp	Data deficient	Yes	✓ (3)	✓ (1)	**Likely**
Leopard seal	*Hydrurga leptonyx*	Vagrant	SO	Least concern	No	×	×	Unlikely
Lesser/pygmy beaked whale	*Mesoplodon peruvianus*	Vagrant	SO	Data deficient	Yes	×	×	Unlikely
Long-finned pilot whale	*Globicephala melas*	Not threatened	DP, SO	Data deficient	Yes	✓ (78)	✓ (5)	**Likely**
Maui's dolphin	*Cephalorhynchus hectori maui*	Nationally critical	CD	Not assessed	Yes	✓ (15)	✓ (4)	Possible ***
Melon-headed whale	*Peponocephala electra*	Vagrant	SO	Least concern	Yes	×	×	Unlikely
New Zealand sea lion	*Phocarctos hookeri*	Nationally critical	RR	Endangered	Yes	×	×	Unlikely
New Zealand fur seal	*Arctocephalus forsteri*	Not threatened	Inc, SO	Least concern	No	-	✓ (many)	**Likely**
Pantropical spotted dolphin	*Stenella attenuata*	Vagrant	SO	Least concern	No	✓ (1)	×	Rare visitor

Common Name	Scientific Name	NZ Conservation Status (Baker et al., 2016)	Qualifier *	IUCN Conservation Status www.redlist.org (July 2017)	Species of Concern (DOC, 2013)	DOC Stranding database (No. of events near Operational Area**)	DOC Sightings database (No. of reports in Operational Area)	Presence in the Operational Area
Pygmy blue whale	*Balaenoptera musculus brevicauda*	Migrant	SO	Data deficient	Yes	✓ (3)	✓ (****)	**Likely *****
Pygmy killer whale	*Feresa attenuata*	Vagrant	DP, SO	Data deficient	Yes	×	×	Unlikely
Pygmy right whale	*Caperea marginata*	Data deficient	SO	Data deficient	Yes	✓ (19)	×	Possible
Pygmy sperm whale	*Kogia breviceps*	Not threatened	DP, SO	Data deficient	Yes	✓ (24)	×	**Likely**
Risso's dolphin	*Grampus griseus*	Vagrant	SO	Least concern	No	✓ (3)	×	Rare visitor
Ross seal	*Ommatophoca rossii*	Vagrant	SO	Least concern	No	×	×	Unlikely
Rough-toothed dolphin	*Steno bredanensis*	Vagrant	SO	Least concern	No	×	×	Unlikely
Sei whale	*Balaenoptera borealis*	Migrant	TO	Endangered	Yes	✓ (1)	×	Occasional visitor
Shepherd's beaked whale	*Tasmacetus shepherdi*	Data deficient	SO	Data deficient	Yes	✓ (6)	×	Possible
Short-finned pilot whale	*Globicephala macrorhynchus*	Migrant	SO	Data deficient	Yes	✓ (1)	×	Occasional visitor
Southern bottlenose whale	*Hyperoodon planifrons*	Data deficient	SO	Least concern	Yes	✓ (2)	×	Possible
Southern elephant seal	*Mirounga leonina*	Nationally critical	RR, SO	Least concern	No	×	✓ (1)	Rare visitor ***
Southern right whale	*Eubalaena australis*	Nationally vulnerable	RR, SO	Least concern	Yes	✓ (1)	✓ (1)	Possible ***
Southern right whale dolphin	*Lissodelphis peronii*	Not threatened	DP,SO	Data deficient	Yes	✓ (8)	×	Occasional visitor ***
Spade-toothed whale	*Mesoplodon traversii*	Data deficient	SO	Data deficient	No	×	×	Unlikely
Spectacled porpoise	*Phocoena dioptrica*	Data deficient	SO	Data deficient	No	✓ (1)	×	Possible
Sperm whale	*Physeter macrocephalus*	Not threatened	DP, TO	Vulnerable	Yes	✓ (40)	×	**Likely**
Strap-toothed whale	*Mesoplodon layardii*	Data deficient	SO	Data deficient	Yes	✓ (16)	×	Possible
Striped dolphin	*Stenella coeruleoalba*	Vagrant	SO	Least concern	No	✓ (3)	×	Possible ***
Subantarctic fur seal	*Arctocephalus tropicalis*	Vagrant	SO	Least concern	No	×	×	Unlikely
True's beaked whale	*Mesoplodon mirus*	Data deficient	SO	Data deficient	Yes	×	×	Unlikely
Weddell seal	*Leptonychotes weddellii*	Vagrant	SO	Least concern	No	×	×	Unlikely

** Qualifiers to the New Zealand Threat Classification System are as follows: Secure Overseas (SO), Threatened Overseas (TO), Data Poor (DP), Conservation Dependent (CD), Sparse (Sp), Range Restricted (RR), Increasing (Inc)*

*** Stranding data from the following locations was deemed to be 'near the Operational Area': North Taranaki, South Taranaki, Whanganui/Manawatu, Kapiti Coast, Outer Marlborough Sounds, Golden Bay, and Tasman Bay.*

**** Likelihood determination has been adjusted to take into consideration information in addition to the DOC Strandings and Sighting Databases.*

***** 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). In total 20 sighting records for Balaenoptera musculus spp. have occurred in the Operational Area. Based on the recent findings of Torres et al. (2017), it is likely that the majority of these sightings are of Balaenoptera musculus brevicauda (pygmy blue whales).*

Blue Whales

Two subspecies of blue whale may be present in New Zealand waters; the pygmy blue whale (*Balaenoptera musculus brevicauda*) and the Antarctic blue whale (*B. musculus intermedia*). Due to difficulties in distinguishing the two subspecies apart, they have generally been reported collectively as 'blue whales'.

Both visual and acoustic detections of these species have occurred throughout New Zealand waters (Olsen et al., 2013; Miller et al., 2014), with acoustic detection most common on the west coast of the North Island, and the east coast of the South Island. Blue whale vocalisations are low frequency (average of 0.01 – 0.110 kHz) (McDonald et al., 2001; Miller et al., 2014); although the amplitude of their calls can reach levels of up to 188 dB re 1ɥPa m^{-1} (Aroyan et al., 2000; Cummings & Thompson, 1971).

Research in the South Taranaki Bight since 2012 has identified a population of resident or semi-resident pygmy blue whales that are present throughout most of the year, and genetic analysis to date suggests that these individuals comprise a unique population (Torres et al., 2017). The South Taranaki Bight and Greater Cook Strait areas have been shown to have the most extensive zooplankton biomass of all of coastal New Zealand (Shirtcliffe et al. 1990) and data collected has identified this region as an important foraging ground for pygmy blue whales which primarily target the krill species *Nyctiphanes australis* as prey. The presence of large prey aggregations is important, as blue whale distribution and movements are typically driven by prey availability (De Vos et al. 2014). In the South Taranaki Bight, the absolute distribution of blue whales has been found to vary with oceanographic patterns that drive prey distribution; where Torres and Klinck (2016) noted that in El Nino conditions whales tend to be located west of the Bight, but they occur inside the Bight during more typical weather patterns. In February 2016 the first evidence of breeding behaviour in this region was documented with 1) a high density of mother/calf pairs being observed and 2) the first ever aerial footage of blue whale nursing behaviour being documented (Torres & Klinck 2016).

The IUCN Red List of Threatened Species currently lists the Antarctic blue whale (at the subspecies level) as "Critically Endangered" and the pygmy blue whale (at the subspecies level) as "Data Deficient"; however at the species level blue whales are listed as "Endangered". In contrast, the New Zealand Threat Classification System classifies blue whales as "Migrant" and therefore does not designate a threat status. Blue whales are however listed as a "Species of Concern" under the DOC Code of Conduct. In light of the new evidence for blue whale breeding behaviour in the South Taranaki Bight, it is possible that the New Zealand Threat Classification status for blue whales will change in the future. Despite their "Migrant" status, based on the recent findings from South Taranaki Bight, blue whales (particularly pygmy blue whales) are considered likely to occur in the Operational Area.

As would be expected from the information provided above, blue whales are routinely detected during seismic surveys in the South Taranaki Bight. A total of 20 sighting records for this species have occurred in the Operational Area. It is therefore likely that blue whales will be present during the Māui 4D Seismic Survey.

Minke Whales

There are two species of minke whale known to occur in New Zealand waters; the Antarctic minke (*Balaenoptera bonaerensis*) and the dwarf minke (*B. acutorostrata subsp.*). Minke whales have been observed around the New Zealand coast, but are reported to be most common south of New Zeland where they feed in Antarctic waters. The distribution of the Antarctic minke is restricted to the southern hemisphere where it is very abundant in Antarctic waters in summer. They are seen at lower latitudes in other seasons, although outside of the summer months their distribution is less well-known (Reilly et al., 2008). The dwarf minke occurs 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). Minke whales feed on krill, crustaceans and small fish that they dive for in foraging bouts that last up to 20 minutes. Minke whales produce complex calls that have a frequency range of 50 Hz – 9.4 kHz (DOSITS, 2017).

Sighting and stranding data from New Zealand indicate that the distribution of minke whales extends around the mainland and throughout New Zealand's subantarctic 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 the Antarctic summer feeding grounds.

DOC sighting records indicate minke whales occasionally utilise the Taranaki region, with observations recorded close to shore off Cape Egmont. Whilst compiling information for this MMIA, the stranding records from Taranaki, Whanganui/Manawatu, Kapiti Coast, the Outer Marlborough Sounds, Tasman Bay and Golden Bay were considered. In total 16 strandings (12 dwarf minkes and 4 Antarctic minkes) have occurred throughout these regions, with the highest numbers occurring in Golden Bay. Based on this information, it is considered that dwarf minke whales in particular are likely to be present in Operational Area.

Humpback Whales

Humpbacks have well-established migration routes between summer feeding grounds in Antarctic waters to winter breeding grounds in tropical waters (Jackson et al., 2014). During their migration, this species passes through New Zealand waters (Berkenbusch et al. 2013), whereby whales move northwards up the east coast of the South Island and through Cook Strait from May to August while others continue up the east coast of the North Island (Gibbs & Childerhouse, 2000). Less is known about the southward migration routes; but it appears that some whales travel down the west coast of New Zealand (Dawbin, 1956), while others travel well off the east coast of New Zealand from September to December (NZGeo.com, 2016). On their migrations, humpback whales can spend considerable time in coastal regions over the continental shelf (Jefferson et al., 2008).

Winter surveys of humpback whales in Cook Strait occurred from 2004 – 2015. The number of individuals recorded during these surveys ranged from 15 (in 2006) to 137 (in 2015) (DOC, 2015). Biopsy samples taken from the individuals seen in Cook Strait have been genetically matched to whales that have also been seen off Australia and New Caledonia.

While both male and female humpbacks vocalise for communication, male humpback whales are infamous for their long, loud, and complex 'songs' associated with breeding activities. These songs typically last from 10 to 20 minutes (American Cetacean Society, 2014) and tend to be between 0.03–8 kHz in frequency (Simmonds et al., 2004).

The majority of humpback sightings in the South Taranaki Bight occur between June and November, a period which corresponds with the migration period (Torres, 2012); however, summer sightings have been reported from other seismic surveys in the Taranaki Basin (D. Lundquist, pers. comm.). Only one sighting has been reported from the Operational Area; however, sightings to the north and south indicate that some humpbacks occasionally pass through the Operational Area (Torres, 2012). Stranded humpback whales are relatively common in the region, with six events listed in the stranding record for the vicinity of the Operational Area. It is possible that this species could be present in the Operational Area; however, most sightings are expected in winter months.

Bryde's Whales

A point of difference between this species and other baleen whales is that they do not migrate (Kato, 2002). Around New Zealand, Bryde's whales are mainly found in the waters of the North Island, where the Hauraki Gulf supports a sub-population of whales that have some level of interaction with a wider regional population (Baker et al., 2010). Systematic surveys for this species around New Zealand have been restricted to the Hauraki Gulf and the east coast of Northland, where the Hauraki Gulf is regarded as an important breeding area (Baker & Madon 2007; Wiseman et al., 2011). Opportunistic sighting data is available for other regions and confirms that Bryde's whales are occasionally sighted in offshore Taranaki waters (Torres, 2012). The latitudinal range of Bryde's whales extends from 40°N to 40°S (as summarised in Reikkola, 2013), and MPA and MPB lie just within this range.

Bryde's whales typically produce low frequency 'tonal' and 'swept' calls that are not dissimilar to other baleen whales. Virtually all calls analysed had a fundamental frequency below 60 Hz and were produced in extended sequences (Oleson et al., 2003).

Only two stranding events have been reported in the vicinity of the Operational Area; one in Manawatu at Foxton Beach and the other in North Taranaki at Mohakataino River Mouth. Sightings at sea are also rare; no sightings have been reported from the Operational Area, one sighting has been reported approximately 25 km to the west of OMV's Maari Well Head Platform, and two were reported northwest of Cape Farewell (Torres, 2012).

The South Taranaki Bight area is outside of the regional population concentration for Bryde's whales; although rare sightings do occur in very low numbers; hence this species could possibly be present in the Operational Area.

Fin Whales

Fin whales, like other baleen 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. The diet of fin whales is variable, but is dominated by krill in the southern hemisphere (Miyashita et al., 1995; Shirihai & Jarrett, 2006). Fin whale vocalisations have been described as short (<1 second) down-swept tones, ranging from 28 to 25 Hz at source levels of 189 +/-4dB re 1ɥPa m-1 (Širović et al., 2004).

Fin whales are not commonly observed in New Zealand coastal waters (Dawson, 1985) and have not been recorded in the Operational Area. Sightings of baleen whales are more common in deep offshore Taranaki waters, where, like blue whales they may take advantage of high densities of krill as a food source (Torres, 2012). Four stranding incidents have occurred in the vicinity of the Operational Area. This species may occasionally visit the Operational Area.

Sei Whales

Sei whales migrate to feed in subantarctic waters (45-60°S) during late summer (Miyashita et al., 1995) where their diet consists mostly of krill, copepods and small fish (Baker, 1999). The remainder of the year is spent in subtropical waters (Miyashita et al., 1995). This species prefers warmer water temperatures than other baleen whales, and are typically found in water temperatures between 8 and 18°C (Horwood, 2002). Sei whale vocalisations are characterised by low frequency 'downsweep' calls. On average these calls transition from 82 to 34 Hz over 1.4 seconds (Baumgartner et al., 2008).

Although there are no records of Sei whales stranding in the Taranaki region, one stranding event for this species was reported from Golden Bay in 2012. Summer sightings of this species have been made in the South Taranaki Bight (Torres, 2012), although none have specifically been reported from the Operational Area. It is therefore possible that sei whales could occasionally visit the Operational Area.

Southern Right Whales

Southern right whales are the only species of baleen whale known to breed in New Zealand waters where they utilise two winter breeding grounds; the Auckland Islands and mainland New Zealand; where Port Ross in the Auckland Islands is the principal calving area (Rayment et al., 2012). The coastal waters around mainland New Zealand represent a historic calving ground for this species, with recent evidence suggesting that a slow recolonization of this range is currently occurring following the cessation of historic whaling (Patenaude, 2003; Carroll et al., 2011).

Summer months for this species are usually spent in latitudes 40 – 50°S (Oshumi & Kasamatsu, 1986) where they feed on dense aggregations of copepods and euphausiids (Tormosov et al., 1998; Rowantree et al., 2008). These whales produce a range of different vocalisations. In New Zealand waters, a majority of 'upcalls' are recorded and on average vocalisations have frequencies of below 1 kHz (Webster & Dawson, 2011).

Pre-exploitation abundance of southern right whales around New Zealand was estimated to have been between 28,800 and 47,100 individuals (Jackson et al., 2016); however, at the end of the whaling era only 30–40 mature females were thought to remain (Jackson et al., 2016). Whale numbers around New Zealand are currently thought to represent approximately 12% of pre-exploitation abundance (Jackson et al., 2016).

Southern right whales are seasonally present in sheltered coastal waters around mainland New Zealand. The majority of southern right whale sightings around the New Zealand mainland occur in winter (60%) and spring (22%) with nearly all sightings occurring close to the coast (Patenaude, 2003). Although inshore winter sightings represent the majority of sightings records for this species, it is possible that individuals will occasionally move through the offshore Operational Area outside of the winter months. Indeed, a southern right whale sighting was made from MPA in the Operational Area during October 2003.

The DOC stranding database contains a single record for this species in the vicinity of the Operational Area. Based on this sighting and stranding information, it is possible that southern right whales could be present in the Operational Area during the Māui 4D Seismic Survey.

Pygmy Right Whales

The majority of knowledge of this species is from stranded specimens as sightings at sea are rare (Reilly et al., 2008a). Pygmy right whales are the smallest of the baleen whales (Baker, 1999) with a diet consisting largely of copepods (Reilly et al., 2008a) and euphausiids (Kemper, 2002). In New Zealand, sightings typically occur near Stewart Island and Cook Strait (Kemper, 2002). In 2001 a group of 14 pygmy right whales was seen at 46°S southeast of New Zealand (Matsuoka et al*.,* 2005). Kemper et al (2013) suggests an association between pygmy right whales and areas of high marine productivity.

Acoustic recordings of a juvenile pygmy right whale from Australia documented at least one type of call: a short thump-like pulse with a down-sweep in frequency and decaying amplitude (Dawbin & Cato, 1992).

Pygmy right whales are well represented in the stranding record, with 16 stranding events from the vicinity of the Operational Area, but no live sightings have been reported. This information suggests that pygmy right whales could possibly be present in the Operational Area.

Sperm Whales

Sperm whales have a wide distribution, and are usually found in open ocean waters deeper than 1,000 m. Sperm whales forage primarily for squid, and dives can last over an hour (Evans & Hindell, 2004; Gaskin & Cawthorn, 1967; Gomez-Villota, 2007) and reach depths of up to 3,000 m. This species is reliant on echolocation to locate prey and to navigate, although echolocation clicks are also produced as a means of communication, to identify members of a group and to coordinate foraging activities (Andre & Kamminga, 2000). Clicks are varied in frequency, ranging from low-frequency clicks (0.1 kHz) to high-frequency clicks (up to 30 kHz) (Simmonds et al., 2004).

The Kaikoura region which is home to a small number of resident male sperm whales that feed in the submarine canyons (Arnold, 2004). Groups of females have occasionally been seen off Kaikoura (two observations in ten years of study; Richter et al., 2003); however, male sperm whales are present year round within a few kilometres of the shore (Jaquet et al., 2000).

Torres (2012) reported that sperm whale sightings in the South Taranaki Bight typically occurred in deep offshore water and were limited to summer months. It is noted that recent summer sightings of this species have been reported from other seismic surveys in the Taranaki Basin (D. Lundquist pers. comm.). Although no sighting records have been made in the Operational Area, 40 sperm whale strandings are reported in the vicinity, the majority of these occurring in Golden Bay, Taranaki and on the Kapiti Coast. Hence, sperm whales are likely to be present in the Operational Area.

Pygmy Sperm Whales

Pygmy sperm whales are difficult to observe at sea on account of their small size, timid behaviour, lack of a visible blow, and their low profile in the water. Little is known of the acoustics of this species; however, data collected from live stranded animals has indicated that the species emits click trains between 60 kHz and 200 kHz (Marten, 2000).

Twenty four pygmy sperm whales have stranded in the vicinity of the Operational Area, mostly along the Kapiti, Manawatu/Whanganui and South Taranaki coasts. These stranding incidents indicate that this species is likely to be present in the Operational Area.

Pilot Whales

Two species of pilot whale occur in New Zealand waters; the long-finned pilot whale and the short-finned pilot whale. Although the two species are loosely separated by water temperature preferences; short-finned pilot whales prefer warm temperate and tropical waters, while long-finned pilot whales are typically found in colder temperate waters (Olson, 2009, as cited in Berkenbusch et al. 2013), they are difficult to distinguish at sea therefore most sighting information does not differentiate between species. Pilot whales often travel in large groups of over 100 individuals and, in New Zealand, feed on cephalopods; usually arrow squid and common octopus (Beatson et al., 2007)

Five sightings of pilot whales have been made from the Operational Area, one of which reported a group of approximately 100 individuals. Torres (2012) reported that sightings of pilot whales within the South Taranaki Bight were more frequent during summer months.

In New Zealand, this species has a high stranding rate, with strandings generally peaking in spring and summer months (O'Callaghan et al., 2001). Farewell Spit, to the southwest of the Operational Area, is a recognised hotspot for mass pilot whale stranding incidents. From 1937 to 2017 at least 30 mass stranding events occurred at Farewell Spit; with up to 416 individuals being involved in any one event. Long-finned pilot whales accounted for virtually all of these stranding events with only one short-finned pilot whale mass stranding recorded.

Long-finned pilot whales have been detected during seismic surveys in the South Taranaki Bight in the past, and have accounted for a number of shut-downs (Childerhouse et al., 2015). Occassional sightings of short-finned pilot whales have also been made during recent seismic surveys (D. Lundquist, pers. comm.). t is therefore likely that pilot whales will be detected during the Māui 4D Seismic Survey. Based on their preference for colder waters and the evidence from the stranding record, long-finned pilot whales are commonly present, but short-finned pilot whales may also be seen.

Killer Whales

Although killer whales are widespread globally, it is recognised that this species is in need of a taxonomic review as evidence suggests there are several morphological forms: Types A – D (Baker et al. 2010). The majority of killer whale sightings in New Zealand coastal waters are believed to be Type A, with Types B – D occurring mostly in Antarctic waters. Type A killer whales have been seen in all coastal regions of New Zealand, including the South Taranaki Bight (Visser, 2000). Although it has been suggested that killer whales are more likely to be present within the region from November through to February (Visser, 2000), Torres (2012) reported that sightings are relatively evenly distributed throughout the year. In 1997, the population size of Type A killer whales in New Zealand was estimated by photo identification techniques at 115 individuals (95% CI 65–167) (Visser, 2000). Around New Zealand small groups of killer whales are typical. They travel an average of 100 – 150 km per day, and most are opportunistic foragers (Visser, 2000).

Echolocation characteristics vary between groups of whales, and are thought to reflect preferences for target prey species (Barrett-Lennard et al., 1996). Echolocation whistles have an average dominant frequency of 8.3 kHz (Thomsen et al., 2001), but variations have been documented between groups (Deecke et al., 2000).

One sighting of this species has been reported from the Operational Area. This sighting, which was made from MPB, comprised 25 individuals (including at least one calf) accompanied by over 50 common dolphins. Sightings elsewhere in the Taranaki region and the wide ranging and highly mobile nature of this species, indicates that killer whales are likely to pass through the Operational Area on a reasonably frequent basis. Three strandings have been reported from around the Operational Area, one from Golden Bay, one from the Kapiti Coast and one from North Taranaki.

False Killer Whales

False killer whales are commonly observed in deep, warm/temperate oceanic waters (Dawson, 1985). Little is known of this species in New Zealand, but false killer whales have been reported to make close associations with bottlenose dolphins in shallow waters off north-eastern New Zealand (Zaeschmaer et al., 2013). This presence in shallow waters seems to coincide with the seasonal influx of warm oceanic waters between December and May (Zaeschmaer et al., 2013). False killer whales prey primarily on fish and cephalopods in dives of up to 500 m (Shirihai & Jarrett, 2006).

The DOC stranding database reports two strandings of this species near the Operational Area; one each in South Taranaki and one in Whanganui/Manawatu. The sighting database holds a single record of this species inside the Operational Area, where a group of seven individuals were observed. This species is likely to be present in the Operational Area, particularly over the summer months when sea surface temperatures are warmer.

Beaked Whales

Eleven species of beaked whales are known from New Zealand waters of which eight are represented in the stranding record in the vicinity of the Operational Area. These eight species are described in **Table 13**. Beaked whales are typically associated with deep offshore water and are generally elusive at sea so few live sightings have been made. However, a pair of Cuvier's beaked whales has been sighted near MPB within the Operational Area.

Beaked whales are mostly found in small groups in cool, temperate waters with a preference for pelagic deep ocean waters or continental slope habitats at depths down to 3,000 m (Baker, 1999). They are deep divers and feed predominately on deep-water squid and fish species. Of all the beaked whale strandings in the vicinity of the Operational Area, the majority are Gray's beaked whales (38%). For this reason it is believed that the South Taranaki Bight may provide an important habitat for this species in particular.

In general, beaked whales are considered to have an occasional presence in the Operational Area; however, Gray's beaked whales and Cuvier's beaked whales are likely to be present.

Table 13 Beaked Whale Ecology of Relevance to the Operational Area

Species	No. of stranding events near Operational Area	Ecology
Arnoux's beaked whale *(Berardius arnuxii)*	South Taranaki x 1 Whanganui/Manawatu x 4 Kapiti Coast x 4 Marlborough Sounds x 1 **TOTAL = 10**	Circumpolar distribution in deep, cold temperate and subpolar waters. Considered to be naturally rare throughout its range; however, higher densities may occur seasonally in Cook Strait (Taylor et al., 2008). New Zealand has the highest number of strandings recorded for this species (Jefferson et al., 1993).
Andrew's beaked whale *(Mesoplodon bowdoini)*	North Taranaki x 1 South Taranaki x 1 Whanganui/Manawatu x 1 Golden Bay x 1 **TOTAL = 4**	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., 2008a).
Gingko-toothed whale *(Mesoplodon ginkgodens)*	North Taranaki x 1 Tasman Bay x 1 Golden Bay x 1 **TOTAL = 3**	Most stranding and capture records for this species are from the tropical and warm temperate waters of the Indo-Pacific (esp. Japan). Only a few records from New Zealand. Biology unknown (Taylor et al., 2008b).
Gray's beaked whale *(Mesoplodon grayi)*	North Taranaki x 3 South Taranaki x 7 Whanganui/Manawatu x 8 Kapiti Coast x 6 Marlborough Sounds x 1 Tasman Bay x 11 Golden Bay x 4 **TOTAL = 40**	Southern hemisphere species with a circumpolar distribution south of 30°. Many sightings from Antarctic and subantarctic waters. Many strandings from coastline of New Zealand implying they may be fairly common here. Occurs in deep waters beyond the shelf edge (Taylor et al., 2008c). Acoustic recordings of this species have recently been made in Cook Strait (Goetz, 2017).
Strap-toothed whale *(Mesoplodon layardii)*	North Taranaki x 2 South Taranaki x 3 Whanganui/Manawatu x 2 Kapiti Coast x 3 Tasman Bay x 1 Golden Bay x 5 **TOTAL = 16**	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., 2008d). Feed on squid (Sekiguchi et al., 1996). Acoustic recordings of this species have recently been made in Cook Strait (Goetz, 2017).
Southern bottlenose whale *(Hyperoodon planifrons)*	Whanganui/Manawatu x 1 Golden Bay x 1 **TOTAL = 2**	Circumpolar distribution in southern hemisphere, south of 30°. Common in Antarctic waters in summer. Typically occurs over submarine canyons in waters deeper than 1,000 m (Taylor et al., 2008e).
Shepherd's beaked whale *(Tasmacetus shepherdi)*	North Taranaki x 2 South Taranaki x 2 Whanganui/Manawatu x 1 Tasman Bay x 1 **TOTAL = 6**	A circumpolar distribution in cold temperate waters is presumed. All strandings have occurred south of 30°, 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., 2008f).
Cuvier's beaked whale *(Ziphius cavirostris)*	North Taranaki x 3 South Taranaki x 3 Whanganui/Manawatu x 8 Kapiti Coast x 5 Tasman Bay x 4 Golden Bay x 1 **TOTAL = 24**	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., 2008g). Genetic studies suggest little movement of individuals between ocean basins (Dalebout et al., 2005). Acoustic recordings of this species have recently been made in Cook Strait (Goetz, 2017).

Bottlenose Dolphins

Bottlenose dolphins are widely distributed throughout the world in cold temperate and tropical seas, with New Zealand representing their southernmost range. Three genetically distinct ‘in-shore’ populations of bottlenose dolphins are recognised in New Zealand as:

- 450 individuals that occur off the northeast coast of Northland (Baker et al, 2010);
- 60 individuals that occur in Fiordland (Baker et al, 2010);
- An unquantified population that occurs in the coastal waters between the Marlborough Sounds and the West Coast (Baker et al, 2010); and
- 92 individuals that form a wide-ranging southern population around Otago and Stewart Island (Brough et al., 2015).

In addition to the inshore populations, bottlenose dolphin sightings are common in offshore waters. Offshore sightings are typically of larger groups than inshore sightings (Torres, 2012). The ‘offshore’ population is thought to number at least 163 individuals which range right around New Zealand (Zaeschmar et al., 2013).

Bottlenose dolphins feed on fish, krill and crustaceans (Shirihai & Jarrett, 2006). 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).

A total of 17 strandings of this species have been recorded near the Operational Area, the majority of which occurred in Tasman Bay.

While no sightings records exist for bottlenose dolphins in the DOC sighting database for the Operational Area, Torres (2012) documented two sightings of offshore bottlenose dolphins in the South Taranaki Bight; these sightings both involved groups of more than 50 individuals with one group observed only 10 km off Cape Egmont (Torres, 2012). These records suggest that offshore bottlenose dolphins are likely to have some presence within the Operational Area; however, this area does not appear to be of particular ecological importance to this species.

Common Dolphins

The common dolphin has a wide cosmopolitan distribution and is known to occur in all regions of New Zealand (Berkenbusch et al. 2013). Total abundance of the New Zealand population is unknown; however, it is likely that numbers are relatively high. Common dolphins often form large groups that include thousands of individuals and occur in water depths ranging from 6 – 141 m (Constantine & Baker, 1997). The primary prey species of common dolphins in New Zealand are jack mackerel, anchovy and arrow squid (Meynier et al., 2008).

Petrella et al. (2012) determined the whistle characteristics of common dolphins in the Hauraki Gulf, indicating that the average frequency and length of whistles are 10 – 14 kHz and 0.27 seconds, respectively.

Torres (2012) reported that the common dolphin is the cetacean species most frequently encountered in the South Taranaki Bight, with sightings recorded in all months of the year. Sightings of common dolphins in the South Taranaki Bight are typically in water depths between 0 and 100 m; however, this species has also been observed in deeper waters (Torres, 2012). In some locations a degree of off-shore/on-shore movement may occur based on prey distribution and availability (Neumann, 2011; Meynier et al., 2008).

This species is common around the Taranaki coastline and it is likely to be observed within the Operational Area during the Māui 4D Seismic Survey. As common dolphins are not listed as Species of Concern in the Code of Conduct, no shutdown requirements apply, although delayed starts are required if present within 200 m of the acoustic source during pre-start observations. Past seismic surveys in the Taranaki Basin have commonly detected this species, and delayed starts have resulted on a number of occasions (Childerhouse et al., 2015).

The DOC stranding database includes 68 records of common dolphin strandings from the vicinity of the Operational Area. These strandings seem to be fairly well spread along the coastlines; 21 in Golden Bay, 14 in Tasman Bay, one in the outer sounds, three on the Kapiti Coast, seven in Whanganui/Manawatu, and 22 in Taranaki. Two sightings records of common dolphins have been reported for the Operational Area, including one group containing an estimated 50 individuals.

Dusky Dolphins

Dusky dolphins are primarily a coastal dolphin found in water depths less than 2,000 m. They prefer cool, upwelling waters and are more commonly seen around the South Island and lower North Island (Wursig et al. 2007). Dusky dolphins are present in New Zealand waters year round (Berkenbusch et al. 2013); however, evidence suggests that they spend more time in offshore waters during the winter months (Wursig 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 (Wursig et al., 2007).

There is a seasonally resident population of dusky dolphins in Admiralty Bay (in the Marlborough Sounds) from April to July (Wursig et al., 2007). There is also a substantial population in the Kaikoura region, which has been estimated at 12,000 individuals, with approximately 2,000 individuals present at any one time (Markowitz et al., 2004). This species feeds on a range of pelagic and benthic prey; typically foraging in relatively shallow waters (less than 130 m deep) (Hammond et al., 2008).

Although no dusky dolphin sightings have been reported specifically from the Operational Area, Torres (2012) found that small numbers of dusky dolphins are seen in Taranaki waters throughout the year. Forty one strandings have occurred in the vicinity, with the majority (21) occurring in Tasman Bay. Although dusky dolphins are likely to occur in the Operational Area, the density of this species is clearly expected to be higher to the south of Taranaki.

Hector's Dolphins

There are two subspecies of endemic Hector's dolphins; the South Island Hector's dolphin (*Cephalorhynchus hectori hectori*) and the Māui dolphin (*C. hectori maui*). Although morphologically and genetically distinct (Baker et al., 2002), the two subspecies cannot be readily differentiated by visual observations. Interpretation of sighting records can therefore become confused as in most circumstances genetic verification (the most reliable way to distinguish between the two subspecies) is not possible. There is no evidence to suggest the ecology is substantially different between the subspecies (Torres, 2012). Over the last 40 years numbers of both subspecies have declined significantly, largely on account of bycatch in coastal fisheries (Currey et al., 2012) and both subspecies are considered to be threatened; South Island Hector's dolphins are classified as 'endangered' and Māui dolphins as 'critically endangered'. The diet of both subspecies consists of small fish and crustaceans that are pursued during shallow foraging dives, where echolocation (with frequencies around 129 kHz) is used during foraging dives to locate prey (Kyhn et al., 2009).

Two geographically and genetically distinct sub-populations of South Island Hector's dolphins are of relevance to the Operational Area; the east coast South Island sub-population extends from Farewell Spit to Nugget Point and is estimated to be comprised of 8,968 individuals (Mackenzie & Clement, 2016), and the west coast South Island sub-population extends from Milford Sound to Farewell Spit and numbers 5,490 individuals (MacKenzie & Clement, 2016). In the top of the South Island, the main concentration of dolphins is found in Clifford and Cloudy Bays. Hector's dolphins are also occasionally observed in Tasman and Golden Bays; however, it is unknown which sub-population these individuals belong to.

Although the South Island Hector's dolphin is typically found in South Island coastal waters, occasional sightings of what are presumed to be South Island Hector's dolphins occur around the lower North Island (i.e. Wellington Harbour, Kapiti Coast; DOC, 2011) and in two instances South Island Hector's dolphins have been genetically identified off Raglan and South Manukau (Hamner et al. 2012), areas which overlap with the distribution of Māui dolphins. It has been hypothesised that South Island Hector's dolphins could use shallow waters in the South Taranaki Bight whilst moving between islands (Hamner et al., 2013).

Māui dolphins occur strictly on the west coast of the North Island with the population concentration occurring between Manukau Harbour and Port Waikato (Slooten et al., 2005). Their total distribution extends from Maunganui Bluff to Whanganui (**Figure 19**). The most recent population estimate for Maui's dolphins is 63 individuals aged one year and over (95% CI = 57–75) (Baker et al., 2016a). Maui's dolphins are thought to occur in very low densities in Taranaki waters (Currey et al., 2012); however, the capture of a Maui's or Hector's dolphin in a commercial set net off Cape Egmont in January 2012 confirms their presence here (DOC 2017).

The majority of sightings of Māui dolphins occur in water depths less than 20 m and within 4 Nm of the coast (Du Fresne, 2010); however, sightings during research surveys have occurred out to 12 Nm offshore (DOC, 2017). Occasional offshore sightings (out to 24 Nm) have been made from Taranaki oil platforms. McConnell (2015) summarises these sightings as follows:

- Two separate sightings of solitary animals have been made from MPA since 2000;
- One sighting of ten dolphins was made from MPB in 2001; and
- A solitary dolphin was observed from a drilling rig stationed at Manaia-2 in 2013

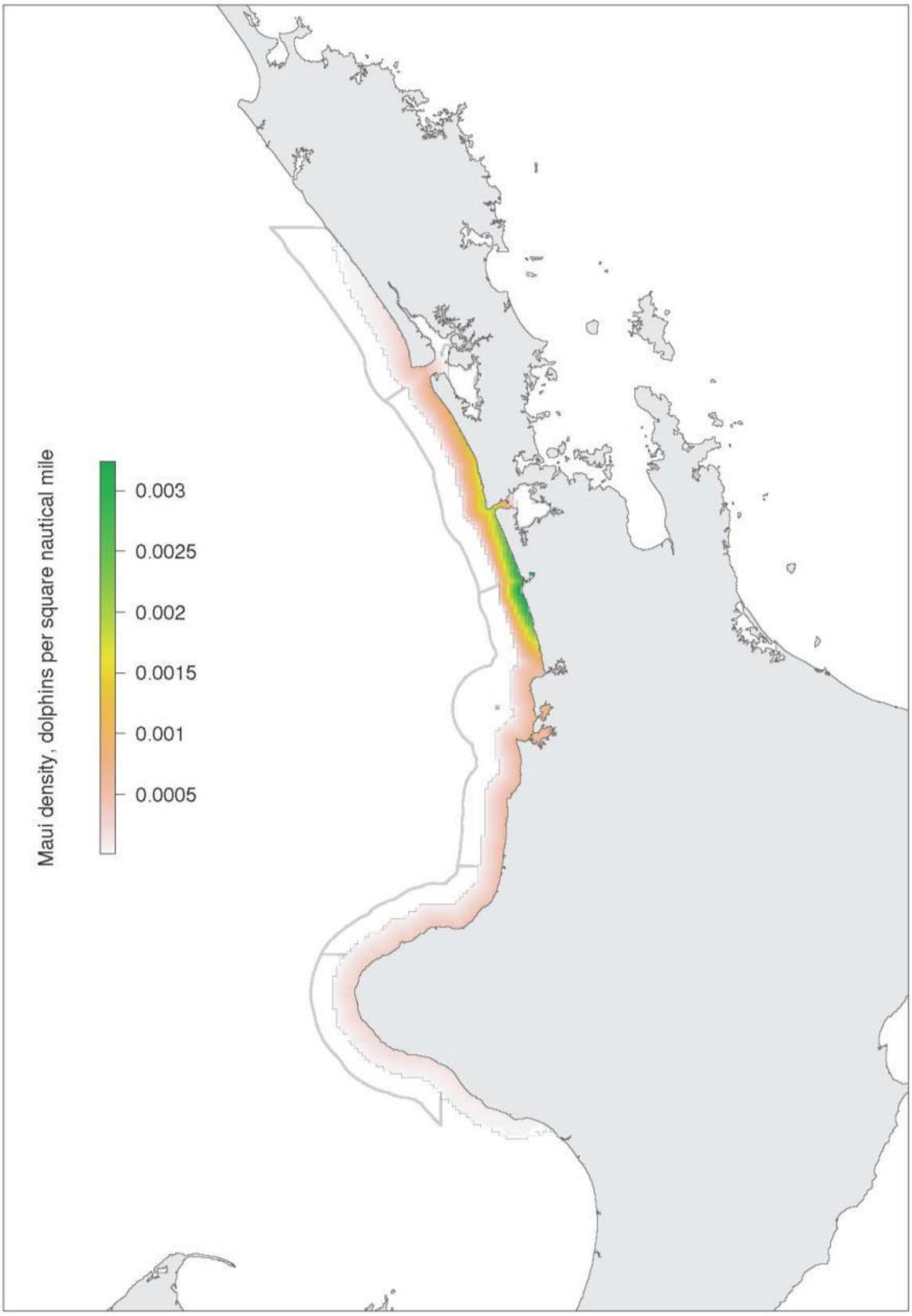
The frequency of offshore sightings tends to increase in winter, suggesting a slight seasonal shift in habitat preference (Slooten et al., 2006; Du Fresne, 2010). Despite occasional offshore sightings, both Māui and South Island Hector's dolphins appear to prefer water depths of 1 – 100 m (Du Fresne, 2010).

The West Coast North Island Marine Mammal Sanctuary covers 2,164 km of coastline and was established to protect the Māui dolphin (**Figure 20**). The Government has recently extended the set net fishing ban off the coast of Taranaki to further reduce pressures on this subspecies.

Although the absolute distribution of the Māui dolphin and South Island Hector's dolphin is unclear, data does not suggest that either sub-species is consistently present in the Operational Area, rather that both subspecies are sporadic visitors to the area (Māui dolphins more so than South Island Hector's dolphin), and that they typically occur in shallower coastal waters. The likelihood of encountering this threatened species is reduced by the offshore nature of the survey. However, the potential for spatial overlap increases where the Operational Area approaches the coast.

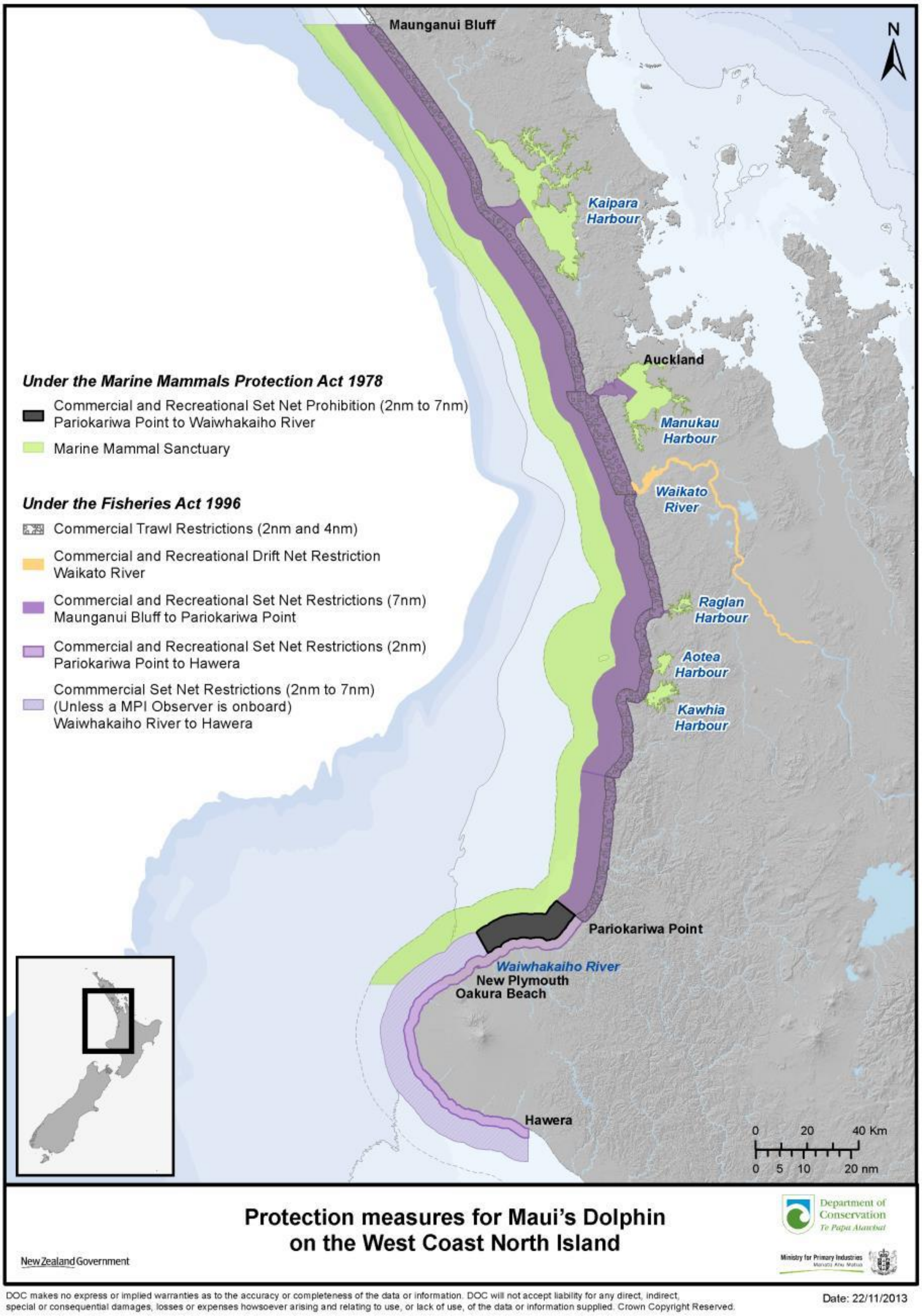
Special protocols will be implemented during the Māui 4D Seismic Survey to facilitate immediate reporting of either subspecies to DOC Taranaki in the event that they are encountered (see **Appendix D**).

Figure 19: Māui dolphin density



(Source: Currey et al. 2012: Based on nine aerial and genetic surveys conducted between 2000 and 2012)

Figure 20: Māui dolphin protection measures



(Source: www.doc.govt.nz)

Southern Right Whale Dolphins

Relative to other species little is known about southern right whale dolphins. This species typically occurs in cool, deep, offshore temperate and subantarctic waters between 30 and 65°S, where it is likely that the range is circumpolar (Hammond et al., 2012). Despite no abundance estimates being available, southern right whale dolphins are thought to be relatively common throughout their range (Jefferson et al., 1994). No information is available on the acoustic repertoire of this species; however, it presumably uses echolocation to navigate and locate food.

Whilst seldom being observed at sea, these dolphins are known to travel in large groups of up to 1,000 individuals (Baker, 1999). No live sightings of this species have occurred within the Operational Area; however, eight strandings have occurred in the vicinity. All of these stranding incidents occurred on the northern coast of the South Island (Golden Bay x 6, Tasman Bay x 1 and Outer Marlborough Sounds x 1). Based on this information, it is possible that this species may occasionally visit the Operational Area.

New Zealand Fur Seals

The New Zealand fur seal is the most common seal in New Zealand waters. This species has a wide distribution around mainland New Zealand and its offshore islands, and are also naturally present along the coasts of South Australia, Victoria and Tasmania. Breeding colonies on mainland New Zealand are mostly located in the South Island. Subsistence hunting and commercial sealing drastically reduced the population size of this species (estimated pre-human population of 3,000,000) to an estimated 100-200 breeding individuals at the peak of commercial harvest (Emami-Khoyi et al., 2017). Since the cessation of commercial sealing in 1894, this species has recolonised its historic range, with an increase in population size and an expansion northwards of its breeding distribution (Lalas & Bradshaw, 2001). A reliable total abundance estimate is not available for this species, but estimates in the vicinity of 100,000 individuals have been suggested (Harcourt, 2001).

New Zealand fur seals feed on fish (e.g. lantern fish, hoki, barracouta, ahuru and jack mackerel) and cephalopods (arrow squid and octopus) (as summarised by Baird, 2011), and are known to dive for up to 12 minutes (to depths of ~ 200 m) (Mattlin et al., 1998). Foraging habitats vary with season whereby both inshore and deeper offshore foraging habitat is used throughout the year (Harcourt et al., 2002; Mattlin et al., 1998).

New Zealand fur seals are present year round in offshore Taranaki waters where they have a continual presence at the offshore oil and gas production platforms. Fur seals are consistently observed around MPA and MPB, they rest on the jacket structure of MPA, and although no resting structures are present at MPB, here they are consistently present in the water under or around the platform legs (McConnell, 2015) These platforms act as artificial reefs and attract large schools of fish, which in turn attract seals. New Zealand fur seals will be consistently present in the Operational Area.

The closest New Zealand fur seal breeding location to the Operational Area is at the Sugar Loaf Island Marine Protected Area. The breeding season is from mid-November to mid-January (Crawley & Wilson, 1976). At the breeding colonies adult males arrive first from late October followed by females in late November. Pups are generally born in January and weaned in July - August when females return to sea (Baird, 2011). Pups are suckled for approximately 300 days and during this time adult females alternate between foraging at sea and returning to shore to feed their pup (Boren, 2005).

4.3.6 Seabirds

Due to the diversity of seabirds in New Zealand waters, New Zealand is often considered to be the seabird capital of the world. There are 96 species of seabird found in the marine waters off New Zealand, of which one third are endemic (DOC, 2017d). New Zealand seabirds include albatrosses, cormorants and shags, fulmars, petrels, prions, shearwaters, terns, gulls, penguins, and skuas (DOC, 2017d). The greatest variety of albatrosses and petrels in the world are found within New Zealand waters, with New Zealand considered as an important breeding ground.

Although the importance of the Operational Area (and, in general, the Taranaki Bight) to seabirds is largely unknown, the surrounding regions are visited by a large diversity of seabirds that either pass through (e.g. during migrations or foraging trips) or use the area as a more permanent breeding and roosting locations (Thompson, 2015). Many of the species present have primarily coastal distributions, such a penguins, shags, gulls, and terns; however, other pelagic species such as albatrosses, shearwaters, and petrels are restricted to offshore waters. Within the 'coastal' species, some individuals will also use offshore areas.

Information on pelagic seabirds within the Taranaki area was obtained from NABIS, Scofield and Stephenson (2013), Robertson et al. (2017), Thompson (2015), and New Zealand Birds Online (2017). Note that strictly coastal species have not been listed here on account of the Operational Area being offshore with no coastal impacts predicted. A list of the species identified as potentially present within the Operational Area are provided in **Table 14**, alongside their threat status and information on breeding season. Some species might only be present as individuals, while others could be present in flocks of thousands (e.g. fairy prions). An estimation of population numbers has not been attempted.

A number of species have been identified by Taranaki Regional Council as being 'regionally significant for their coastal indigenous biodiversity values' (Taranaki Regional Council, 2016). These species have been identified within **Table 14** by an asterisk. Caspian terns, grey-faced petrels, and black-fronted terns have been further identified by Taranaki Regional Council as 'regionally distinctive' (Taranaki Regional Council, 2016).

Table 14 Seabird Species Potentially Present in the Operational Area

Common Name	Scientific Name	Breeding season	Breeds Near Operation Area	IUCN Status www.redlist.org	NZ Threat Status Robertson et al., 2017
Antipodean Albatross*	*Diomedea antipodensis antipodensis*	Eggs laid Jan/Feb	×	Not assessed	Nationally Critical
Back-billed gull	*Larus bulleri*	Aug – Mar	×	Endangered	Nationally Critical
Fairy tern	*Sternula nereis*	Oct – Feb	×	Vulnerable	Nationally Critical
Gibson's albatross	*Diomedea antipodensis gibsoni*	All year	×	Not assessed	Nationally Critical
Salvin's mollymawk	*Thalassarche salvini*	Sep – Apr	×	Vulnerable	Nationally Critical
Black-fronted tern*	*Chlidonias albostriatus*	Oct – Jan	×	Endangered	Nationally Endangered
Black petrel*	*Procellaria parkinsoni*	Oct – Jul	×	Vulnerable	Nationally Vulnerable
Caspian tern*	*Hydroprogne caspia*	Sep – Jan	✓	Least Concern	Nationally Vulnerable
Flesh-footed shearwater*	*Puffinus carneipes*	Sep – May	×	Least Concern	Nationally Vulnerable

Grey-headed albatross*	*Thalassarche chrysostoma*	Sep – May	✗	Endangered	Nationally Vulnerable
Pied shag*	*Phalacrocorax varius varius*	All year	Possible	Not assessed	Nationally Vulnerable
Red billed gull*	*Larus novaehollandiae scopulinus*	Sep – Jan	Possible	Least Concern	Nationally Vulnerable
Hutton's shearwater	*Puffinus huttoni*	Oct – Mar	✗	Endangered	Nationally Vulnerable
Little/Blue penguin*	*Edyptula minor*	Jul – Feb	✓	Least Concern	Declining
Sooty shearwater*	*Puffinus griseus*	Nov – May	✓	Near Threatened	Declining
White-capped mollymawk	*Thalassarche cauta*	Nov – Aug	✗	Not assessed	Declining
White-chinned petrel	*Procellaria aequinoctialis*	Nov – May	✗	Vulnerable	Declining
White-fronted tern*	*Sterna striata striata*	Oct – Jan	✓	Least Concern	Declining
Little shearwater	*Puffinus assimilis*	Apr – Nov	✗	Vulnerable	Recovering
Sooty tern*	*Onychoprion fuscata serratus*	Oct - Dec	✗	Least Concern	Recovering
Broad-billed prion*	*Pachyptila vittata*	Aug – Jan	✗	Least Concern	Relict
Cook's petrel	*Pterodroma cookii*	Sep - Apr	✗	Vulnerable	Relict
Fairy prion*	*Pachyptila turtur*	Oct – Feb	✓	Least Concern	Relict
Fluttering shearwater*	*Puffinus gavia*	Aug – Jan	✗	Least Concern	Relict
Grey-backed storm petrel	*Garrodia nereis*	Sep – Apr	✗	Least Concern	Relict
Mottled petrel	*Pterodroma inexpectata*	Dec – May	✗	Near Threatened	Relict
Northern diving petrel*	*Pelecanoides urinatrix urinatrix*	Aug – Dec	✗	Not assessed	Relict
Wedge-tailed shearwater	*Puffinus pacificus*	Oct – May	✗	Least Concern	Relict
White-faced storm petrel*	*Pelagodroma marina*	Oct – Apr	Possible	Least Concern	Relict
Antarctic Prion*	*Pachyptila desolata*	Dec – Apr	✗	Least Concern	Naturally Uncommon
Black shag*	*Phalacrocorax carbo*	All year	✓	Least Concern	Naturally Uncommon
Brown skua	*Catharacta anterctica lonnbergi*	Sep – Feb	✗	Least Concern	Naturally Uncommon
Buller's mollymawk	*Thalassarche bulleri*	Oct – Jun	✗	Not assessed	Naturally Uncommon
Buller's shearwater*	*Puffinus bulleri*	Sep – May	✗	Vulnerable	Naturally Uncommon
Campbell black-browed mollymawk	*Thalassarche impavida*	Aug – May	✗	Vulnerable	Naturally Uncommon

Fulmar prion	*Pachyptila crassirostris*	Oct – Feb	×	Least Concern	Naturally Uncommon
Grey petrel	*Procellaria cinerea*	Apr – Nov	×	Near Threatened	Naturally Uncommon
Little black shag*	*Phalacrocorax sulcirostris*	Oct – Dec	✓	Least Concern	Naturally Uncommon
Northern giant petrel*	*Macronectes halli*	Aug – Feb	×	Least Concern	Naturally Uncommon
Northern royal albatross*	*Diomedea sandfordi*	Eggs laid Oct/Nov	×	Endangered	Naturally Uncommon
Southern royal albatross*	*Diomedea epomophora*	Eggs laid Nov/Dec	×	Vulnerable	Naturally Uncommon
Westland petrel	*Procellaria westlandica*	Mar - Dec	×	Vulnerable	Naturally Uncommon
Arctic skua	*Stercorarius parasiticus*	Does not breed in NZ		Least Concern	Migrant
Arctic tern	*Sterna paradisaea*	Does not breed in NZ		Least Concern	Migrant
Blue petrel	*Halobaena caerulea*	Does not breed in NZ		Least Concern	Migrant
Cape pigeon/petrel	*Daption capense*	Nov – Feb	Possible	Least Concern	Migrant
Little tern	*Sternula albifrons*	Does not breed in NZ		Least Concern	Migrant
Medium-billed prion	*Pachyptila salvini*	Does not breed in NZ		Least Concern	Migrant
Short-tailed shearwater	*Puffinus tenuirostris*	Does not breed in NZ		Least Concern	Migrant
Southern giant petrel	*Macronectes giganteus*	Does not breed in NZ		Least Concern	Migrant
Thin-billed prion	*Pachyptila belcheri*	Does not breed in NZ		Least Concern	Migrant
Wandering/snowy albatross	*Diomedea exulans*	Does not breed in NZ		Vulnerable	Migrant
Wilson's storm petrel	*Oceanites oceanicus*	Does not breed in NZ		Least Concern	Migrant
White winged black tern	*Childonias leucopterus*	Does not breed in NZ		Least Concern	Migrant
Little pied shag	*Phalacrocorax melanoleucos melanoleucos*	Aug – Mar	Possible	Least Concern	Vagrant
Black browed mollymawk	*Thalassarche melanophys*	Sep – May	×	Near Threatened	Coloniser
Indian ocean yellow-nosed mollymawk	*Thalassarche carteri*	Eggs laid Sep/Oct	×	Endangered	Coloniser
Australasian gannet	*Morus serrator*	Aug – Mar	✓	Least Concern	Not Threatened
Grey faced petrel*	*Pterodroma macroptera gouldi*	Mar – Jan	✓	Least Concern	Not Threatened
Little shag	*Phalacrocorax melanoleucos brevirostris*	Aug – Mar	✓	Not assessed	Not Threatened
Southern black-backed gull	*Larus dominicanus dominicanus*	Sep – Mar	✓	Not assessed	Not Threatened

White-headed petrel	*Pterodroma lessonii*	Nov – Jun	×	Least Concern	Not Threatened

Seabird Breeding Colonies

Due the offshore nature of the Māui 4D Seismic Survey, no seabird breeding occurs in the Operational Area itself; however, a number of sites along the coast are of breeding value to seabirds. Of particular importance are the Nga Motu/Sugar Loaf Islands (see **Section 4.3.2**) and coastal estuaries in South Taranaki/Whanganui such as the Waikirikiri Lagoon, and Whanganui, Whangaehu, Turakina, Manawatu and Rangitikei River estuaries (Thompson, 2015). **Figure 21** identifies the locations of known seabird breeding sites; however, it is important to note that these sites are coastal and will therefore not be affected by the Māui 4D Seismic Survey unless in the event of an oil spill.

Important Bird Areas for Seabirds

Forest and Bird, Birdlife International, and Birds New Zealand have identified Important Bird Areas for Seabirds within New Zealand as part of the international Important Bird Area Program. Important Bird Areas are areas that have been identified as internationally important for bird conservation and are known to support key species and other biodiversity. To date there have been 141 sites of global significance on land and 69 in the marine environment identified as Important Bird Areas for Seabirds (Forest & Bird, 2014). There have been no sites on land identified adjacent to the Operational Area (Forest & Bird, 2015; Forest & Bird, 2016). There are two sites at sea that are of relevance to the Operational Area; the West Coast North Island Important Bird Area and the Cook Strait Important Bird Area. These areas are used by seabird colonies for feeding, maintenance behaviours and social interactions, and also encompass the passage of pelagic species to and from colonies, and congregations close to breeding islands (Forest & Bird, 2014a). Note that these areas do not have legal protection and therefore do not have any imposed restrictions on activities within the designated Important Bird Area.

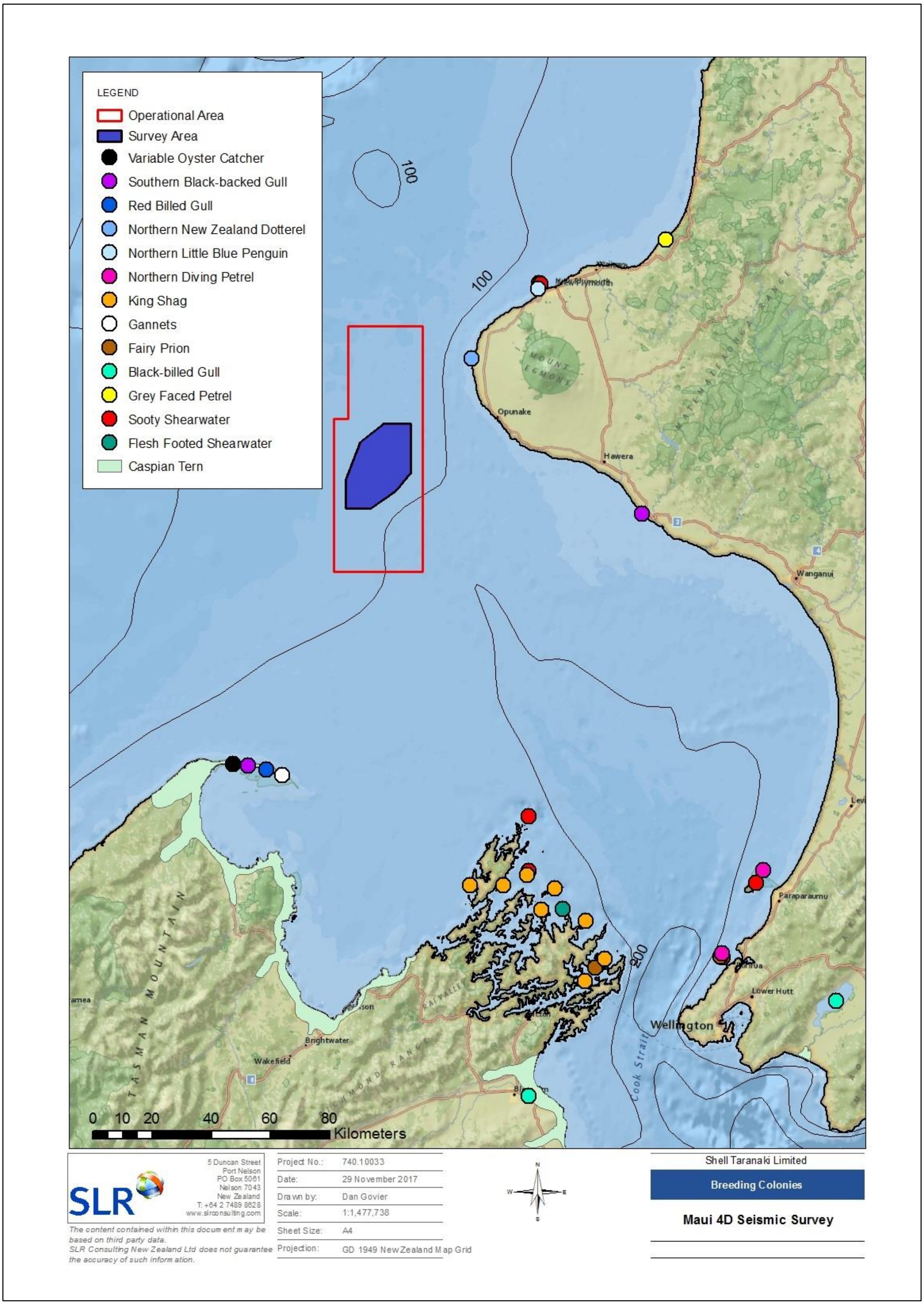
The West Coast North Island Important Bird Area extends from north of Auckland down to approximately Waikawau, and is to the north and inshore of the Operational Area. The Cook Strait Important Bird Area covers the entire South Taranaki Bight and Cook Strait and includes the southern extent of the Operational Area from approximately Cape Egmont.

The Cook Strait Important Bird Area is a major flyway for pelagic seabirds breeding outside the region and is identified as important due to 1) the regular presence of threatened species, 2) it contains more than 1% of the world population of one of more seabird species, and 3) it supports more than 10,000 pairs of seabirds (Forest and Bird, 2014a).

Little Blue Penguin Foraging

Recent GPS tracking data has identified the South Taranaki Bight as a foraging ground for little blue penguins (*Eudyptula minor*) (Poupart et al., 2017). It was previously thought that the foraging range of this species is within 30 km of their nesting site; however, Poupart et al. (2017) have shown that little blue penguins from breeding colonies in the Marlborough Sounds can forage up to 214 km from their nesting site. Furthermore, birds from Marlborough Sounds carry out long-distance foraging trips and utilise waters as far away as the South Taranaki Bight. This is particularly the case during the important egg incubation stage; eggs are typically laid in July to December (NZ Birds Online, 2017). After incubation, the chicks are fed by their parents who carry out foraging trips closer to the nest (Poupart et al., 2017). Little blue penguins nest along the Taranaki coastline and although tracking has not been carried out on Taranaki birds, based on the findings of Poupart et al. (2017) there is potential for Taranaki penguins to also carry out large-distance offshore foraging trips into the Operational Area.

Figure 21: Breeding Colonies of Seabirds around the Operational Area



4.3.7 Marine Reptiles

Marine reptiles include the turtles, sea snakes and sea kraits. They are ectotherms, relying on ambient temperature to regulate physiological processes and as a result their distribution is usually restricted to tropical and subtropical regions (Godoy, 2016). Their presence in New Zealand waters varies from vagrants incidentally carried by ocean currents to seasonal visitors or year round residents (Godoy, 2016). All marine reptiles in New Zealand waters are self-introduced, therefore they are considered native and are fully protected under the Wildlife Act 1953 (Godoy, 2016; DOC, 2017e).

There are five species of sea turtle and four species of sea snake and krait that have been recorded in New Zealand waters. **Table 15** lists these species, their IUCN Threat Status, New Zealand Threat Classification Status, and any observed seasonality in their presence as reported by Godoy (2016).

Table 15 Marine Reptiles Sighted in New Zealand Waters

Species common name	Seasonal presence (Godoy, 2016)	NZ Threat Status (Hitchmough et al., 2015)	IUCN Red List Status
Leatherback turtle	Summer and Autumn	Migrant	Critically Endangered
Green turtle	Year round	Migrant	Endangered
Hawksbill turtle	Winter	Vagrant	Critically Endangered
Loggerhead turtle	Year round	Vagrant	Vulnerable
Olive Ridley turtle	Winter	Vagrant	Vulnerable
Yellow bellied sea snake	N/A	Not threatened	Least Concern
Yellow-lipped/Banded sea krait	N/A	Vagrant	Least Concern
Saint Girons’ sea krait	N/A	Vagrant	Least Concern
Blue lipped/Common sea krait	N/A	Vagrant	Least Concern

Apart from leatherback turtles, marine reptiles are generally found in warm temperate waters and as a result most sightings of marine reptiles in New Zealand occur off the northeast coast of the North Island.

Green turtles were considered to be occasional visitors to New Zealand waters that had been incidentally blown ashore by storms and currents; however, recent data has shown that New Zealand is in fact a temperate intermediary habitat, with green turtles migrating to New Zealand waters (Godoy et al., 2016). Relatively little is known of the presence of marine turtles in New Zealand and considering the findings of Godoy et al. (2016), other turtle species could also actively utilise New Zealand waters as opposed being passive strays as has been the ongoing assumption. Leatherback turtles in particular are a cold-tolerant species (DOC, 2017f) that have a wider distribution than their sub-tropical contemporaries.

Sea snakes and sea kraits are considered ‘accidental visitors’ as New Zealand is outside of their natural range; the tropics (DOC, 2017e).

The Herpetofauana Database run by the Amphibian and Reptile Distribution Scheme provides records of marine reptiles in New Zealand and has been used to develop the ‘Atlas of the Amphibians and Reptiles of New Zealand’ (DOC, 2017g). Based on this atlas, only leatherback turtles and yellow-bellied sea snakes have been recorded in the vicinity of the Operational Area (i.e. the Taranaki region); however, sea snakes are particularly rare visitors to Taranaki and leatherback turtles are uncommon.

4.4 Existing Interests

4.4.1 Cultural Values

The marine environment is highly valued by all Māori communities for the following reasons:

- Mahinga kai (food gathering/preparation area);
- Commercial fisheries;
- Estuaries and coastal waters;
- Sacred and spiritual pathways; and
- Transport and communication.

Māori believe in the importance of protecting Papatuanuku (earth) including the footprints and stories left on the whenua (land) and wai (water) by ancestors. In accordance with this, the role of kaitiakitanga (guardianship) is passed down between generations. Kaitiakitanga is central to the preservation of wahi tapu (sacred places or sites) and taonga (treasures).

Māori first arrived to the Taranaki region between 1250 and 1300 AD. In the early 1800's war parties descended into Taranaki and many people migrated south. The coast adjacent to the Operational Area is testimony to this troubled past as it was the scene of many battles and now contains numerous urupa (burial sites). Throughout the region are also many wahi tapu sites, including large pā (fortified villages), tauranga waka (boat channels), and traditional mahinga kai.

The 2013 census identified that Māori comprise 17.4% of the population in Taranaki. *Te Kāhui Māngai*, a directory of iwi and Māori organizations developed by *Te Puni Kokiri* (the Ministry of Maori Development), highlights twelve iwi in the Hauauru (Western North Island) region (**Figure 22**) of which the following iwi hold kaitiakitanga over coastal rohe within the Taranaki region: Ngāti Tama, Ngāti Mutunga, Te Atiawa (Taranaki), Te Kahui o Taranaki Trust, Te Korowai o Ngāruahine Trust, Ngāti Ruanui, Ngā Rauru Kītahi and Whanganui Iwi. Extending from Cape Egmont to Whanganui, the Operational Area adjoins the rohe of most of these iwi. **Table 16** provides a brief overview of each of these iwi and describes the rohe (area of interest) of each iwi and in particular, the marine attributes of cultural interest.

Figure 22: Hauāuru Iwi Boundaries

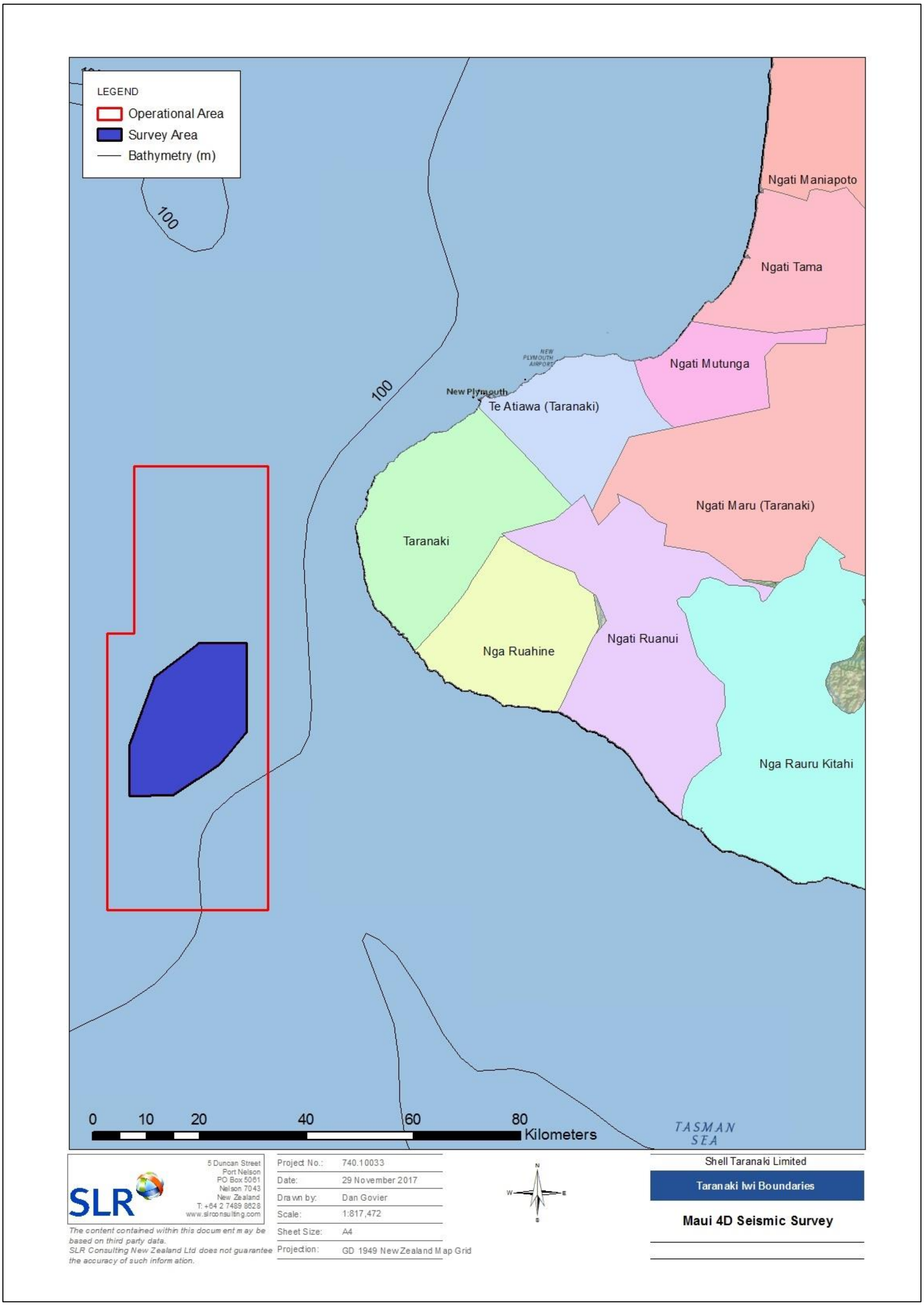


Table 16 Iwi interests in the wider Taranaki region

Iwi (tribal group)	Region/s	Coastal Statutory Acknowledgement Areas	Taonga (treasured) species*	Further comments
Whanganui Iwi	Manawatu/Whanganui	Whanganui iwi have not yet received a historical settlement from the Crown, therefore no statutory acknowledgement rights have been formalised.	Freshwater species that spawn or have a larval development phase in marine waters (e.g. bully species, inanga (whitebait), and tuna (eels)), and marine species that feed in freshwater (e.g. kanae (mullet), pātiki (flatfish/flounder), and kahawai) (Waitangi Tribunal, 1999).	The Whanganui River holds particular spiritual significance and its life force is considered to extent well into the coastal zone beyond the river mouth (Waitangi Tribunal, 1999).
Ngā Rauru Kītahi	Manawatu/Whanganui	Nukumaru Recreation Reserve; Tapuarau Conservation Area; Patea River; Whenuakura River; and Waitotara River. (Ngā Rauru Kiitahi, 2003)	Traditional kaimoana	Along the coastline of Ngā Rauru's rohe lay a number of pa, kainga and marae, including Rangitaahwi and Wai-o-Turi which remain today (Ngā Rauru Kiitahi, 2003). Ngā Rauru Kiitahi gathered food over a large area of coastal South Taranaki and there are many sites of cultural and spiritual significance to this iwi along their coastal rohe (TRC, 2016).
Ngāti Ruanui	Taranaki Whanganui	Tangahoe River; Patea River; and Whenuakura River. (Ngāti Ruanui, 2001)	Hapuku, kahawai, kane, marari (butterfish), moki, paraki (smelt), para (frostfish), pātiki, patukituki (red cod), pioke (rig), reperepe (elephantfish), tuna, kaeo (sea tulip), koeke (shrimp), wheke (octopus), koiro (conger eel), koura (freshwater crayfish), kaunga (hermit crab), papaka parupatu (mud crab), pāpaka (paddlecrab), kotere (sea anemone), rore (sea cucumber), patangatanga (starfish), kina, kūkū (mussels), paua, pipi, pupu (snails), purimu (surf clams), tuangi (cockles), tuatua, waharoa (horse mussel), waikaka (mud snail), tio (oyster), and tupa (scallop) (Ngāti Ruanui, 2001).	Ngāti Ruanui are partners in the South Taranaki Reef Life project. This project aims to discover and document the subtidal rocky reef communities that are found in the South Taranaki Bight (Curious Minds, 2017).
Ngāruahine	Taranaki	Taungatara Stream; Kapuni Stream; Kaupokonui Stream; Ohunuku Otakeho; Waingongoro River; and Puketapu. (Nga Ruahine, 2014)	Traditional kaimoana (TRC, 2010)	Collectively made up of various hapu, including Kanihi-Umutahi, Okahu-Inuawai, Ngati Manuhiaka, Ngati Tu, Ngati Haua and Ngati Tamaahuroa-Titahi (Nga Ruahine, 2014).
Te Kahui o Taranaki Trust	Taranaki	Nga Motu; Paritutu to Oakura River; Oakura River to Hangatahua River; and Kapoaiaia River to Moutoti River. (Taranaki Iwi Claims Settlement Act, 2016)	Traditional kaimoana e.g. paua, kina, kōura (crayfish), kūkū, pūpū (molluscs), ngākihi (limpets), pāpaka, toretore (sea anemones), tāmure (snapper), kahawai, pātiki, and mako (shark).	The Coastal Marine Area is known as Ngā Tai a Kupe (the shores and tides of Kupe) and contains a number of kaimoana reefs, wāhi tapu sites and tauranga waka. Te Kahui o Taranaki Trust places substantial historical and spiritual importance in the Ngā Motu (Sugar Loaf) Islands (Taranaki Iwi Trust, 2013). The Tapuae Marine Reserve is encompassed by the rohe.
Te Atiawa (Taranaki)	Taranaki	Waiwhakaiho River Mouth; and The CMA from Herekawe Stream to Onaero River. (Te Atiawa Claims Settlement Act, 2016)	Traditional kaimoana (TRC, 2010)	Within this rohe lies the Ngā Motu/Sugar Loaf Islands Marine Protected Area.
Ngāti Mutunga	Taranaki	Mimi-Pukearuhe Coast Marginal Strip; Waitoetoe Beach Recreation Reserve; Onaeroa Coast Marginal Strip; and Coastal Marine Area adjoining the area of interest. (Ngāti Mutunga, 2005).	Traditional kaimoana, e.g. mako, tāmure, and araara (trevally) (Ngāti Mutunga Iwi, 2014).	Ngāti Mutunga has strong cultural, historical and spiritual links to the marine environment. The iwi relies heavily on natural coastal resources as a food supply with kaimoana gathering still occurring in accordance with traditional values and tikanga (teachings) (Ngāti Mutunga, 2005).
Ngāti Tama	Taranaki	Mimi-Pukearuhe coast marginal strip; Mohakatino coastal marginal strip; and Coastal marine area adjoining the Ngati Tama area of interest. (Ngāti Tama, 2016)	Traditional kaimoana, e.g. mako, tāmure, and araara (TRC, 2010).	Coastal waahi tapu sites include tauranga waka (canoe berths) and pā sites (Māori villages) at Titooki, Whakarewa, Otumatua and Pukearuhe) (TRC, 2015). A unique fishing technique from the coastal cliffs was developed to catch shark, snapper, and trevally (TRC, 2015). The Paraninihi Marine Reserve is located within the Ngāti Tama rohe and is managed using an "integrated management approach" which involves Ngāti Tama Iwi Authority alongside DOC and the Paraninihi Marine Reserve Conservation Board.

* Formal lists of taonga species are not typically available; however those species documented as providing traditional kaimoana have been included here.

Customary Fishing and Iwi Fishing Interests

The collection of kaimoana is an essential part of Māori life and their relationship with the sea. Kaimoana provides sustenance for tangata whenua and an important food source for whānau (family), and is vital for provision of hospitality to manuhiri (guests) (Wakefield & Walker, 2005). The ability to provide reasonable amounts of kaimoana is an indicator of a tribe's mana (power/status).

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) 57 recognised iwi across the country were allocated fisheries assets including fishing quota. In addition to the fishing quota held by individual iwi, each recognised iwi is allocated income shares in Aotearoa Fisheries Limited which is managed and overseen by Te Ohu Kai Moana (Māori Fisheries Commission).

In addition to the commercial fisheries interests provided for under the Māori Fisheries Act (2004), iwi have Customary Fishing Rights which are provided for under the Fisheries (Kaimoana Customary Fishing) Regulations 1998. These regulations stem from the Treaty of Waitangi (Fisheries Claims) Settlement Act 1992. These customary fishing rights are separate, and in addition to, the commercial fisheries assets described above.

The allocation of customary fishing rights is undertaken by Tangata Kaitiaki/Tiaki in accordance with tikanga Maori. Tangata Kaitiaki/Tiaki are individuals or groups appointed by the local Tangata Whenua and confirmed by the Minister of Fisheries who can authorise customary fishing within their rohe moana. Under the regulations customary fishing rights can be caught by commercial fishing vessels on behalf of the holder of the customary fishing right. Fish caught under a customary fishing authorisation can only be used for customary purposes (e.g. tangi) and cannot be commercially traded. Customary fishing rights are in addition to recreational fishing rights and do not remove the right of Tangata Whenua to catch their recreational limits under the amateur fishing regulations.

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. Rohe moana allow for management controls to be established, issuing of permits for customary take, penalties to be established for management breaches, and for restrictions to be established over fisheries areas to prevent stock depletion or overexploitation. The legally recognised boundaries of rohe moana typically mirror the landward boundary of the CMA. A number of rohe moana occur in the vicinity of the Operational Area as listed below. In particular, two rohe moana occur just inshore of the Operational Area (see **Figure 23**).

- Ngāti kinohaku, Ngāti Te Kanawa and Ngāti Peehi Rohe Moana;
- Ngāti kinohaku Rohe Moana;
- Ngāti Haumia Rohe Moana;
- Titahi-Ngaruahine Rohe Moana; and
- Te Atihaunui a Paparangi and Nga Rauru Rohe Moana

An additional rohe moana, the 'Deepwater Customary Pataka' has been proposed. This pataka (food supply) represents an agreement between 16 iwi groups, Sealords and Te Ohu Kaimoana to facilitate customary fishing in deeper waters of the South Taranaki Bight. In essence, the Sealords fleet will be able to take fish for customary purposes and supply the customary catch to relevant iwi interest groups for customary events such as tangi.

Mātaitai Reserves

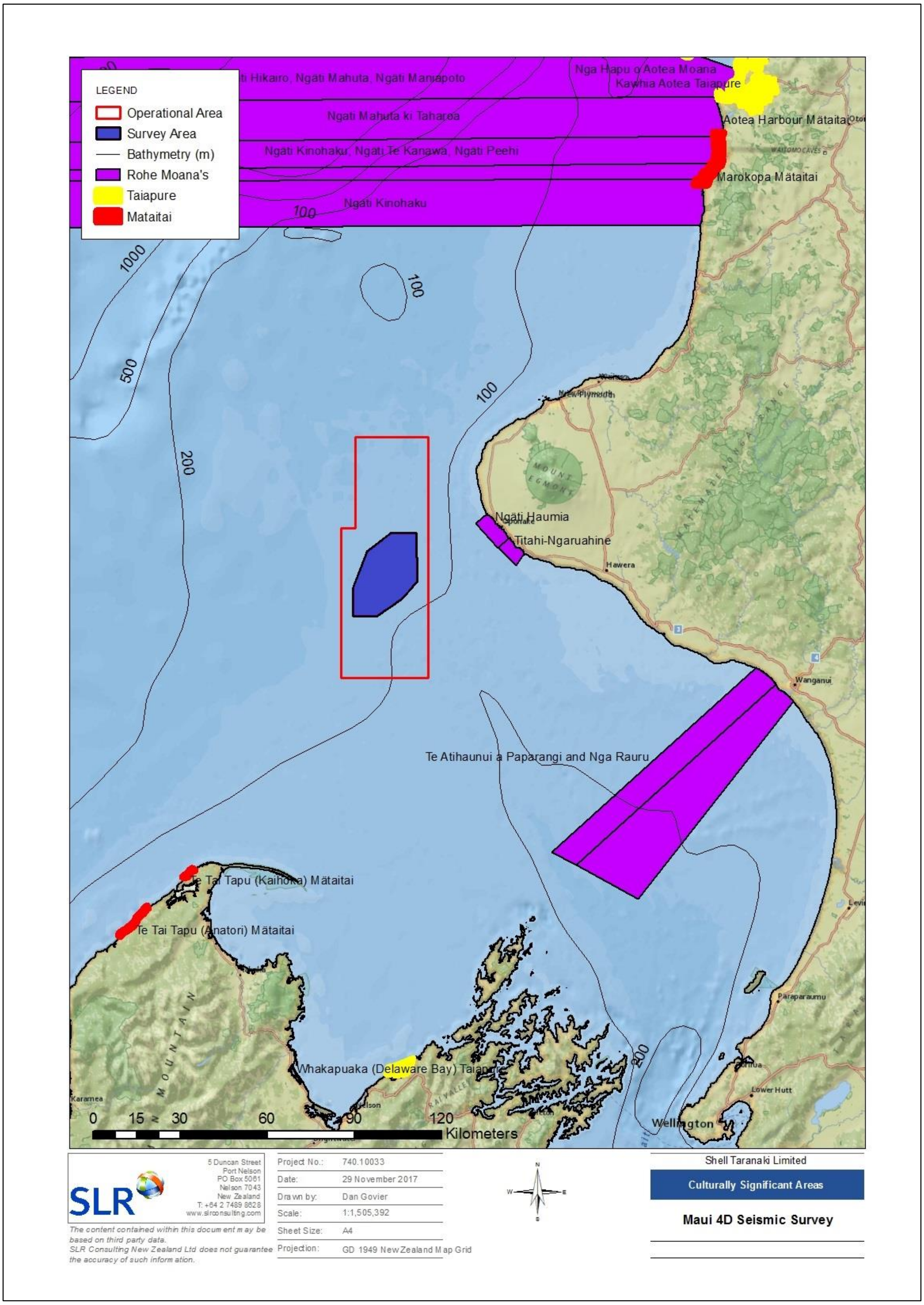
Mātaitai Reserves recognise traditional fishing grounds and are established to provide for customary management practices and food gathering. Commercial fishing is prohibited within a Mātaitai Reserve; however, recreational fishing is allowed. There are three Mātaitai Reserves in the general vicinity of the Operational Area:

- Te Tai Tapu (Kaihoka) Mataitai – 85 km to the southwest;
- Te Tai Tapu (Anatori) Mataitai – 100 km to the southwest; and
- Marokopa Maitaitai – 120 km to the northeast.

Taiapure

A Taiapure can be established in an area that has customarily been of significance to an iwi or hapū (sub-tribe) as either a food source or for cultural or spiritual reasons. A Taiapure allows Tangata Whenua to be involved in the management of both commercial and non-commercial fishing in their area but does not stop all fishing. The Whakapuaka (Delaware Bay) Taiapure is located 150 km to the south of the Operational Area.

Figure 23 Culturally Sensitive Areas in the Vicinity of the Operational Area



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 and provides for the recognition of the customary rights of iwi, hapū and whānau in the common marine and coastal area (the area between mean high water springs and the outer limits of the territorial sea). Iwi, hapū or whānau groups can get recognition of two types of customary interest under the Marine and Coastal Area Act, these are 1) customary marine title, and 2) protected customary rights. The recognition that these two types of customary interest provide are summarised by the Department of Justice (2017) as outlined below.

Customary Marine Title

Customary marine title recognises the relationship of an iwi, hapū or whānau with a part of the common marine and coastal area. Free 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' which lets the group say yes or no to activities that need resource consents or permits in the area;
- A 'conservation permission right' which lets the group say yes or no to certain conservation activities in the area;
- The right to be notified and consulted when other groups apply for marine mammal watching permits in the area;
- The right to be consulted about changes to Coastal Policy Statements;
- A wāhi tapu protection right which lets the group seek recognition of a wāhi tapu and restrict access to the area if this is needed to protect the wāhi tapu;
- The ownership of minerals other than petroleum, gold, silver and uranium which are found in the area;
- The interim ownership of taonga tūturu found in the area; and
- The ability to prepare a planning document which sets out the group's objectives and policies for the management of resources in the area.

Protected Customary Rights

Protected customary rights can be granted for a customary activity like collecting hāngi stones or launching waka in the common marine and coastal area.

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

Table 17 outlines the applications which have been made under the Marine and Coastal Area (Takutai Moana) Act 2011 and that are relevant to the Operational Area. Note that all of these applications are still being processed and no Customary Marine Title or Protected Customary Rights have been recognised at this stage.

Table 17 Applications under the Marine and Coastal Area (Takutai Moana) Act 2011

Applicant	Region	Recognition Sought	Application Area
Nga Hapu o Poutama	North Taranaki	Customary Marine Title (CMT) and Protected Customary Rights (PCR)	The area from Onetai in the north to Pukearuhe in the south. This extends out 12 nm between these two points.
Puketapu Whanau (Te Atiawa)	North Taranaki	CMT & PCR	The area north east of the Waiwhakaiho river to the mouthe of the Waitara river. This are extends out 12 nm offshore between these two points
Te Atiawa (Taranaki) Iwi	North Taranaki	CMT & PCR	Herekawe stream in the south to Te Rau o Te Huia in the north and 12 nm offshore.
Ngāti Mutunga (Taranaki)	North Taranaki	CMT & PCR	Titoki Ridge to the Esplanade Reserve out 12 nm
Ngāti Tama	North Taranaki	CMT & PCR	From south of Pariokariwa point to the southern bank of the Mokau river out 12 nm
Te Kahui o Taranaki Trust	North & South Taranaki	CMT & PCR	Paritūtū to Rawa-o-Turi stream out to 12 nm offshore
Ngāti Ruanui	South Taranaki	CMT & PCR	Northern boundary is Waingongoro River, southern boundary is Whenuakura River, out to 12 nm.
Ngā Hapū ō Ngāruahine	South Taranaki	CMT & PCR	Between the Taungatara and Waihi Rivers
Ngaa Rauru	South Taranaki	CMT & PCR	From Te Awanui-a-Taikehu (Patea River) in the north, south to Whanganui River, out to 12 nm.
Ngā Wariki Ngāti Apa	South Taranaki	CMT & PCR	The area from the coast abutting Motu Karaka in the North to the coast abutting Omarupapako in the south. The area covers all water from the coastline out to 12 nm.
Ngāti Hāua Hapū, Ngāruahinerangi Iwi	South Taranaki	CMT	Between the mouth of Raoa (Rawa) stream to the mouth of Ōtakeho stream to 12 nm.
Rakautaua 9 Whenua Topu Trust	Whanganui	CMT	The area from the mouth of the Whangaehu River, south to the mouth of the Turakina River. This area extends out 12 nm offshore between these two points.
Te Awa Tupua and Nga Hapu me Nga Uri o Te Iwi o Whanganui	Whanganui	CMT & PCR	Northern Boundary is Kai river, Southern Boundary is Whangaehu River - out to 12 nm.
Te Patutokotoko	Whanganui	CMT & PCR	The area lies on the west coast of the North Island. It is bounded by the Kai Iwi River in the North and Lake Papaitonga in the south.
Rakautaua 1C Maori Reservation	Whanganui	CMT & PCR	Kaitoke stream to the Whangaehu river and out 12 nm offshore.

4.4.2 Commercial Values

Commercial Fisheries

The Quota Management System is the primary fisheries management tool to provide for commercial utilisation of New Zealand's fish resources in a sustainable manner. New Zealand waters have been split into ten Fisheries Management Areas (FMAs) (**Figure 24**), with the Operational Area falling mainly within FMA8 Central (Egmont) and a small portion of FMA7 (Challenger/Central (Plateau).

In general, FMA8 supports a mixed trawl fishery for snapper, gurnard, tarakihi, trevally, and white warehou. Long-lining for snapper, potting for rock lobster, and set netting for rig and school shark (outside of the Marine Mammal Sanctuary) also occur (MPI, 2017). Langley (2013) characterised the FMA8 fishery and identified five distinct trawl fisheries within the area:

- Two fisheries targeting tarakihi in the north and south of FMA8;
- A trawl fishery targeting red gurnard, and to a lesser extent flatfish, in 30-80 m water depth in the southern portion of FMA8. This fishery spends some time targeting South Taranaki Bight areas but predominantly fishes further south;
- An inshore barracouta trawl fishery in the South Taranaki Bight; and
- A snapper, red gurnard and trevally trawl fishery predominantly focussed north of New Plymouth, but with a small amount of fishing in South Taranaki Bight.

The top five species of finfish caught within FMA8[2] according to Total Allowable Commercial Catch (TACC) are presented in **Table 18** (MPI, 2017). Total Allowable Commercial Catch represents the total quantity of each fish stock that the commercial fishing industry can catch in a given year (MPI, 2017). The catch presented in **Table 18** represents the TACC for the 12 month period to 30 September 2017.

Table 18 Total Allowable Commercial Catch Allocations for Finfish in FMA8

FMA7		FMA8	
Species	TACC (tonnes)	Species	TACC (tonnes)
Barracouta	11,173	Snapper	1,300
Red Cod	3,126	Gurnard	543
Flatfish	2,066	School Shark	529
Spiny Dogfish	1,902	Rig	310
Stargazer	1,122	Tarakihi	225

While **Table 18** provides an indication of the most commonly targeted fish species, the Operational Area does not cover the entire FMA8 area and therefore regional catch variations are not well represented by TACC data. The Ministry for Primary Industries undertook a fisheries assessment for the area west of Cape Egmont within FMA7 and FMA8. Although this data is dated, it provides a more specific idea of the fisheries within the Operational Area, and excludes the wider Taranaki Bight/FMA8 and FMA7. The assessment area is shown in **Figure 25**.

[2] Only species with a stock that includes the Operational Area have been included. For example rig stock SPO1 covers part of FMA8 but does not include the Operational Area.

Five years' worth of fishing data was used in this assessment (1 October 2006 to 30 September 2011) from completed catch effort returns from commercial fishers. Data was included in the assessment if the fishing event started, ended or passed through the assessment area. The total catch that this data was based upon was 17,818 tonnes. The vast majority of the total catch was jack mackerel and barracouta (74.4% and 20.4% respectively). The remainder of the top five species caught (including barracouta, frostfish, blue mackerel and redbait) were caught as bycatch from jack mackerel trawls.

As jack mackerel and barracouta made up nearly 95% of the total landings within the assessment area, only these two dominant species were considered in order to investigate what time of year they are targeted. The catch peaks of the jack mackerel fishery occurred during October, December, January and June. The least amount of fishing effort occurs during the months of March through to May.

More recently, Gibbs (2015) has reported on the year-round commercial trawl fisheries operating within FMA8. Gibbs (2015) states that while there is no seasonality when total catches are viewed as a whole, catch of certain species is seasonal, including snapper and john dory, which peaks in October – March, and trevally which peaks in January – February.

Gibbs (2015) also outlines other fisheries in the vicinity of the Operational Area as:

- Inshore mixed trawl fisheries (e.g. snapper, gurnard, trevally, barracouta, leatherjacket, tarakihi and john dory);
- Inshore set net fisheries (school shark and rig) - where permitted outside of the Marine Mammal Sanctuary;
- Coastal fisheries (rock lobster, paua, scallops and other shell fish); and
- Various smaller fisheries (potting, lining or trolling).

The Operational Area is also part of the CRA9 rock lobster fishery which extends from Kaipara Harbour in the north to Bruce Bay on the West Coast of the South Island. Although the CRA9 is geographically large, it has the smallest catch allocation of any of the commercially-fished rock lobster regions. Within CRA9 catch is generally restricted to the north-west coast of the South Island and the area between Patea and Kawhia, in particular the Taranaki coastline. It is also noted that the rock lobster fishery occurs over reef structure, which are largely confined to coastal habitats inshore of the Operational Area.

Ports and Harbours

Port Taranaki is the closest port to the Operational Area and is situated to the northeast of the seismic operations. Port Taranaki is the only deep water seaport on New Zealand's west coast with a maximum port draft of 12.5 m. It is a modern port, offering nine fully serviced berths which cater to a wide variety of cargo requirements; however, cargo transiting Port Taranaki typically relates to the farming, engineering and petrochemical industries. The port also offers a full range of support services: providoring, stevedoring, ship agency and government border protection services (Port Taranaki, 2017).

Figure 24: Fisheries Management Areas

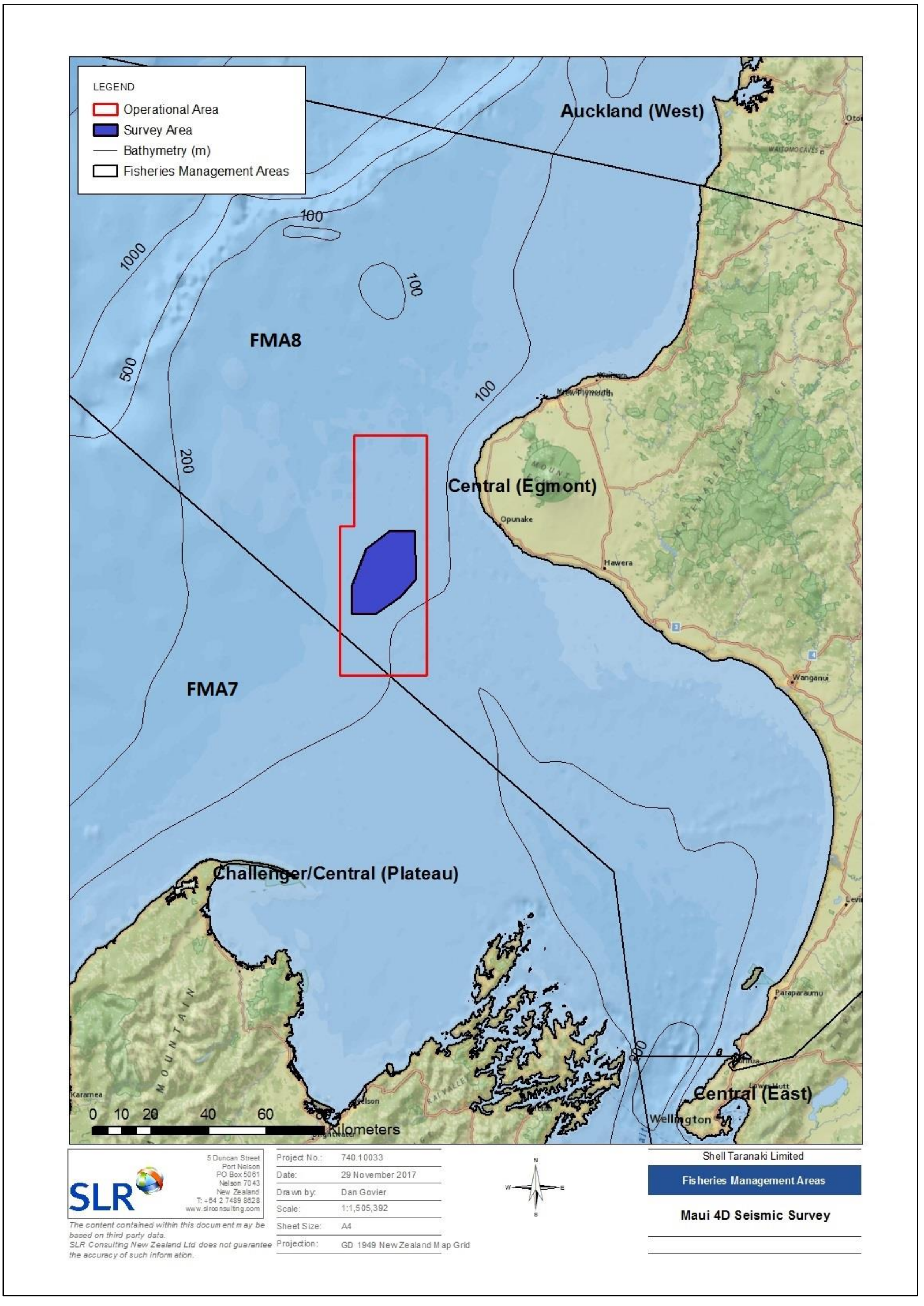
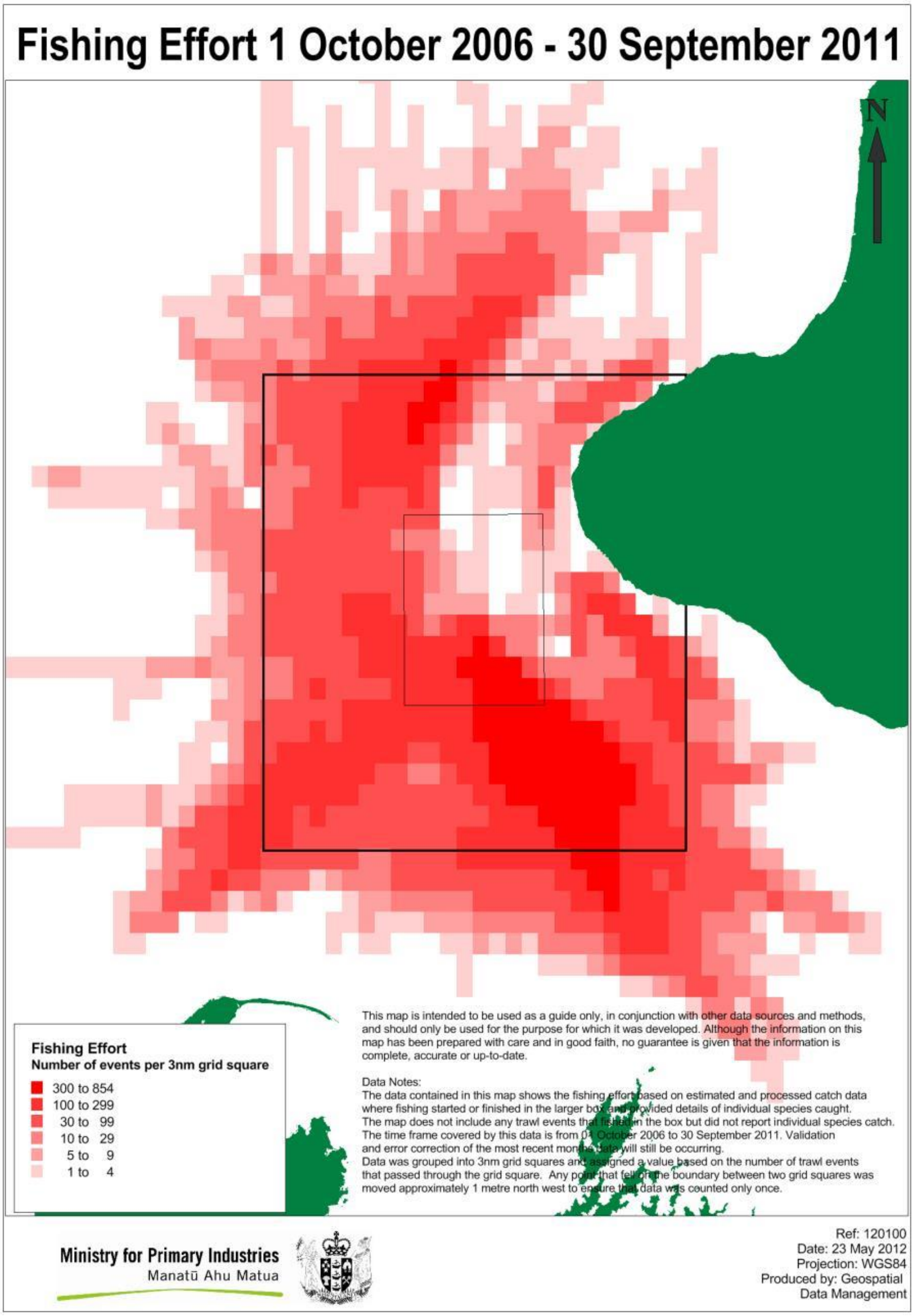


Figure 25: Fishing Effort west of Cape Egmont from October 2006 – September 2011



(Source: MPI report)

Shipping Routes

In general, Maritime New Zealand recommends commercial vessels stay a minimum of 5 Nm from the mainland, any charted danger or offshore islands. For the movement of cargo, commercial vessels typically use the most direct path between two ports. This is well illustrated by the regionally recognised shipping routes presented in **Figure 26**. In general, shipping traffic within Taranaki waters is relatively high on account of it comprising part of the northern approach to both Port Wellington and Port Nelson.

The New Zealand Nautical Almanac provides guidance for vessels operating in the vicinity of production platforms and exploration rigs. The guidance recommends that an adequate safe margin of distance should be maintained, and where there is sufficient sea room, vessels should keep at least 5 Nm clear of the installations.

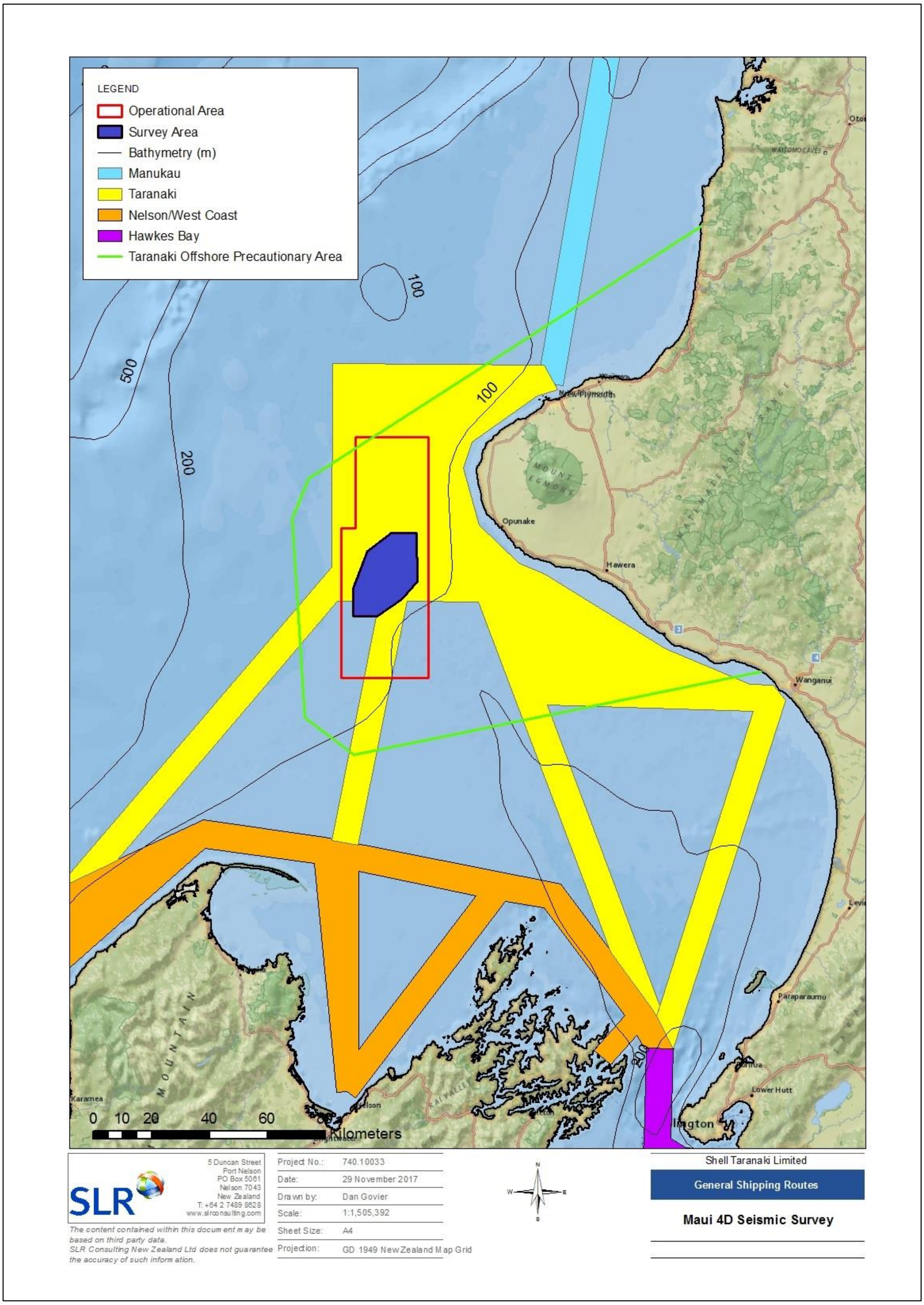
A precautionary area was established in offshore Taranaki by the International Maritime Organisation in 2007. All ships traversing this area must navigate with particular caution in order to reduce the risk of a maritime casualty and resulting marine pollution.

This precautionary area is a standing notice in the annual Notice to Mariners that is issued each year in the New Zealand Nautical Almanac. The Almanac lists the navigation hazards within this precautionary area, including the Pohokura, Māui, Maari, Tui and Kupe fields.

The navigational hazards of particular relevance to the Māui 4D Seismic Survey are the Māui A and B platforms and associated pipelines which are protected by the:

- Continental Shelf (Māui A Safety Zone) Regulations 1975;
- Continental Shelf (Māui B Safety Zone) Regulations 1991; and
- Submarine Cables and Pipelines Protection Order 2009.

Figure 26: Recognised Shipping Routes around Taranaki



Oil and Gas Activity

The Taranaki Basin is currently New Zealand's only offshore oil and gas producing basin. Hydrocarbon exploration and production activities in Taranaki have been ongoing for the last 100 years, and offshore more than 50 years. Producing offshore fields include: Maari, Māui, Kupe, Pohokura, and Tui. **Figure 27** shows the current extent of offshore oil and gas production within the Taranaki Basin.

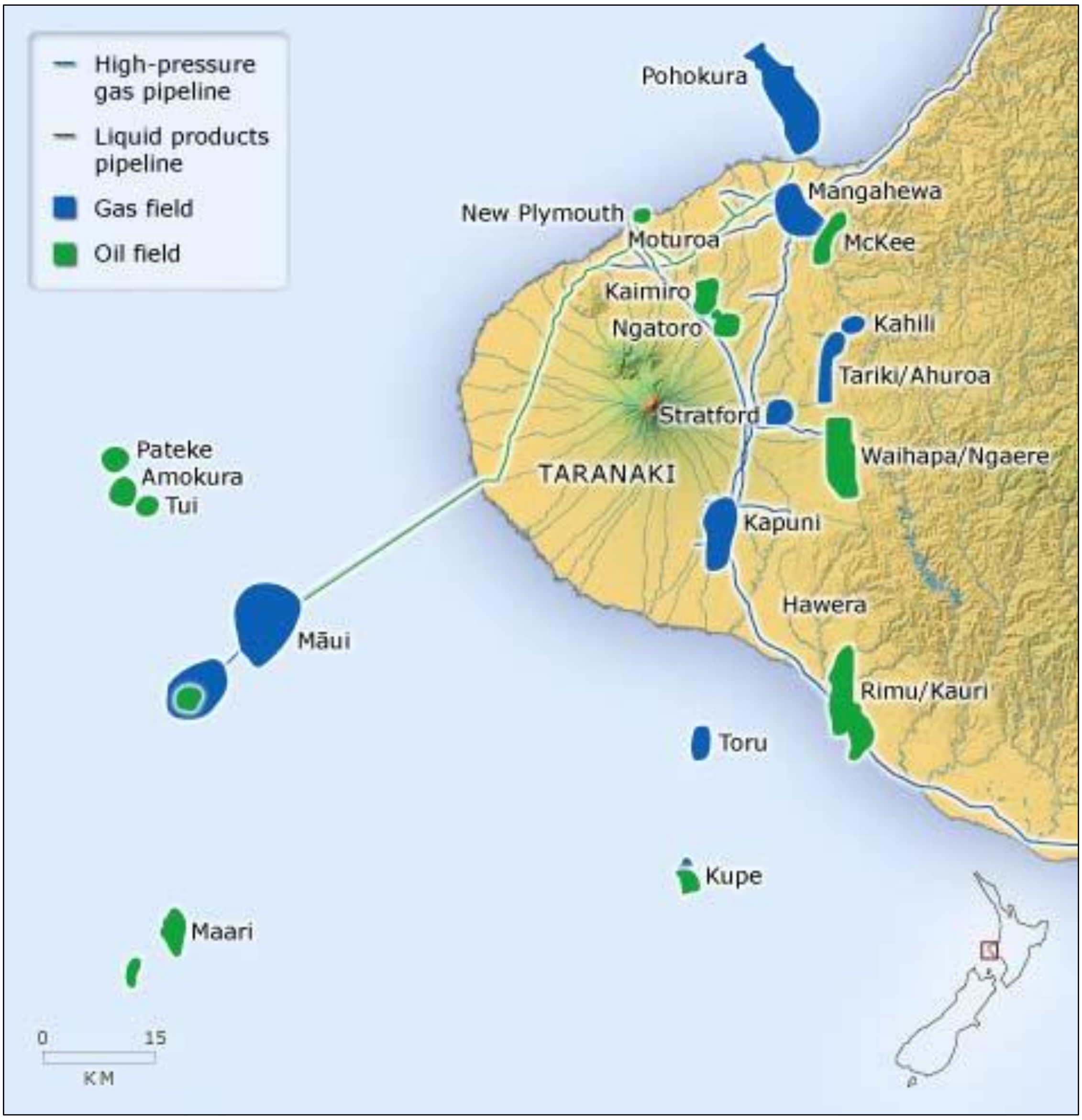
The Māui Natural Gas Field covers 157 km^2 and is situated 3,000 m below the sea floor. At its time of discovery in 1969 by a joint venture between Shell, BP and Todd Petroleum, it was one of the largest in the world. The Māui Field currently consists of two platforms; Māui-A and Māui-B. Māui-A was installed in 1977, with full production from the platform commencing in 1979. A pipeline connects Māui-A to the shore based Māui Production Station at Oaonui, where condensate is treated and the LPG and associated gasses are removed. Māui-B lies 15 km from Māui-A and was installed in 1992 to allow full drainage of hydrocarbons from the field and production from deeper reservoirs. All products from Māui-B are transported to Māui-A via an undersea pipeline (STOS, 2017).

The Tui Area Oil Project consists of three oil fields; Tui, Amokura, and Pateke that are tapped by four wells. Production from the Tui Oil Project began in 2007, with produced oil from the wells transported to the FPSO 'Umuroa' (AWE, 2017). In November 2016 Tamarind Taranaki Limited took over sole ownership of Tui from AWE (Offshore Technology, 2017).

The Maari Oil Field lies slightly to the south of the Operational Area, covering an area of 34 km^2, making it the largest crude oil field in New Zealand. It was first discovered in 1983; however, commercial production of light crude oil did not occur until February 2009. The field consists of two producing fields (Manaia and Matariki), a platform (Tiro Tiro Moana), the FPSO 'Raroa' and associated subsea connecting pipelines (Offshore Technology, 2017a).

With regard to exploration, seismic surveys have been commonplace off the Taranaki coastline since the 1950s. To date there have been no recorded incidents of harm to marine mammals as a result of these seismic operations.

Figure 27: Taranaki Oil and Gas Fields



(Source: http://www.teara.govt.nz/en/map/8934/taranaki-oil-and-gas-fields)

Tourism Industry

Land-based tourism is a significant contributor to the economy in the Taranaki region. However, on-water tourism is limited on account of the exposed coastline and the frequently rough seas. Despite this, 5 - 10 commercial tourism operators have businesses based around maritime activities (e.g. surfing, fishing, and kayaking).

4.4.3 Social Values

Recreational Fisheries

Due to its distance offshore, prevailing weather conditions, and the abundance of recreational fishing opportunities available to anglers closer to shore, the majority of the Operational Area is not widely utilised by recreational anglers. The areas at the western/inshore boundary of the Operational Area, close to New Plymouth and Cape Egmont will however be utilised by some recreational anglers, particularly during summer months when vessels troll further offshore when targeting pelagic species such as striped marlin, mahi mahi, and albacore, bigeye and skipjack tuna. Recreational anglers are increasingly venturing out to the edge of the continental shelf from New Plymouth to fish the canyon systems for deepwater species such as groper, bass, bluenose and gemfish, as well as to target large deepwater gamefish such as broadbill swordfish.

The North Island's west coast contains regionally significant recreational fisheries including reef, beach, and boat fisheries, as well as a nationally significant blue-water fishery for warm-water pelagic species. The Taranaki coastline inshore of the Operational Area comprises of a mix of sandy beaches, boulder coastlines and steep sea-cliffs. Although the steep sea-cliffs limit opportunities for shore fishing along much of the coast, a small amount of beach fishing still takes place. Technological innovations in recent years in the form of electric 'kontikis' and, even more recently with fishing drones, allows recreational anglers to target waters up to 2 km from the coast. The largest recreational fishery inshore of the Operational Area involves boats and kayaks targeting demersal and pelagic species such as snapper, kingfish, gurnard, trevally, kahawai, tarakihi, and hapuka/bass. This is mainly through rod-and-line fishing, although small amounts of set-line and set-netting also occurs, where permitted (set-netting is prohibited within the West Coast North Island Marine Mammal Sanctuary). The majority of recreational fishing occurs in water depths of 10 – 80 m.

As well as line fishing, SCUBA diving and spearfishing are also popular with recreational anglers along the coastline and at offshore reef systems such as the Sugar Loaf Islands and The Traps off south Taranaki. Divers and spear-fishers target both finfish and shellfish (e.g. crayfish, paua and kina). Although popular activities, frequent large swells along the coast often reduce water visibility to near zero, making underwater fishing activities such as diving and spearfishing difficult.

The sandy, shallow shelving beaches and shallow subtidal areas, particularly in the South Taranaki Bight, provide opportunities for recreational gathering of pipi, surf clams and tuatua.

During summer months, Taranaki waters support one of New Zealand's most significant big game fisheries. Warm currents from the north bring with them warm-water pelagic species such as striped marlin, albacore, bigeye and skipjack tune, mako sharks and other occasional species such as black marlin, mahi mahi, and yellowfin tuna. The season for pelagic game-fishing in Taranaki generally runs from late January through to April, with timing dependant on the movement of warm water masses which vary annually. While the majority of game fish are caught in water depths of 30 to 200 m, there is a particular focus of effort along the 100 m isobath between Cape Egmont and Tirau Point, as well as around notable seabed features such as deepwater reefs, pinnacles and trenches (e.g. Mokau and Southern Trench). Some species, such as broadbill swordfish, are targeted in deeper waters at the edge of the shelf area, although fishing at these areas is limited to periods of very good weather and calm seas.

Various Taranaki fishing clubs host fishing competitions throughout the year, with a number of these coinciding with the presence and/or increased numbers of inshore and big game species over the summer months, as well as the greater likelihood of calmer weather conditions during the summer season.

Ecological Research

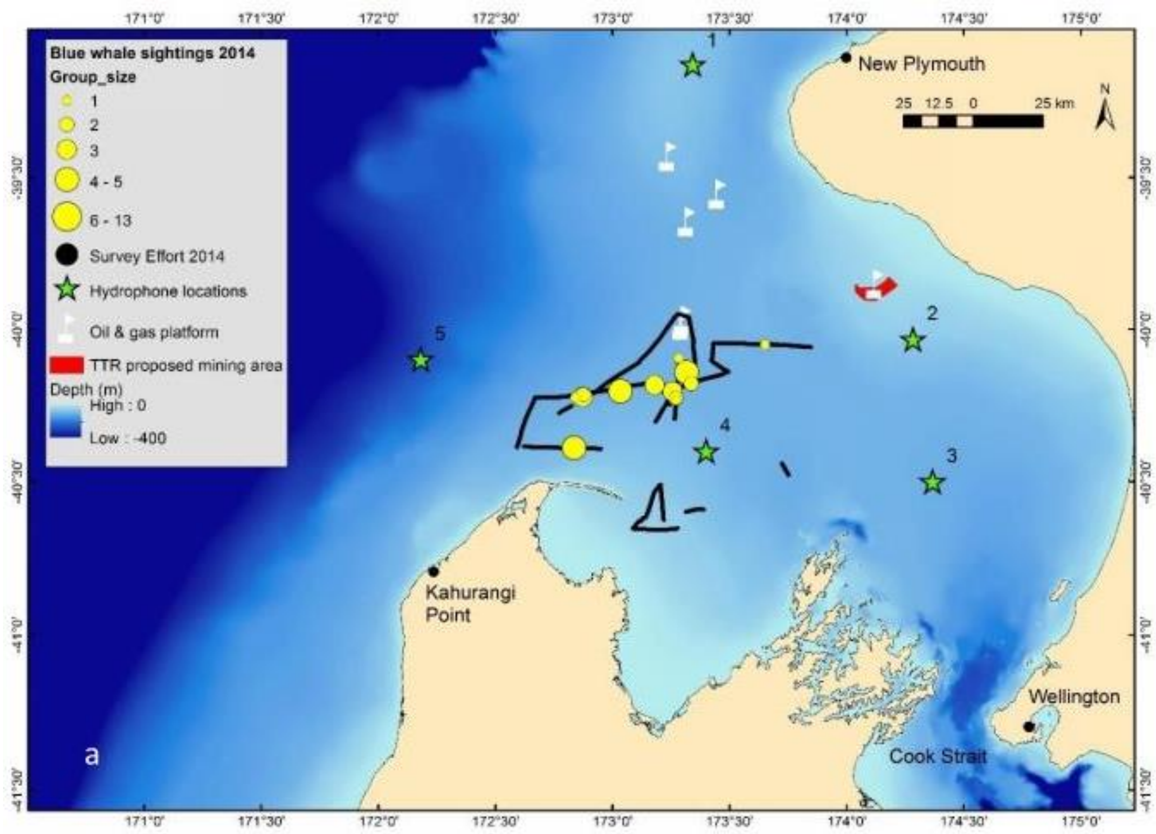
Various organisations conduct research within or near the Operational Area (e.g. NIWA, DOC, the Ministry for Primary Industries, various oil and gas companies etc.). Ecological monitoring at Marine Reserves, Marine Protected Areas, and locations associated with oil and gas activities (e.g. production platforms and for drilling programmes) form the primary basis for marine research in the region. Māui dolphin population surveys also occur periodically along the West Coast of the North Island.

With regard to other marine mammal research in the vicinity of the Operational Area, the following projects should be noted:

- Since 2012, summer surveys for blue whales in the South Taranaki Bight have been undertaken. No boat survey is occurring during the 2017/18 summer; however, hydrophones are currently deployed and will remain in-situ at the locations illustrated in **Figure 28** until January or February 2018. There is a possibility that these devices will have been retrieved by the time the Māui 4D Seismic Survey commences; however, if they are still deployed, 'Mooring location 1' will occur just to the north of the Operational Area; and
- Hydrophones have been deployed by DOC in shallow water at Whanganui, Patea Project Reef, Bell Block, and Tongaporutu. These hydrophones are collecting acoustic data to determine the southern alongshore range of Maui dolphins. There is no direct spatial overlap between these deployments and the Māui 4D Seismic Survey.

All of the institutes involved in the research activities above have been contacted during the engagement process and are aware of the proposed Māui 4D Seismic Survey.

Figure 28 Oregon State University Hydrophone Locations (green stars)



(Source: Torres et al., 2017)

The Code of Conduct states that during marine seismic surveys, research opportunities relevant to the local species, habitats and conditions should be undertaken where possible in order to increase the understanding of the effects of seismic surveys on the marine environment (DOC, 2013).

The Māui 4D Seismic Survey will contribute to the knowledge of marine mammals and other mega-fauna in the Operational Area through the reporting of wildlife observations by the dedicated MMOs on-board the survey vessel. In particular, the Code of Conduct requires that within 60 days following the completion of seismic operations, a MMO report is to be submitted to DOC. This report includes all marine mammal observation data recorded during the survey, including all mitigation actions.

In addition to this and due to public concerns about possible links between marine mammal strandings and seismic operations, dead stranded marine mammals in the vicinity of a seismic survey are often necropsied to investigate links between seismic operations and acoustic injury. If a marine mammal is found inshore of the Operational Area during or soon after the survey, Shell Taranaki Limited (in discussions with DOC) will consider covering the necropsy costs on a case-by-case basis. DOC has indicated that their determination of whether to undertake a necropsy will not be affected by STL's decision to cover costs (or not).

5 POTENTIAL EFFECTS AND MITIGATIONS

This section considers the potential effects of the Māui 4D Seismic Survey on the environment and existing interests; and measures which will be employed by Shell Taranaki Limited to avoid, remedy or mitigate the potential adverse effects.

As part of the Māui 4D Seismic Survey a number of planned activities will be undertaken in accordance with industry best practice. The potential effects of these planned activities and associated mitigation measures are outlined in **Section 5.3**.

In addition to the planned activities, it is theoretically possible that unplanned events could occur under accidental circumstances. These events and their associated mitigation measures are considered in **Section 5.4**.

5.1 Methodology

The following steps were followed in order to assess the significance of potential effects from the Māui 4D Seismic Survey:

- 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 19**.

Table 19: Assessing 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 µPa^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 µPa^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 µPa^2.s; i.e. Permanent Threshold Shift or other physiological damage is possible.

5.2 Sources of Effect – Planned Activities

The first step of the assessment process is to identify potential sources of environmental effect or effects on existing interests.

Table 20 outlines the planned activities associated with the Māui 4D Seismic Survey that have the potential to effect the baseline environment.

Table 20: Sources of effect and associated potential effects – planned activities

Physical presence of the seismic vessel, towed gear and support vessels

Potential Effects:

- Ship strike and entanglement - marine mammals;
- Collision – seabirds;
- Displacement of marine fauna from important habitat
- Displacement or collision hazards for existing interests; and
- Indirect effects, such as changes in the availability of target species by fisheries or marine predators.

Acoustic disturbance

Potential Physical Effects:

- Injury – including permanent and temporary threshold shift.

Potential Perceptual Effects:

- Auditory 'Masking' of important biological sounds (reduced ability of marine fauna to perceive natural acoustic signals used by conspecifics for communication, navigation, predator avoidance, foraging etc.).

Potential Behavioural Effects:

- Interruption of behavioural patterns and/or displacement from important habitat (feeding, breeding, migrating or resting).

Indirect Effects:

- Indirect effects such as changes in the availability of target species by fisheries or marine predators.

The discharge of approved waste from survey vessels

Potential Effects:

- Reduced habitat quality on account of waste discharge (sewage, greywater, galley waste etc.).

5.3 Potential Effects and Mitigation Measures – Planned Activities

5.3.1 Physical Presence of Seismic Vessel, Towed Gear and Support Vessels

Ship Strike and Entanglement - Marine Mammals

'Ship strike' - the collision between a vessel and marine fauna - has been recognised as an increasing conservation concern for marine mammals globally (IWC, 2014). In areas where whales and marine traffic overlap, the potential for ship strike is present for all vessel types and sizes. As described in **Section 4.3.5**, a number of marine mammal species may be present in the Operational Area during the Māui 4D Seismic Survey; and the nature of marine seismic surveys require the presence of a primary seismic survey vessel and at least one support vessel. Hence, an overlap between marine mammal habitat and survey vessels will clearly occur during the Māui 4D Seismic Survey.

A number of primary factors influence the likelihood of ship strikes, these are:

- Vessel size – larger vessels (> 80 m) are more frequently involved in ship strike incidents than smaller vessels (Laist et al., 2001; Jensen & Silber, 2003);
- Vessel speed – most lethal ship strike incidents involve vessels travelling at faster speeds (> 12 knots) (Laist et al., 2001; Vanderlaan & Taggart, 2007);
- Species – large whales are the most common victims of ship strike (e.g. fin whales, right whales, humpback whales, minke whales and sperm whales) (Laist et al., 2001; Jensen & Silber, 2003; Van Waerebeek et al., 2007); and
- Behaviour - species that remain at or near the sea surface for extended periods are particularly vulnerable to ship strike (Constantine et al. 2012); as are species that are attracted to vessels (Bejder et al. 1999; Wursig et al., 1998).

All cetacean species potentially present in the Operational Area are ship strike candidates. However, data indicates that in open ocean habitat, large whales are at greater risk than smaller marine mammal species (Laist et al., 2001; Jensen & Silber, 2003). The size and agility of dolphins and seals probably means that these groups are more successful at avoiding potential collisions. Seismic vessels have only been responsible for one known fatality globally; however, records of sub-lethal effects are less reliable on account of the difficulty in assessing injury in free swimming cetaceans following a collision (Jensen & Silber, 2003).

DOC staff are unaware of any ship strike reports for the Taranaki region (D. Lundquist, L. Boren, C. Lilley; pers. comm.), and no ship strikes have been reported by seismic survey vessels in New Zealand waters (http://iwc.int/scprogress). In addition to this, interrogation of data on anthropogenic related mortality for large cetaceans as submitted via 'New Zealand Progress Reports on Cetacean Research' to the Scientific Committee of the International Whaling Commission between 2010 and 2015 confirmed no reported ship strike mortality or injury for large whales in the Operational Area. In New Zealand waters, ship strike is a particular concern for Bryde's whales in the Hauraki Gulf. Riekkola (2013) reported that a reduction in vessel speed in the Hauraki Gulf from 13.2 to 10 knots could reduce the likelihood of lethal injury in any ship strike incident from 51% to 16%. Voluntary measures have been in place here since 2013 to reduce the likelihood of ship strike. So far these measures appear to be working well (i.e. only one ship strike incident has been reported since the measures were introduced) (D. Lundquist, pers comm.).

It is possible that marine mammals could interact with and become entangled in the towed seismic equipment; however, this is highly unlikely on account of marine mammals displaying exceptional abilities to detect and avoid obstacles in the water column and the lack of loose surface lines associated with the towed equipment reduces the risk of marine mammal entanglement (see Rowe, 2007). Marine mammals are known to interact with fishing gear; however, a point of difference with seismic surveys is that there is no food attractant involved (i.e. bait or catch).

Mitigations:

- The 3D seismic vessel will have a total overall length of 106.8 m. A vessel of this size is capable of causing traumatic damage during a ship strike. However, seismic data acquisition requires a very slow vessel speed (4.5 knots) relative to most other marine traffic (10 – 20 knots). This reduction in speed dramatically reduces the likelihood of ship strike during the Māui 4D Seismic Survey;
- In accordance with the Code of Conduct, MMOs will be on-watch during daylight hours for all periods of acquisition during the Māui 4D Seismic Survey;
- Observations for marine mammals during transit increase the chances of their detection and allow any fine scale changes of vessel route in order to avoid them; and
- MMOs will be briefed to be vigilant for marine mammal entanglements and will be expected to report any dead marine mammals observed at sea.

With these mitigation measures in place, it is considered that the potential for a ship strike with marine mammals is sufficiently managed and no residual effect is predicted. Therefore, the significance of this potential effect is considered to be **negligible**.

Collision - Seabirds

The presence and movement of the survey vessels during the Māui 4D Seismic Survey have the potential to affect seabirds. Potential adverse effects are largely limited to collisions between flying seabirds and the survey vessel. During daylight hours collisions are unlikely as most seabirds are agile flyers with keen eyesight and should be able to avoid collisions with structures.

The seismic and support vessels will be illuminated at night for safety, navigational and operational purposes. A number of birds navigate by starlight at night (Black, 2005) and some species also feed on bioluminescent prey (Telfer et al., 1987); therefore, the presence of any artificial lighting at sea can potentially disorientate and/or attract seabirds; this in turn increases the probability of collisions. It is noteworthy that seismic vessels confer no greater collision threat than any other commercial vessel operating on a 24 hour basis (e.g. fishing vessels).

Diving petrels, albatrosses, shearwaters and storm petrels are particularly sensitive to artificial lighting (Black, 2005; Poot et al., 2008), as are fledglings and inexperienced fliers (Telfer et al., 1987). Poor weather and reduced visibility conditions (such as from rain and fog) further increases the potential for lighting to affect navigating seabirds (Merkel & Johansen, 2011). DOC New Plymouth has confirmed that from the offshore oil and gas industry in Taranaki only one or two collision casualties are reported per year, with no reports received in many years (C. Lilley, pers. comm.). For this reason the Māui 4D Seismic Survey is not expected to have any significant adverse effect on seabirds.

Potential positive interaction is that the slow moving survey vessels could provide loafing or perching opportunities that would not otherwise be available to seabirds.

Mitigations:

No specific mitigation actions are in place to minimise the likelihood of collisions between seabirds and the seismic vessels; however, the short term duration of the Māui 4D Seismic Survey and the slow operational speed of the seismic vessel will reduce the potential for any long-term residual effects on seabirds.

The significance of the residual impact associated with collision of seabirds is considered to be **negligible**.

Displacement of Marine Fauna from Operational Area

The constant physical presence of the seismic survey vessels and the span of towed gear in the Operational Area during the Māui 4D Seismic Survey may cause some species of marine mammal, seabird, or pelagic fish to avoid the area. Constant disruptions to normal behaviours from the survey assets and infrastructure could cause some mobile species to seek alternative habitat elsewhere and affect energy expenditure. Displacement from an area is of particular concern when these changes occur frequently over a prolonged period and/or when they affect critical behaviours (i.e. feeding, breeding and resting). However, during the Māui 4D Seismic Survey this displacement will only persist for the survey duration (~40 days) and will be localised to the Operational Area.

It is likely that the Operational Area provides important habitat for some marine species, but it does not encompass any recognised unique habitat (**Section 4.3**). Hence, alternative habitat at similar water depths is accessible to both the north and south of the Operational Area for those species exhibiting avoidance behaviour.

Mitigations:

No specific mitigation actions are in place to minimise this potential effect; however, the following points have been considered in the determination of significance for this potential effect:

- The information presented in **Section 4.3**, suggests that no single species or population relies entirely on the Operational Area for critical habitat;
- Marine mammals, seabirds and pelagic fish are typically wide ranging and have the ability to move away from a constant source of disruption if necessary; and
- The short term duration of the Māui 4D Seismic Survey will reduce the potential for any long-term displacement impacts on marine fauna.

Therefore, the significance of the residual impact is considered to be **minor**.

Displacement and Collision Hazard for Existing Interests from Operational Area

The constant physical presence of the seismic survey vessels and the span (700 m) and extent (3,000 m) of towed gear during the Māui 4D Seismic Survey will certainly displace fishing operations and marine traffic within the Operational Area for the survey duration.

With regard to fishing, this displacement could cause a temporary reduction of access to fishing grounds, and/or the requirement for alternative fishing equipment to be used. Seismic survey operations can also create a collision hazard for other marine users within the Operational Area. Whereby marine traffic (including fishing vessels) may need to take a less direct route to their destination in order to safely avoid the survey operations; this could have measurable effects in relation to time and fuel consumption.

Any displacement effects and collision risks to existing interests will be strictly temporary during the Māui 4D Seismic Survey.

Mitigations:

- Seismic survey operations will occur 24 hours a day, 7 days a week (weather and marine mammal encounters permitting) to minimise the overall duration of the survey;
- Commercial fishers, recreational fishing clubs and boating clubs who use the Operational Area have been notified of the upcoming seismic survey;
- The survey vessels will comply with the COLREGS (e.g. radio contact, day shapes, navigation lights, etc);

- A support vessel and chase vessel will be present to inform other marine users of the approaching seismic vessel;
- A Notice to Mariners will be issued and a coastal navigation warning will be broadcast on marine radio;
- A tail buoy with lights and radar reflector will be displayed at the end of each streamer to mark the overall extent of the towed equipment; and
- Safety Zones around the platforms and pipelines have been in place for more than 35 years, so restricted fishing access in this area is not a new concept.

With these mitigation measures in place, it is considered that the potential for displacement effects on existing interests are sufficiently managed. Therefore, the significance of this potential effect is considered to be **minor**.

Indirect Effects

Displacement of marine fauna could result in changes in the abundance, distribution or behaviour of pelagic fish species targeted by either fisheries or marine predators.

Mitigations:

- Seismic survey operations will occur 24 hours a day, 7 days a week (weather and marine mammal encounters permitting) to minimise the overall duration of the survey. This will reduce the potential for any long-term indirect effects on fisheries or marine predators.

Therefore, the significance of any residual effects being associated with indirect effects is considered to be **minor**.

5.3.2 Acoustic Disturbance – Potential Effects

Acoustic source arrays used for marine seismic surveys generally produce sound at 260 - 262 dB re 1µPa^{-1}.m at frequencies between 50 and 100,000 Hz (McGregor et al., 2013). These low-frequency sounds propagate more efficiently through water than higher frequencies.

The pulses associated with seismic surveys produce a steep-fronted detonation wave which is transformed into a high-intensity pressure wave (shock wave with an outward flow of energy in the form of water movement). There is an instantaneous rise in maximum pressure followed by an exponential pressure decrease and drop in energy. The physics of underwater sound mean that there is potential for seismic survey operations to have an adverse effect on most marine fauna.

In deeper waters, spherical spreading loss (the reduction in intensity (or power) caused by the spreading of waves into an ever increasing space) from an acoustic source array results in a loss of around 6 dB per doubling of distance. The majority of the sound energy from an acoustic source array travels vertically downwards; however, some is radiated horizontally and at shallow angles. This sound energy can travel significant distances (a few tens of kilometres to over 100 km) depending on the propagation conditions (McCauley, 1994).

Sound waves travel until they meet an object or they attenuate by normal exponential signal decay. Low frequency sounds attenuate slowly, hence travel long distances in the marine environment. High frequency sounds, on the other hand, attenuate rapidly to levels similar to those produced from natural sources.

Exposure of marine fauna to acoustic disturbance is determined by:

- The acoustic source size and pressure;
- The frequency of the emitted sound;
- The firing sequence and tow speed;
- The duration of exposure;
- The propagation conditions (bathymetry, substrate, physical water properties); and
- The distance between the organism and the acoustic source.

In order to assess the potential exposure of marine fauna to underwater noise from the Māui 4D Seismic Survey, and in accordance with the Code of Conduct, sound transmission loss modelling was commissioned. This modelling was undertaken by SLR in order to predict sound propagation from the acoustic parameters specific to the Māui 4D Seismic Survey and the local bathymetry.

Note that all mitigations regarding potential acoustic disturbance are presented collectively at the end of this section; in order to minimise repetition throughout sub-sections.

Sound Transmission Loss Modelling

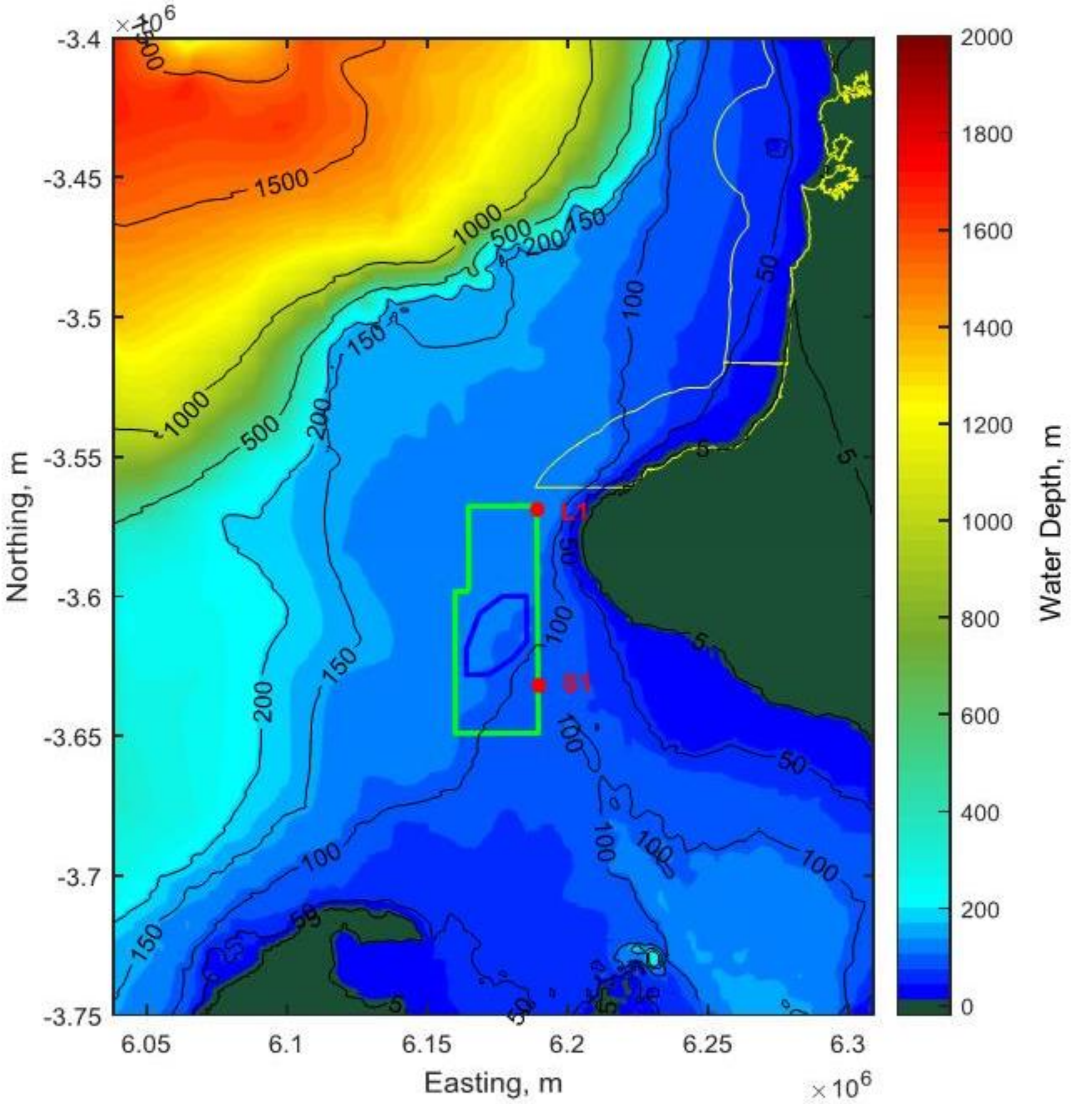
The Māui 4D Seismic Survey Operational Area is located within an AEI, and in accordance with the Code of Conduct, a sound transmission loss modelling report was commissioned (**Appendix E**). In order to predict worst case scenario received Sound Exposure Levels (SEL), the modelling was undertaken in two parts:

- Short range modelling: to assess maximum predicted sound propagation at the boundary of each mitigation zone to validate the sound thresholds (as defined by the Code of Conduct); and
- Long range modelling: to evaluate maximum sound propagation into the West Coast North Island Marine Mammal Sanctuary and southwards into blue whale habitat.

The modelling inputs were specific to the acoustic parameters and survey design for the Māui 4D Seismic Survey as listed below:

- Acoustic specifications - as described in **Section 2.3.1**, namely the 3,147 in^3 Boltgun acoustic array;
- Water depth - Bathymetry used was a merged bathymetry grid using Shell Taranaki Limited and LINZ data and is considered to be the most accurate bathymetry for the Operational Area.
- An 80 m source modelling location was used for the short range modelling in alignment with the shallowest water depth within the Operational Area, as illustrated by S1 in **Figure 29**;
- The source location L1 (as illustrated in **Figure 29**) was used as the geographical basis for the long range modelling. This location was selected as the closest point of the Operational Area to the West Coast North Island Marine Mammal Sanctuary (6.7 km away); hence is the best indicator of the maximum possible SELs experienced at the sanctuary boundary;
- Sea floor substrate type – Fine sand was used to inform the model based on this substrate type being the most reflective substrate known from the Operational Area; and
- Time of year – autumn sound profiles were used to inform the model as these profiles produced the worst case condition for sound propagation.

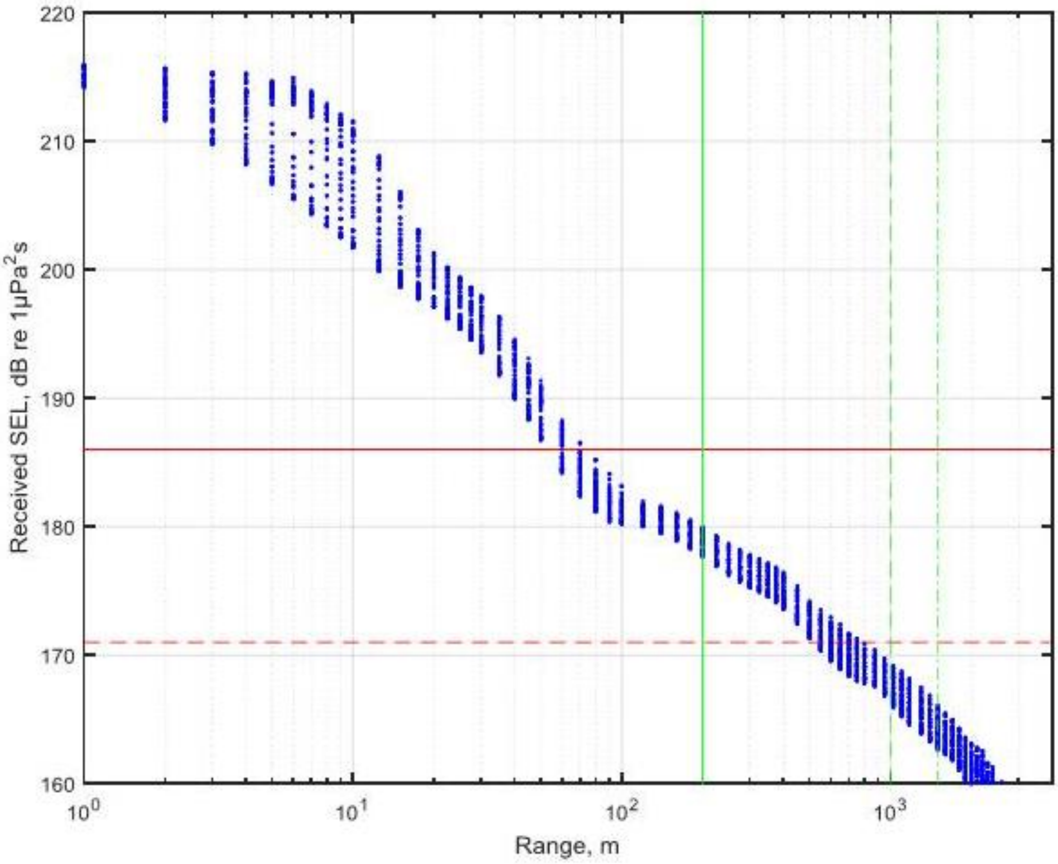
Figure 29: Source locations for modelling



Short range modelling results:

Short range modelling allows for predictions to be made about the likelihood of compliance with the standard Code of Conduct mitigation zones. The model results predicted that the maximum SELs would be below the threshold for permanent threshold shift as defined by the Code of Conduct (186 dB re 1 µPa^2.s) at the 200 m Mitigation Zone (compliance is predicted to occur at 74 m from the source); and that the maximum SELs would be below the threshold for temporary threshold shift (171 dB re 1 µPa^2.s) at the 1,000 m Mitigation Zone (compliance is predicted to occur at 800 m) (**Figure 30** and **Table 21**).

Figure 30: Predicted maximum received SEL at shallowest depth



(For all azimuths as a function of range from the centre of the source array; solid red line = predicted onset of permanent threshold shift (186 dB re 1 µPa^2.s); dashed red line = predicted onset of temporary threshold shift (171 dB re 1 µPa^2.s); solid green line = 200 m from source, dashed green line = 1000 m from source; dot-dash green line = 1500 m from source)

Table 21: Maximum sound exposure levels as a function of range from source location S1

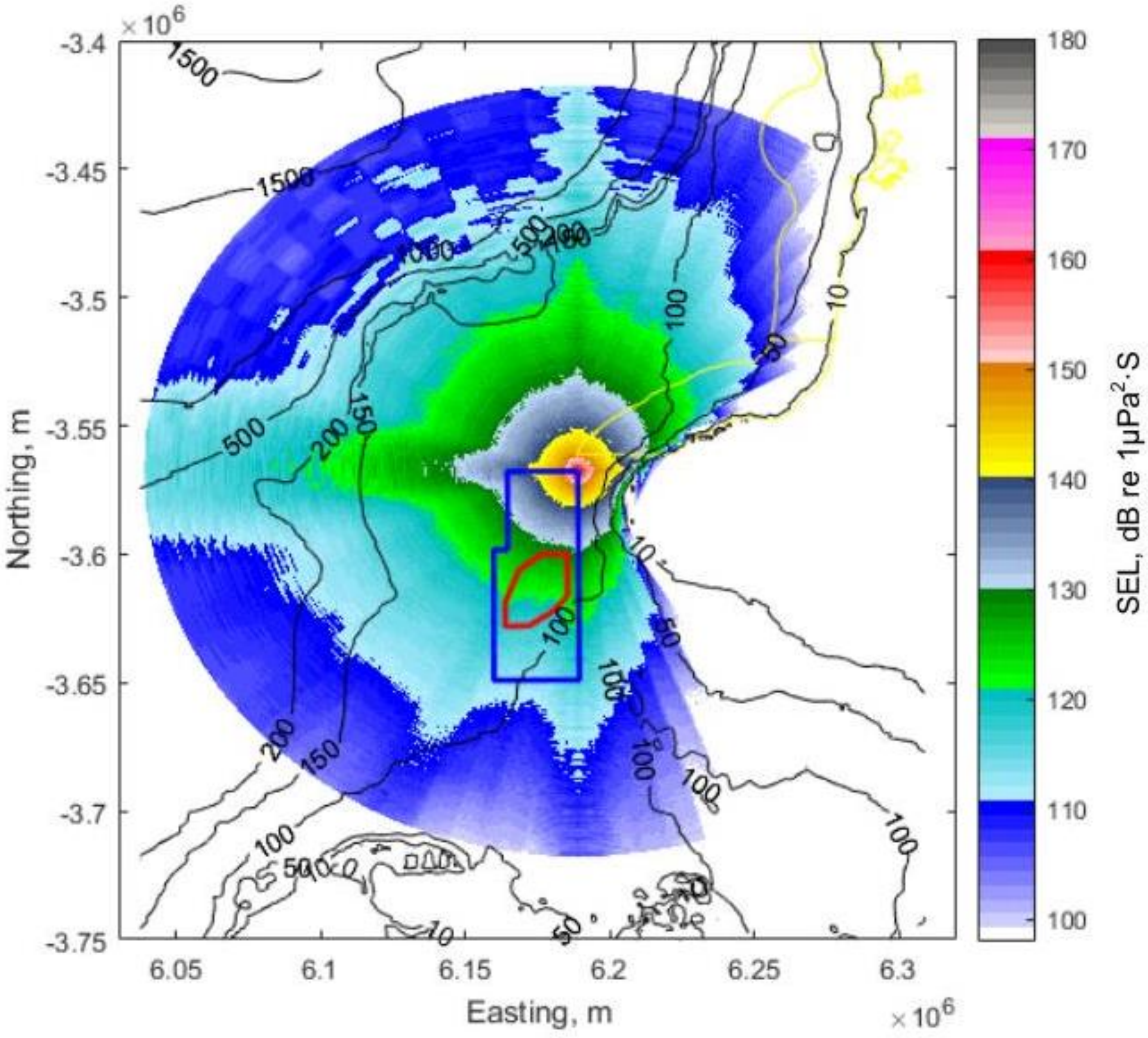
Range	Maximum Predicted SEL (dB re 1 µPa^2.s)
200 m	180.0
1,000 m	169.4
1,500 m	166.2

Long range modelling:

Long range modelling was undertaken to investigate the geographical distribution of sound energy from the seismic source within the Operational Area in relation to the nearby marine mammal sanctuary.

The southern boundary of the West Coast North Island Marine Mammal Sanctuary is approximately 6.7 km from the Operational Area. The maximum SELs received from the source location S1 at the sanctuary boundary are predicted to be around 148 dB re 1µPa^2·S. The SELs are predicted to be approximately 130 - 148 dB re 1µPa^2·S over the southwest corner of the sanctuary area that the propagation paths overlap with **Figure 31**. The SELs are predicted to drop below 100 dB re 1µPa^2·S when the sound propagation reaches the sanctuary area off the Kawhia coast over 140 km away from the source location.

Figure 31: Long range geographical distribution of modelled SEL



Physical and Physiological Effects

Potential physical and physiological effects of acoustic disturbance on marine fauna are discussed throughout this section and mitigation measures which address these physical effects are outlined at the end of this section**.**

Generally speaking, marine fauna that are unable to avoid the acoustic source (because of behavioural or physical constraints) are more at risk of physical effects than highly mobile organisms that can detect and respond to an approaching seismic survey. Fauna that may not be capable of eliciting an avoidance response include plankton and sessile benthic organisms.

Marine Mammals

Marine mammals that are exposed at close range to high intensity underwater noise (or the associated pressure effects) could potentially suffer trauma or auditory damage (DOC, 2013). However, the sound intensity (energy levels, frequencies and duration) required to produce these physiological effects is unknown for most marine fauna, and what is known is based on a limited number of studies (Richardson et al., 1995; Gordon et al., 2003).

Auditory damage is referred to by way of threshold shifts, whereby an elevation of the lower limit of auditory sensitivity occurs (i.e. hearing loss). Threshold shifts can either be temporary or permanent (Temporary Threshold Shift, TTS; or Permanent Threshold Shift, PTS). In most cases threshold shifts will be temporary i.e. a temporary loss of hearing sensitivity following exposure to high intensity sound; and most mobile species, if given the opportunity, are thought to avoid the range in which physical effects occur.

For marine mammals, the SEL required to elicit a threshold shift varies with species. For example, captive bottlenose dolphins exhibit TTS at 190 – 192 dB re 1 μPa^2-s (Schlundt et al., 2000; Finneran et al., 2005), whereas captive harbour porpoises have shown that TTS occurred at SEL 164 dB re 1 μPa^2-s (Lucke et al., 2009). Captive studies are important as quantifying physiological change in free-ranging marine mammals is virtually impossible; however, it is noteworthy that there are remarkably few reported incidents of obvious and sustained marine mammal surface distress behaviours in the immediate vicinity of seismic surveys.

The estimated onset of PTS in marine mammals has been calculated by Southall et al. (2007) to be 198 dB re 1 μPa^2-s for all cetaceans exposed to sound pulses and 186 dB re 1 μPa^2-s for pinnipeds in water. In addition, the criteria for TTS-onset in marine mammals were calculated to be 183 dB re 1 μPa^2-s for all cetaceans and 171 dB re 1 μPa^2-s for pinnipeds (Southall et al., 2007).

The Code of Conduct interprets the SEL criteria set out by Southall et al. (2007) based on a conservative approach to predict thresholds for both temporary and permanent physiological changes of marine mammals as follows:

- 186 dB re 1 μPa^2-s; i.e. the lowest SEL at which PTS is possible
- 171 dB re 1 μPa^2-s; i.e. the lowest SEL at which TTS is possible

The mitigation measures outlined in the Code of Conduct are designed specifically to address these thresholds by protecting marine mammals from physiological damage (temporary and permanent). As outlined earlier in this section, sound transmission loss modelling has confirmed that the standard mitigation measures in the Code of Conduct should sufficiently protect marine mammals from both temporary and permanent auditory injury during the Māui 4D Seismic Survey. Indeed, the modelling predicts that SELs capable of causing PTS (> 186 dB re 1 μPa^2-s) will be restricted to within 100 m of the source (**Figure 30**). The mitigation measures that will be employed during the Māui 4D Seismic Survey ensure that species of concern are fully protected from such sound levels as the acoustic source must be shut down if species of concern approach to within 1,000 m of the source (or 1,500 m if they are accompanied by a calf). In addition, soft starts (a gradual increase in the acoustic power level) will ensure marine mammals in the immediate vicinity of the survey will be given adequate opportunity to leave the area before full power operations get underway.

Fish

As with marine mammals, fish may also suffer physical effects from exposure to underwater noise, including temporary or permanent threshold shifts (Smith, 2004; Popper et al., 2005), damage to sensory organs (McCauley et al., 2003), or an increase in stress levels (Santulli et al., 1999; Smith, 2004; Buscaino et al., 2010).

Popper et al. (2005) documented TTS for northern pike and lake-chub following exposure to a small seismic source with a received mean SEL of 176-180 dB re 1μPa^2-s. These fish experienced an initial reduction in hearing sensitivity of 10 - 25 dB; however a full recovery occurred within 24 hours. Another species, the broad whitefish, was also involved in this study, but showed no sign of TTS. Hence responses are thought to be highly species specific. Popper et al. (2014) developed guidelines to predict at what threshold levels seismic surveys might cause physiological damage to fish. The TTS threshold is thought to occur at 186 dB SEL_{cum}, whereas the PTS threshold occurs between 203-216 dB SEL_{cum} depending on whether or not fish possess a swim bladder (Popper et al., 2014).

Studies involving New Zealand species are scarce; however, McCauley et al. (2003) investigated the effects of seismic exposure on snapper (*Pagrus auratus*). This experiment exposed caged snapper to SELs in exceedance of 180 dB re 1μPa^2-s from a seismic source, after which the ear structures of the fish were examined for any damage. A small percentage (2.7%) of sensory hair cells sustained severe damage in several of the exposed fish up to two months following exposure; potentially representing permanent auditory damage. However, McCauley et al. (2003) urge caution in interpreting these results as the caged fish were presumably exposed to SELs much greater than those of wild fish on account of the fact that the caged fish had no option to move away from the sound source. In general, physiological changes are thought to be limited to fish in the immediate vicinity of the acoustic source (Popper & Hastings, 2009).

There is some evidence to suggest that seismic exposure can elicit a stress response in some fish; however this may be species and circumstance dependent. For example, Sverdrup et al. (1994) reported an increase in adrenaline and cortisol levels in Atlantic salmon following seismic exposure; and Santulli et al (1999) also detected significant changes in stress hormones in caged sea bass in response to seismic exposure. In the latter investigation, it is noteworthy that hormone levels returned to normal within 72 hours. Fewtrell (2003) investigated cortisol levels in caged pink snapper following seismic exposure off Western Australia and detected no significant changes.

Despite the potential for fish to experience physical effects in close proximity to a seismic survey, the risk of any lasting effects during the Māui 4D Seismic Survey is reduced as:

- Pelagic fish are predicted to move away from the acoustic source to avoid the greatest SELs;
- Soft starts will allow pelagic fish to leave the vicinity before full operational capacity is reached;
- STLM indicates that injury thresholds (according to Popper et al., 2014) will only be exceeded in the immediate vicinity of the acoustic source (within approximately 10 m).

Seabirds

Seismic surveys could presumably have physiological effects on deep diving seabirds, but little information is available to suggest the mechanisms and likelihood of impacts (Addison et al., 2004). The likelihood of birds diving in the immediate vicinity of the acoustic source is thought to be relatively low as seabirds on the sea surface (resting or feeding) are typically startled by an approaching seismic vessel and therefore would be displaced from the immediate line of transit well ahead of the acoustic source (MacDuff-Duncan & Davies, 1995).

Non-Planktonic Invertebrates

Non-planktonic invertebrates include a wide range of marine organisms from all possible marine habitats, e.g. benthic invertebrates, shellfish, crustaceans, and cephalopods. Note that planktonic invertebrates and planktonic larvae are discussed in the 'Plankton' section below. The bullet points below briefly describe research findings on the impact of underwater noise on non-planktonic invertebrates; however as noted by Carroll et al. (2017), limited investigations on the physiological responses of marine invertebrates to seismic noise are available and even less is understood about how physiological changes may negatively affect populations.

- Christian et al. (2004) conducted a stress test on snow crabs to investigate the impacts of seismic surveys and found no stress bio-indicators present following seismic exposure. In line with these findings, Harrington et al. (2010) documented no changes to scallop meat and roe quality after two different seismic surveys, and blue mussels (*Mytilus edulis*) exposed to a seismic source level of 223 dB re 1µPa at distances of 0.5 m or greater showed no physiological effects (Kosheleva, 1992; Dalen, 1994 as reported in Moriyasu et al., 2004).
- Solan et al. (2016) documented no change in tissue levels of glucose or lactate in lobsters, clams or brittle stars exposed to impulsive noise, but La Bella et al. (1996) described how the levels of glucose, hydrocortisone and lactate increased in clam tissues after seismic exposure.
- High intensity seismic source exposure caused shell damage for one of three species of mollusc exposed to a source level of 233 dB re 1 µPa at a distance of 2 m; whereby the Iceland scallop (*Chlamis islandicus*) suffered splits to the shell, but the other two species were unaffected (Matishov, 1992 as reported in Moriyasu et al., 2004).
- In field studies off Tasmania, Day et al. (2016) assessed the physiological effects of exposure to a 150 in^3 airgun on red rock lobster (*Jasus edwardsii*). During this study statocyst hair cells of exposed lobster sustained long-term damage; however, these lobsters did not show impaired righting reflexes suggesting that they had adapted to cope with the damage. Despite haemolymph counts being slightly lower, haemolymph biochemistry did not change in response to seismic exposure, which was interpreted to indicate physiological resilience to acoustic disturbance.
- All captive cephalopods exposed to low frequency sounds with SELs up to 175 dB re $1µPa^2$-s exhibited changes to the sensory hair cells of the statocysts (responsible for balance) (Andre et al., 2011). Changes became more pronounced with longer exposure durations and it was estimated that animals within a 1.5 – 2 km radius from an operating acoustic source could be affected.
- Respiration rates of *Octopus ocellatus* were suppressed during periods of exposure to low frequency sound (Kaifu et al., 2007), yet oxygen consumption rates of large crabs increased after low frequency sound exposure (Wale et al., 2013).
- In response to seismic exposure, haemocyte levels in the scallop *Pecten fumatus* were assessed by Day et al., (2016) as an indicator of circulation, immunity and stress. Exposed scallops had significantly lower haemocyte levels than control scallops and although the ecological implications of these changes warrant further investigation, it seems that scallops may exhibit a depressed immune response following exposure to seismic operations.

In general terms it appears that the effects of underwater noise on invertebrates vary depending on species, proximity to the source, water depth and exposure characteristics (amplitude, frequency and duration). Early studies in this field which focused solely on mortality rates suggested that for macro-invertebrates (scallop, sea urchins, mussels, periwinkles, crustaceans, shrimp, gastropods, and squid) little mortality is expected below sound levels of 220 dB re 1µPa@1m (Addison et al., 2004). In waters deeper than about 15 m, the SELs from a typical seismic array (3,000 in^3) reduce with depth (Duncan, 2016). At the seafloor, the SELs from a 3,000 in^3 array would be lower than 220 dB re 1µPa at a water depth of 80 m (Duncan, 2016). The shallowest water depth within the Operational Area during the Māui 4D Seismic Survey is 80 m; on this basis no macro-invertebrate mortality is expected. The sound transmission loss modelling results support this conclusion as sound levels of the intensity required to elicit mortality (220 dB re 1µPa@1m) are not predicted even in very close proximity to the source (see **Figure 30**).

During consultation, the effect of seismic surveys on rock lobster populations around the Taranaki coast was raised as a potential issue (see **Section 7**). With regard to this, Payne et al. (2007) didn't observe any significant differences between lobsters exposed to seismic sound (227 dB peak-to-peak) and control lobsters in terms of delayed mortality, damage to mechanosensory systems, or appendage loss. However, serum biochemistry changes were documented weeks to months after exposure, potentially indicating some sub-lethal organ stress (Payne et al., 2007). The effects of seismic surveys on rock lobster settlement rates are unknown; however, it is understood that most rock lobster larvae do not settle in the same region from which their larvae originate, indeed most rock lobster larvae from the Taranaki coastline settle in coastal areas further north, and primary settlement phases typically occur in late winter/spring (Forman et al., 2014) which does not overlap with the proposed survey operations. It is therefore unlikely that seismic operations would affect rock lobster settlement rates; however any effects that did occur would most likely be observed north of the Operational Area.

Plankton

Until recently, seismic surveys were thought to only cause mortality of plankton in the immediate vicinity (i.e. within 5 m) of an active acoustic source (Payne, 2004; DIR, 2007). McCauley et al. (2017) have however documented significant mortality to zooplankton populations over a much broader radius from a seismic source. These findings are discussed in detail below.

Using a single 150 in^3 acoustic source, McCauley et al. (2017) used the following techniques to assess changes to the surrounding plankton community both before and after seismic exposure: 1) sonar surveys, 2) net tows for zooplankton abundance, and 3) counts of dead zooplankton. During this investigation, the baseline zooplankton community was comprised of copepods (71%), cladocerans (15%), euphausiid larvae (*Nyctiphanes australis*) (4%), appendicularians (5%), and 'other' (5%). Following seismic exposure, McCauley et al. (2017) documented significantly lower zooplankton abundance, with a 64% decrease in median abundance one hour after exposure. Within a range of 509 – 658 m of the source, a 50% reduction in zooplankton abundance was detected and the SEL at this range was 156 dB 1 $\mu Pa^2 s^{-1}$. The range at which no impact was detected was 973 - 1,119 m (at an SEL of 153 dB 1 $\mu Pa^2 s^{-1}$). Zooplankton counts revealed a two- to three-fold increase in dead zooplankton following exposure and all krill larvae in the samples were dead following exposure regardless of distance to the source.

The net tow and zooplankton count findings from this study (as described above) were verified by the sonar backscatter imaging which revealed a sequence of 'holes' in the plankton community from 15 minutes after exposure. These holes followed the track of the seismic source and extended from the sea surface to a water depth of 30 m. The authors hypothesised that zooplankton mortality was caused by damage to the statocysts (i.e. the small organs responsible for balance and orientation in zooplankton); however, the exact mechanism for the observed effect is unknown. With regard to potential flow on effects to food-webs, the relationship between blue whales and krill are discussed towards the end of this section under the heading 'Indirect Effects'.

As an outcome of these research findings, the oil and gas industry has commissioned follow-up investigations. In particular the Commonwealth Scientific and Industrial Research Organisation are modelling the potential impacts of a typical marine seismic survey (3,200 in^3 source over an area of 2,900 km^2 for 35 days) based on the McCauley et al. (2017) results. Early modelling data suggests that although zooplankton biomass within the survey area was reduced out to 2.5 km from the source, recovery occurred within three days after completion of the survey and no obvious impacts were detected at a regional level (Richardson et al., 2017). Fast growth rates of zooplankton and the dispersal and mixing of zooplankton and water masses in the offshore marine environment were suggested to be responsible for the prompt recovery rates (Richardson et al., 2017). As the source capacity, survey area and survey duration are similar between the modelling study and the proposed survey, it is reasonable to expect that impacts of a similar magnitude as those observed by Richardson et al. (2017) could occur during the Māui 4D Seismic Survey. Both industry and environmental groups will be watching developments around this topic carefully, but until the underlying mechanism for the observed effects are understood, it is difficult to mitigate potentential impacts on zooplankton during seismic operations.

The effects of seismic surveys on commercially important larvae are also of interest to the fishing industry. A study by Aguilar de Soto et al. (2013) examined the effects of a seismic source on the larvae of New Zealand scallops (*Pecten novaezelandiae*). During this experiment scallop larvae were exposed to seismic pulses of 160 dB re 1 µPa@1m within one hour of fertilisation and were then morphologically compared to a control group. Soft tissue malformations were detected in 46% of the exposed larvae, with no malformations detected in control groups. In contrast to this, Day et al. (2016) assessed the development and hatching rates of red rock lobster larvae following seismic exposure and could not detect any differences between exposed larvae and control larvae. Hence, the effects of seismic on planktonic larvae appear to be highly species specific.

Auditory Masking

Many different marine organisms use sound for various functions in the marine environment. Sound travels efficiently underwater and, in an environment where light often limits the suitability of visual communication, communication by sound has obvious benefits (DOSITS, 2017).

Marine mammals use sound extensively for communication. Many marine mammal species are social animals that live in groups, whereby group cohesion is maintained by short-range vocalisations between individuals. Bottlenose dolphins are a good example of this where each individual has a ‘signature’ whistle for recognition (Quick & Janik, 2012). Short-range vocalisations are particularly important for mother/calf pairs. Some marine mammal species also reserve a specific range of communication vocalisations for reproductive behaviours (e.g. humpback whale song). Whilst aggression is displayed by another range of vocalisations or sound producing behaviours (e.g. tail slapping).

Marine mammals produce sound not only for communication with conspecifics, but also for foraging, navigation, reproduction, parental care, avoidance of predators, and to gain an overall awareness of the surrounding environment (Thomas et al., 1992; Johnson et al., 2009). Toothed whales and dolphins use echolocation to forage and navigate, whilst all marine mammals are believed to use passive listening to gather useful navigational cues (e.g. the sound of waves breaking on coastline etc.).

Fish also use sound to communicate with one another with sounds typically being associated with reproductive activities or stressful situations (DOSITS, 2017). Many fish species also produce sounds while feeding, and these sounds may attract other individuals to a food source. Little is known about New Zealand fish species, but Ghazali (2011) has documented red gurnard to produce vocalisations in the 100 – 500 Hz range. Information suggests that sound may also be important for components of invertebrate ecology with crustaceans commonly producing sounds (DOSITS, 2017) and larval coral and reef fishes using sound to detect suitable settling locations (Simpson et al., 2004; Vermeij et al., 2010).

Sound producing animals in the marine environment must be able to perceive and effectively respond to biologically important sounds. Underwater noise generated by human activity can interfere with the perception of these sounds. Such interference is referred to as 'masking'. The likelihood of masking is determined by how much overlap occurs between animal vocalisations and anthropogenic sounds; the frequency of the two competing sounds is particularly important (Richardson et al., 1995). The following examples demonstrate the potential for masking in both marine mammals and fish:

- The noise from an ice-breaker ship was predicted to mask beluga whale communication signals (Erbe & Farmer, 2000); and
- Boat noise was found to mask acoustic communications in three vocalising fish species in the Adriatic Sea (Codarin et al., 2009).

Studies on masking to date have largely focussed on commercial shipping noise; however potential masking effects are also relevant to seismic operations (Clark et al., 2009; Erbe et al., 2016).

Masking occurs at received sound levels less than those which would elicit an observable behavioural response (Tougaard et al., 2015). In situations when masking occurs, evidence suggests that adaptive shifting in vocalisation can result (McGregor et al., 2013). This is when animals change their vocalisation behaviour in an attempt to overcome a masking effect (also known as the Lombard Effect). Examples of this adaptive behaviour are:

- Di Iorio & Clark (2009) investigated changes in blue whale vocal behaviour during a low-medium power seismic survey (mean seismic source = 131 dB re 1µPa at 30 – 500 Hz; mean SEL = 114 dB re 1µPa^{2}s). Results showed that blue whales called consistently more on days when the seismic source was active than on days when it was not. It is believed that an increase in calling rate increased the probability of blue whale signals being successfully received by conspecifics;
- Foote et al. (2004) demonstrated that killer whales increased the duration of their calls in response to high levels of boat traffic; and
- Van Ginkel et al. (2017) reported that the peak frequencies of bottlenose dolphin whistles increased in response to increasing noise levels to avoid masking.

Although some marine mammal species show adaptations to increased anthropogenic noise, in some species adaptations to masking may be limited to circumstances when whales are subject to only low to moderate SELs. The calling rates of bowhead whales near a seismic survey provide an example of this, where at very low SELs (only just detectable) calling rates increased, but as SELs continued to increase, calling rates levelled off (as SELs reached 94 dB re 1µPa^2-s), then began decreasing (at SELs greater than 127 dB re 1µPa^2-s), with whales falling virtually silent once SELs exceeded 160 dB re 1µPa^2-s (Blackwell et al., 2015).

Based on the information above it is clear that seismic surveys could have effects on marine fauna acoustics and communication. This may be particularly so for marine mammals when the sounds generated by the survey overlap with the frequency range used by animals (Richardson et al., 1995).

Table 22 summarises the known frequencies of echolocation and communication calls for selected species of whales and dolphins. These species could be present in the Operational Area at the time of the survey.

Table 22: Frequencies of Cetacean Vocalisations

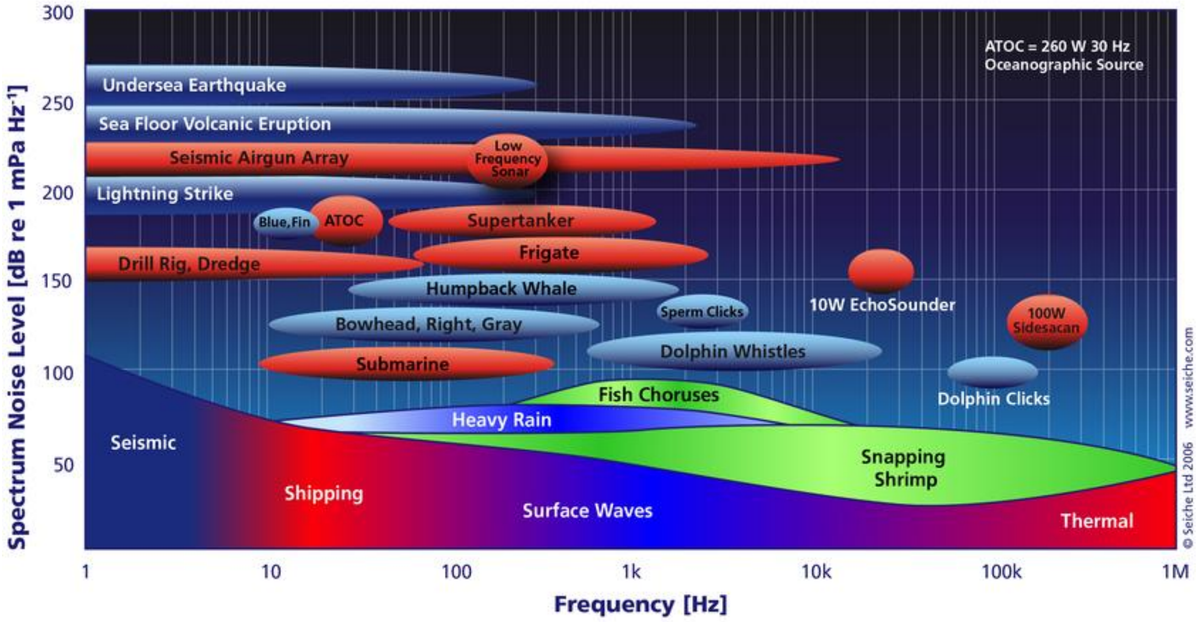
Species	Communication Frequency (kHz)	Echolocation Frequency (kHz)
Southern right whale	0.03 – 2.2	N/A
Minke whale	0.06 – 6	N/A
Sei whale	1.5 – 3.5	N/A
Bryde's whales	nd	nd
Blue whale	0.0124 – 0.4	N/A
Fin whale	0.01 – 28	N/A
Humpback whale	0.025 – 10	N/A
Sperm whale	< 9	0.1 – 30
Pygmy sperm whale	nd	60 - 200
Beaked whales*	3 - 16	2 - 26
Hector's/Maui's dolphin	nd	129**
Common dolphin	0.5 - 18	0.2 - 150
Pilot whale	1 – 8	1 – 18
Dusky dolphin	nd	40 - 110***
Killer whale	0.1 – 25	12 – 25
Bottlenose dolphin	0.2 - 24	110 - 150

Source: Summarised from Simmonds et al., 2004

Key:
nd = no data available
* = using the bottlenose whale as an example
** = Kyhn et al., 2009
*** = Au and Wursig, 2004

For the most part the echolocation frequencies for those species listed are much higher than the Māui 4D Seismic Survey seismic source; where the majority of energy is concentrated between 0.1 kHz and 0.25 kHz. There is however the potential for the acoustic source to interfere with lower frequency marine mammal communications; e.g. for blue whales a small overlap occurs at the highest end of the seismic spectrum and the lowest end of the vocalisation spectrum. **Figure 32** indicates which cetacean vocalisations are most at risk of overlap with marine seismic surveys. Vocalisations of mid and high frequency cetaceans are less likely to be masked.

Figure 32 Overlap of ambient and localised noise sources in the ocean



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

Recent research has highlighted the potential for seismic surveys in the South Taranaki Bight to mask blue whale calls (Torres & Klinck, 2017) and while this MMIA recognises this potential affect, we note that the ability to quantitatively assess masking is currently limited on account of 1) a lack of robust masking models (Erbe et al., 2016), 2) a lack of relevant background information which would be necessary undertake such modelling (e.g. the actual communication range of blue whales and the ambient noise levels; Clark et al, 2009), 3) the complexity of variables that affect individual masking scenarios and the fact that in real-life situations these are constantly changing (e.g. source level, directivity and orientation of both the whale and the seismic source; sound transmission path conditions; and ambient noise; Clark el al., 2009). Despite the challenges in assessing how masking could potentially affect blue whale calls during the Māui 4D Seismic Survey, it is reasonable to assume that the potential for masking is widespread throughout the South Taranaki Bight.

Mitigation measures to address acoustic disturbance are outlined at the end of this section.

Interruption of Behavioural Patterns and Displacement from Habitat

The most commonly observed behavioural response to active seismic operations is avoidance, which has been widely documented for 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). Avoidance is most common in mobile pelagic species and can potentially lead to temporary displacement of animals from optimal habitat. Displacement and other potential behaviour effects are discussed below.

A full description of mitigation measures to address acoustic disturbance are outlined at the end of this section**.**

Marine Mammals

Behavioural changes of marine mammals are readily documented in response to seismic surveys. Responses include:

- Avoidance: change in travel direction away from seismic source and/or lower density than expected in area affected by seismic surveys (e.g. Johnson et al., 2007; Potter et al., 2007; Koski et al., 2009; Stone & Tasker, 2006; Weir, 2008);
- Changes in vocal behaviour (e.g. Di Iorio & Clark 2010; IWC, 2007, as cited in Weilgart, 2007; Bowles et al. 1994; Cerchio et al. 2014); and
- Changes in dive behaviour (e.g. Gailey et al., 2007).

Temporary avoidance is the most commonly reported response by marine mammals in the vicinity of strong acoustic sources (Stone & Tasker, 2006); although some species appear to be attracted to low/medium acoustic sources (e.g. Wursig et al. 1998; Simmonds et al. 2004). Other changes in localised movements in marine mammals include: swimming away from the source, rapid swimming at the surface, and breaching (McCauley et al., 1998; McCauley et al., 2003). Surface behaviours are thought to reduce exposure to underwater noise on account of the 'Lloyd mirror effect' (Carey, 2009) which significantly reduces sound intensity in the upper-most part of the water column.

Avoidance behaviours may culminate in marine fauna being displaced from habitat. Detrimental effects could be expected if this displacement occurs from optimal habitat into sub-optimal alternatives; particularly if such displacement persists in the long-term. Consequences of displacement are poorly understood (Forney et al. 2013). It is likely that some short-term displacement will occur during the Māui 4D Seismic Survey for any marine mammals in the immediate vicinity of the active seismic vessel.

However, despite temporary avoidance responses being common some authors have concluded that longer term population level effects are unlikely (Johnson et al., 2007; Thompson et al., 2013). Thompson et al. (2013) documented that during a 2D seismic survey (SEL 145 – 151 dB re 1 $\mu Pa^2 s^{-1}$) in Scotland, harbour porpoises showed an initial avoidance response, but were typically detected again within a few hours; indicating that short-term disturbance may not necessarily lead to long-term displacement from habitat. Other studies have failed to detect any distributional changes, for example sperm whales in the vicinity of seismic operations in the Gulf of Mexico (Benoit-Bird et al., 2008).

A number of studies have investigated how temporary displacement might affect whale migration. Richardson et al. (1995) found that migrating bowhead whales avoided an operating seismic source by 20 – 30 km. In addition to this, migrating humpback whales exposed to 160 – 170 dB re 1 µPa (peak to peak) sounds from seismic surveys consistently changed their course and speed to avoid any close encounters with a seismic vessel (McCauley et al., 2003); however, the authors of this study concluded that acoustic disturbance did not cause changes in the overall regional migration patterns of cetaceans.

Changes in vocalisations (that are not considered to be a masking response) have also been documented. Examples of such changes are:

- Sperm whales reportedly decrease their vocalisations in response to seismic surveys (IWC, 2007, as cited in Weilgart, 2007; Bowles et al. 1994). A decrease in vocalisations associated with foraging behaviour (IWC, 2007, as cited in Weilgart, 2007) is particularly noteworthy as it may indicate a disruption to feeding behaviour or success;
- Fin whales stopped vocalising in the presence of a seismic survey (IWC, 2007, as cited in Weilgart, 2007);
- The number of 'singers' in a humpback whale population off Northern Angola significantly decreased with increasing exposure to seismic surveys (Cerchio et al. 2014). This effect may indicate disruption to breeding behaviours; and
- Blackwell et al. (2015) documented changes in bowhead whale calling rates to demonstrate that the magnitude of a response was heavily dependent upon the received sound levels, and that this effect was likely to apply to distributional changes as well.

Changes in dive behaviour are less well documented, but Gailey et al. (2007) found that dive time in grey whales increased in response to seismic noise.

Despite the effects of seismic surveys on beaked whales being unknown, their observed responses to mid-frequency active sonar (increased swim speed, unusual dive behaviours, multiple unusual mass strandings gas embolisms and changes in blood biochemistry) indicate that this group is particularly sensitive to anthropogenic noise (Stimpert et al., 2014; Fahlman et al., 2014).

The Code of Conduct uses the SEL criteria set out by Southall et al. (2007) to predict the potential for behavioural change in marine mammals; where behavioural change is predicted at SELs less than 171 dB re 1 μPa^2-s. As outlined earlier in this section, sound transmission loss modelling indicates that the SEL of 171 dB re 1 μPa^2-s will occur at 800 m from the acoustic source during the Māui 4D Seismic Survey. However, the potential displacement of pygmy blue whales (particularly mother/calf pairs) from optimal foraging areas warrants further discussion as outlined under the 'Indirect Effects' heading below.

Fish

There are a number of challenges associated with investigating the behavioural responses of fish to underwater noise (e.g. limitations of using caged fish and variability in experimental design). Despite these limitations, the following short-term responses have been observed for fish species:

- Changes in distribution both laterally and vertically within the water column (Pearson et al., 1992; McCauley et al., 2000; Woodside, 2007; Colman et al., 2008; Fewtrell & McCauley, 2012).
- Startle responses (Pearson et al., 1992; Wardle et al., 2001; Hassel et al., 2004; Boeger et al., 2006) or freezing (Sverdrup et al., 1994); and
- Modification in schooling patterns and swimming speed (Pearson et al., 1992; McCauley et al., 2000; Mueller-Blenkle et al. 2010; Fewtrell & McCauley, 2012).

Controlled exposure experiments were conducted to examine the effect of underwater noise on sole and cod which showed an increase in swimming speed during exposure periods; however, there was a high variability between individuals and a decrease in response indicated that habituation occurred through time (Mueller-Blenkle et al. 2010). Hassel et al. (2004) also found evidence of habituation to underwater noise through time; and other studies have failed to detect any changes in fish behaviour after exposure to underwater noise. For example, Peña et al. (2013) observed no changes in swim speed, direction or school size of herring in response to a six hour exposure to a full-scale 3D seismic survey.

The only evidence of a long-term behavioural effect from a seismic survey was noted by Slotte et al. (2004) who investigated the distribution and abundance of herring and blue whiting during a commercial 3D seismic survey off the Norwegian coast. During this study fish distribution was mapped acoustically within the seismic area and in the surrounding waters (up to 30 – 50 km away). The abundance of pelagic fish was consistently higher outside the seismic area than inside which the authors interpreted to be an indication of long-term displacement.

Seabirds

Little information exists about the behavioural effects of underwater noise on seabirds, but the following studies provide some evidence to suggest that significant population level effects are unlikely for surveys with limited durations:

- Turnpenny and Nedwell (1994) found no obvious response from diving birds in the presence of a seismic vessel;
- Webb and Kempf (1998) investigated shorebirds and waterfowl in an intertidal zone of the North Sea during a seismic survey and found no significant effect on bird counts and distribution; however some evidence of temporary avoidance within a 1 km radius of the seismic vessel was noted;
- Lacroix et al. (2003) conducted a quantitative radio-tracking study to assess the effect of seismic operations on the foraging behaviour of moulting male long-tailed ducks in the Beaufort Sea. These ducks are incapable of flying during the moult and during this time they spend more time foraging. This study found that 1) The abundance and distribution of ducks in both seismic and control areas changed similarly; 2) Seismic activity did not significantly change diving intensity; and 3) there was no evidence of displacement away from active seismic operations; and
- Pichegru et al. (2017) investigated the response of breeding African penguins to seismic operations near penguin colonies using GPS tracking. The results of this study showed strong avoidance of the seismic vessel; whereby individuals did not use preferred foraging areas when seismic surveys were active nearby. Birds reverted to normal behaviours as soon as operations ceased.

Non-Planktonic Invertebrates

Behavioural changes have been documented for cephalopods, crustaceans and shellfish as follows:

- Caged cephalopods exposed to acoustic sources demonstrated a startle response to sources above 151 – 161 dB re 1 µPa and showed behavioural changes towards surface activity in order to avoid high levels of sound exposure (McCauley et al., 2000). However, the use of soft-starts during this study decreased the magnitude of the startle response;
- Fewtrell and McCauley (2012) demonstrated that a source level of 147 dB re 1 µPa was necessary to induce an avoidance response in squid. Fewtrell and McCauley (2012) also reported alarm responses (inking and jetting away from the source), increased swimming speed, and aggressive behaviour in response to acoustic disturbance; however, reactions decreased with repeated exposure, suggesting either habituation or hearing loss;
- McCauley et al. (2000) suggested that thresholds affecting squid behavior occur at 161-166 dB re 1 µPa rms;
- A field experiment to assess behavioural effects of a 150 in^3 acoustic source on red rock lobster found that the ‘righting time’ in lobsters that had been placed on their backs significantly increased (Day et al., 2016); and
- Day et al. (2016) assessed the behavioural response of scallops to seismic exposure and found that seismic exposure increased the rate that scallops recessed themselves into the sediment, but that exposed scallops were slower at righting themselves than control scallops.

Indirect Effects

In many circumstances the distribution of marine mammals is linked to that of their prey (see Fielder et al., 1998), therefore avoidance of the seismic vessel by marine mammals could lead to abandonment of valuable feeding grounds (e.g. large aggregations of krill or fish) or overall reductions in foraging effort.

In addition, seismic data acquisition is known to alter the behavioural patterns or abundance of some prey species (e.g. fish; Pearson et al., 1992; McCauley et al., 2000; Colman et al., 2008; Handegard et al., 2013, and zooplankton; McCauley et al., 2017). Hence, distributional changes and changes in abundance of prey species are also well recognised as potential indirect effects of seismic surveys (Simmonds et al., 2004) and, in turn, could lead to decreased foraging efficiency, higher energetic demands, lower group cohesion, higher predation rates and decreased reproduction rates in marine mammals (Weilgart, 2007). Such indirect effects are much more difficult to detect and measure than direct effects; however, as with direct effects, they are likely to vary with species, individuals, age, sex, past exposure and behavioural state (IWC, 2007).

Of particular note, with regards to the Māui 4D Seismic Survey, is that pygmy blue whale distribution in the South Taranaki Bight is positively correlated with that of their zooplankton prey (Torres et al., 2015). Because of this, the fine-scale distribution of pygmy blue whales varies both within years and between years as oceanic conditions change (Torres & Klinck, 2016). Sightings of this species are relatively common within the Operational Area (see **Section 4.3.5**). In addition to potential blue whale displacement, a recent study by McCauley et al. (2017) suggests that seismic surveys may cause mortality of larval krill. While there is no information available with regard to how adult krill are affected by seismic surveys and there is some evidence to suggest that zooplankton populations may recover relatively quickly (Richardson et al., 2017), the mortality of krill larvae could presumably have a negative effect on the prey availability of pygmy blue whales in the South Taranaki Bight during the Māui 4D Seismic Survey. The potential presence of pygmy blue whale mother/calf pairs during the summer months (see Torres & Klinck, 2016) suggests that high quality prey at this time of year could be particularly important.

The indirect effects that changes in fish and crustacean distribution and abundance may have on commercial fishing operations are well documented. Reductions in catch per unit effort for commercial fishing vessels operating close to seismic operations have been demonstrated (Skalski et al., 1992; Engas et al., 1996; Bendell, 2011; Handegard et al., 2013), with effects lasting between one and five days after the conclusion of seismic operations. Streever et al. (2016) reported significant changes to catch rates (both increases and decreases) in response to seismic surveys in Prudhoe Bay, Alaska and postulated that these changes were a result of fish displacement where acoustic source activity could increase or decrease catches depending on the location and timing of the fishing effort in relation to the seismic survey. In other instances no evidence has been found to suggest that seismic surveys affect commercial fisheries (e.g. Pickett et al., 1994; Labella et al., 1996; Jakupsstovu et al., 2001; Andriguetto-Filho et al., 2005; Parry & Gason, 2006).

In general it is expected that any indirect effects would be spatially restricted to the immediate vicinity of the seismic vessel, with baseline conditions resuming relatively quickly after survey completion.

Acoustic Disturbance – Mitigations

Table 23 outlines the mitigation measures that will be employed during the Māui 4D Seismic Survey in order to minimise acoustic disturbance to the marine ecosystem and existing interests. Those mitigation measures that are required by the Code of Conduct are presented in the top section of the table, with those additional measures (i.e. over and above the requirements of the Code of Conduct) presented in the bottom section of the table.

Table 23: Mitigation measures to minimise acoustic disturbance

Requirements of the Code of Conduct

• The Māui 4D Seismic Survey will strictly adhere to the mitigation requirements as prescribed by the Code of Conduct and outlined in **Section 1.2.2** of this MMIA;
• A detailed Marine Mammal Mitigation Plan (MMMP) for the Māui 4D Seismic Survey is presented in **Appendix D**. This MMMP shall be used by observers and crew to guide operations in relation to marine mammal encounters at sea;
• Sound transmission loss modelling has been undertaken to predict the suitability of the mitigation zones required by the Code of Conduct. The modelling verifies that compliance with the standard mitigation zones should sufficiently protect marine mammals from permanent and temporary physiological effects;
• Ground-truthing of the modelled results for sound loss transmission will be undertaken during the Māui 4D Seismic Survey according to the methodology outlined in **Appendix F**;
• In accordance with the Code of Conduct, DOC will be notified immediately in the following circumstances:
  • For any instances of non-compliance with the Code of Conduct; and
  • Should high numbers of a species of concern be observed within the Operational Area.

Additional Management Actions
• Seismic survey operations will occur 24 hours a day, 7 days a week (weather and marine mammal encounters permitting) to minimise the overall duration of the survey; • Whilst transiting to and from the Operational Area, during daylights hours and if sighting conditions are good, a MMO will be on watch and recording marine mammal sightings. Any observations outside of the Operational Area will be reported in the DOC 'Off Survey' forms; • If any stranding's occur that result in mortality during or soon after the Māui 4D Seismic Survey, Shell Taranaki Limited will, on a case-by-case basis, consider covering the costs of undertaking a necropsy in an attempt to determine the cause of death; • Weekly MMO reports will be provided to DOC and the EPA; and • DOC will be notified immediately of any sightings of Māui or Hector's dolphins.

With these mitigation measures and management actions in place, the residual effects associated with acoustic disturbance are minimised. Assessments of significance for the residual impacts of acoustic disturbance are presented in **Table 24**.

Table 24: Predicted residual impacts of acoustic disturbance.

Residual Impacts	Comment	Significance
Physical and Physiological	• Marine Mammals: The sound transmission loss modelling predicts that the maximum SELs will be below the threshold for permanent threshold shift as defined by the Code of Conduct (186 dB re 1 µPa^2.s) at the 200 m Mitigation Zone (compliance is predicted to occur at 74 m from the source); and that the maximum SELs will be below the threshold for temporary threshold shift (171 dB re 1 µPa^2.s) at the 1,000 m Mitigation Zone (compliance is predicted to occur at 800 m from the source). Delayed starts and shut down mitigations which will be adopted in accordance with the Code of Conduct serve to limit marine mammal exposure to injurious SELs; i.e. 'species of concern' will only be exposed to these levels if they go undetected within the Mitigation Zones, and all other marine mammals will only be exposed to these levels if they chose to make close approaches to the source after full power operations have commenced.	**Moderate** (for 'species of concern') **Major or Severe** (for 'other marine mammals' or undetected 'species of concern'), depending on their distance of approach
	• Fish: The sound transmission loss modelling predicts that SELs greater than 186 dB_{cum} (the physiological injury threshold defined by Popper et al., 2014) will be restricted to within 10 m of the acoustic source.	**Minor**
	• Seabirds: The likelihood of birds diving in the immediate vicinity of the acoustic source is thought to be low as seabirds are typically startled from the sea surface by approaching vessels.	**Minor**
	• Non-Planktonic Invertebrates: sound transmission loss modelling predicts that SELs eliciting mortality (220 dB re 1µPa@1m) (Addison et al., 2004) are not predicted even in very close proximity to the source.	**Negligible**
	• Plankton: sound transmission loss modelling predicts that SELs eliciting a reduction in zooplankton abundance (156 dB 1 µPa^2 s^{-1}) (McCauley et al., 2017) would occur out to about 2.5 km from the source (following Richardson et al., 2017). No regional scale effects are predicted.	**Moderate**
Auditory Masking	• Despite mitigations being in place, there is the potential for masking of low frequency marine mammal vocalisations (e.g. pygmy blue whales in South Taranaki Bight) to occur. This residual effect would be limited to the survey duration and would cease immediately after survey completion.	**Moderate**
Interruption of Behaviour/ Displacement	• Marine Mammals: The sound transmission loss modelling predicts that SELs will fall below 171 dB re 1 µPa^2-s beyond 1,000 m of the acoustic source. Although mitigation measures (delayed starts and shut downs in accordance with the Code of Conduct) serve to protect marine mammals from physiological effects, behavioural responses may still result from exposure to noise from seismic surveys; and these behavioural responses are expected to occur at distances beyond the 1,000 m Mitigation Zone. Aside	**Moderate**

	from the extended mitigation zone for 'species of concern with calves' (1,500 m), the Code of Conduct does not specifically address the full range of potential behavioural effects that may result; however recovery from these effects typically occurs quickly after exposure ceases.	
	• Fish: Short-term displacement of some pelagic species is possible; however distribution is predicted to return to normal as soon as the survey is complete.	**Minor**
	• Seabirds: Some temporary avoidance may occur in the immediate vicinity of the seismic vessel. Significant population effects are unlikely.	**Minor**
	• Non-Planktonic Invertebrates: Some temporary behavioural effects may occur.	**Minor**
Indirect	• Despite mitigations being in place some indirect effects could occur. These effects (i.e. a localised change in distribution or abundance of prey species or quota species) would be temporary and localised. Any such effects are expected to return to baseline conditions rapidly.	**Moderate**

5.3.3 Solid and Liquid Waste Discharges

The discharge of waste overboard may contribute a number of potentially harmful pollutants to the marine environment that could reduce habitat quality. This is particularly so for sewage and non-biodegradable garbage. The discharge of waste at sea is regulated in New Zealand by the Resource Management (Marine Pollution) Regulations 1998 within the territorial sea and MARPOL requirements as enacted by Marine Protection Rules under the Maritime Transport Act 1994 within the EEZ.

The resultant effect of waste discharge depends on the type of waste and the flow characteristics of the water body into which the waste is discharged and the proximity to sensitive marine environments.

Biodegradable wastes produced during a seismic survey include black water (sewage/ wastewater from toilets), greywater (wastewater from sinks, showers, laundering, etc), galley wastes and oily water (from bilges). Once discharged to the marine environment these wastes undergo a process of bacterial decomposition either in the water column or on the seabed. There are two consequences to this process (Perić, 2016; Wilewska-Bien et al., 2016):

- Oxygen is required for bacteria to break down the waste, resulting in an increase in the local oxygen demand which, in turn, can lead to a depletion of the oxygen concentration in the surrounding waters; and
- Nitrogen and phosphorous are released and introduced into the surrounding environment.

As a result of these two processes oxygen can become limited for marine organisms, particularly in areas of low flow and restricted mixing, and the addition of nitrogen and phosphorous can enrich the surrounding environment leading to (potentially toxic) algal blooms. Black water and grey water may also contain a number of pathogens detrimental to human health such as *Salmonella* and gastro-intestinal viruses (Perić, 2016; Wilewska-Bien et al., 2016), while ground galley waste can provide a food source for larger organisms such as fish (Wilewska-Bien et al., 2016).

When discharged into the marine environment non-biodegradable wastes/garbage, for example plastics used in food wrapping and packaging, can have severe detrimental effects on marine fauna. Effects include entanglement, ingestion of foreign objects (leading to internal injury, blockage of intestinal tracts, and a reduction in fitness etc.), and accumulation of debris on the seabed and water column (Derraik, 2002). Various species of seabirds, fish, turtles, and marine mammals have all been found to ingest plastic debris (Derraik, 2002). Non-biodegradable wastes persist in the marine environment for extensive periods of time and may be transported large distances (Li et al., 2016).

Table 25 summarises the relevant legislation and the appropriate disposal routes for various common waste types within the EEZ and the territorial sea.

Table 25: Waste Disposal – Relevant Legislation and Requirements

Waste Type	Relevant National Legislation	Appropriate Disposal within Territorial Sea (within 12 Nm)	Relevant MARPOL Annex	Appropriate Disposal within EEZ (beyond 12 Nm)
Non-Biodegradable Garbage	Marine Protection Rules Part 170 Resource Management (Marine Pollution) Regulations 1998	Must be stored on-board until disposal onshore is possible.	Annex V	Generally must be stored on-board until disposal onshore is possible, however some exceptions may apply as detailed in MARPOL Annex V.
Biodegradable Food Waste	Marine Protection Rules Part 170 Resource Management (Marine Pollution) Regulations 1998	Comminuted food waste (ground to <25 mm particle size) can be discharged beyond 3 Nm.	Annex V	Non-comminuted food waste can be discharged
Sewage	Resource Management (Marine Pollution) Regulations 1998	Treated sewage (comminuted and disinfected) can be discharged beyond 3 Nm	Annex IV	Untreated sewage can be discharged
Grey water	NA	Permitted discharge	NA	Permitted discharge

<u>*Mitigations:*</u>

- The seismic source vessel and the support vessels will have an approved International Sewage Pollution Prevention Certificate as per the regulations of MARPOL Annex IV;
- Only treated sewage which meets the requirements of the Resource Management (Marine Pollution) Regulations 1998 will be discharged;
- Over and above the requirements of the Resource Management (Marine Pollution) Regulations 1998, biodegradable galley waste may be incinerated on-board to dissuade potential shark attraction and subsequent damage to streamers;
- All other solid and non-biodegradable liquid wastes will be retained aboard for subsequent disposal to managed facilities ashore;
- The seismic contractor will comply with a comprehensive Garbage Management Plan as per the '2012 guidelines for the development of Garbage Management Plans' with regard to Regulation 10 of the revised MARPOL Annex V;
- Garbage Management Plans will detail procedures for minimising, collecting, sorting, processing and disposing of all garbage and designate the crew responsible for garbage management;
- Garbage record books will be kept to enable operators and officials to audit all garbage discharges;
- All wastes returned to shore will be disposed of in strict adherence to local waste management requirements, with all chain of custody records retained by the seismic contractor; and
- Shell Taranaki Limited are committed to a 'Reduce, Reuse and Recycle wherever possible' approach to waste management.

With these mitigation measures in place, it is considered that there will be no residual effects from the discharge of waste during the Māui 4D Seismic Survey. Therefore waste discharges are considered to be **negligible**.

5.3.4 Atmospheric Emissions

The internal combustion engines onboard the vessels involved in the Māui 4D Seismic Survey will produce combusted exhaust gasses in the form of carbon dioxide and carbon monoxide. Other toxic inorganic gasses such as nitric oxide and nitrogen dioxide will also be produced by the engines (Steiner et al., 2016); however, these will be in much smaller quantities.

Emissions of carbon dioxide (and other gasses) are classed as greenhouse gas emissions and are linked to climate change. Combusted exhaust gasses can also reduce ambient air quality. A reduction in air quality is particularly problematic for populated areas where human health issues may arise or be exacerbated such as pulmonary disease, cardiovascular disease and cancer (Steiner et al., 2016)

Mitigations

The survey vessels will hold International Air Pollution Prevention Certificates, ensuring that all engines and other equipment are regularly serviced and maintained. The use of low sulphur fuel is also common place on seismic vessels, serving to reduce atmospheric emissions.

Given the largely offshore nature of the Operational Area and the proactive management of emissions, the environmental risk of atmospheric emissions during the Māui 4D Seismic Survey is considered to be **minor**.

5.4 Sources of Impact - Unplanned Events

Unplanned events are rare during marine seismic operations; however, they do pose a small potential risk and hence for completeness they are considered below.

Table 26 outlines the unplanned events which could occur in association with the Māui 4D Seismic Survey and that have the potential to impact the baseline marine environment.

Table 26: Sources of effect and associated potential effects – unplanned events

Fuel oil spill
Potential Effects: • Toxic effects on marine fauna; • External contamination of wildlife and coastal environment; and • Indirect effects on environment and existing interests.
Loss of towed gear
Potential Effects: • Introduction of marine debris.
Vessel collision
Potential Effects: • Introduction of marine debris; and • Accidental release of hazardous substances.
Biosecurity Incursion
Potential Effects: • Introduction of marine pests.

5.5 Potential Effects and Mitigation Measures – Unplanned Events

5.5.1 Fuel Oil Spill

A fuel oil spill from the seismic vessel or support vessels during the Māui 4D Seismic Survey could occur on account of:

- Leaking equipment/storage containers;
- Accidental releases from fuel containers;
- Hull/fuel tank failure due to collisions/sinking; and
- Accidental spill during a refuelling operation.

A fuel tank rupture poses the largest potential risk of environmental effect. Other potential spills are more readily contained on board and are generally only small volumes.

The effects of hydrocarbon spills are well known and include, but are not limited to, the following (Moore & Dwyer, 1974; as summarised in McConnell, 2014):

- Toxicity effects – can include direct and indirect (does not cause immediate death, although mortality may follow due to abnormal behaviour or other indirect causes (Moore & Dwyer, 1974)) and sub-lethal population effects such as disruption of feeding behaviours, physical damage (e.g. burns and ulcers), immunosuppression, and impaired reproduction. Internal contamination can occur if hydrocarbons are inhaled or ingested;
- Removal and damage to, or exclusion from habitats and other important areas (e.g. areas used for feeding, resting, migrating and breeding);
- Bioaccumulation of toxic substances in fauna. This is particularly relevant for molluscs;
- Long-term disruption of food chains and predator/prey interactions;
- External oiling on marine mammals and seabirds leading to loss of waterproofing, buoyancy, swimming ability, filtering capabilities (such as by baleen whales) and thermoregulatory abilities. These effects are particularly detrimental to seabirds and fur seals; and
- Exclusion of users of the marine environment due to contamination/tainting of edible species of altered perception.

Incidents while refuelling at sea, leakages from storage areas or equipment, and rupture/failure of the hull or fuel tank are potential causes of a hydrocarbon spill during the Māui 4D Seismic Survey. Of these causes, a refuelling incident at sea is the most likely, with hose ruptures, coupling failures, and tank overflow having the potential to result in a spill. Refuelling of the seismic vessel will occur either from the support vessel at sea (every two to three weeks) or at the start of the survey if a port call occurs. Hydrocarbon spills caused by handling mishaps are rare due to well-tested monitoring and management systems. A detailed refuelling protocol will be in place which will outline the procedures to be followed during refuelling operations.

The worst-case scenario for a fuel oil spill during the Māui 4D Seismic Survey would be the complete loss of fuel from the seismic vessel following a collision. However, this size of spill would only occur as a result of complete failure of the vessel’s internal fuel containment system or catastrophic hull damage. The likelihood of such an incident is considered to be extremely low due to the sophisticated navigational systems on board to minimise the chance of collisions, the presence of a support vessels and compliance with the COLREGS.

In the event of a hydrocarbon spill, a spill response will initially be undertaken in accordance with the Shipboard Oil Pollution Emergency Plan, and notification will be provided to Maritime New Zealand and the appropriate local authorities (e.g. Taranaki Regional Council).

Mitigations:

During refuelling the following mitigation measures will be adhered to in order to prevent a spill:

- Refuelling will only be undertaken during daylight hours and in sea conditions that have been deemed appropriate by the vessel master/s;
- Prior to each fuel transfer a Job Hazard Analysis (or equivalent) will be in place and reviewed by all parties participating in the refuelling;
- All transfer hoses will be fitted with 'dry-break' couplings (or similar). These will be checked for integrity before each use/fuel transfer;
- Emergency spill response kits will be maintained and located in close proximity to hydrocarbon refuelling, storage, and bunkering areas;
- Refuelling operations will be continuously manned throughout, with constant visual monitoring of equipment such as gauges, hoses, fittings and the sea surface (to identify any spill/leak);
- Radio communication will be maintained between all vessels involved in refuelling operations;
- The support vessel will not be refuelled at sea, and will instead refuel at an appropriate port; and
- Where applicable, all vessels involved in the survey will have an approved and certified Shipboard Oil Pollution Emergency Plan and an International Oil Pollution Prevention Certificate, as per MARPOL 73/78 and Marine Protection Rules Part 130A and 123A.

The mitigation measures outlined above are considered to sufficiently minimise the risk of fuel oil spills associated with the Māui 4D Seismic Survey. The severity and range of effects is dependent on a number of factors such as the spill scenario (i.e. substance spilt (e.g. diesel, petrol, crude oil), spill volume, location in relation to sensitive sites, and the sensitivity of the affected species, which may change between individuals of the same species (Moore & Dwyer, 1974). The most likely spill scenario associated with the Māui 4D Seismic Survey is a refuelling spill. Such a spill would result in a relatively small volume of fuel oil being discharged into a high energy marine environment, resulting in rapid evaporation and dispersion. For these reasons the potential effects of a spill of this nature are considered to be **minor** as effects are predicted to be short-term and highly localised.

5.5.2 Loss of Towed Gear

During marine seismic surveys it is possible that one or multiple components of towed gear could be lost at sea. The breakage of a streamer cable carries the highest potential risk and could occur on account of 1) severe weather, 2) snagging on floating and/or semi-submerged marine debris, 3) shark bite, or 4) being severed by the propeller of another vessel.

Gear that is lost and cannot be retrieved at sea could contribute to the broader issue of marine pollution. Towed gear for seismic surveys is typically negatively buoyant so would sink to the seafloor if lost. Potential impacts are therefore limited to benthic ecosystems and would be highly localised, e.g. crushing of individual macro-benthic organisms as gear settles onto the seabed. However the mitigations below reduce the likelihood of gear being lost to the sea bed.

Mitigations:

- The Māui 4D Seismic Survey will use negatively buoyant solid streamers, with 'self-recovery devices' (e.g. the GeoSpace SRD-500S). This means that any severed streamer would most likely be recovered before it settled onto the seafloor; and
- The Māui 4D Seismic Survey will adhere to international best practise with regard to gear deployment and retrieval and these operations will be managed by experienced personnel.

The likelihood of loss of towed gear at sea is low during a marine seismic survey, and given the mitigations in place any potential effect associated with gear loss is considered to be **minor**. In the event that a streamer does make contact with the seafloor, it is useful to note that areas of archaeological interest or cultural significance are typically associated with intertidal and subtidal coastal environments, instead of offshore areas like those in the Operational Area.

5.5.3 Vessel Collision and/or Sinking

The most significant environmental effects associated with a vessel collision or sinking is 1) the potential for the discharge of hazardous substances (including fuel oil, lubricants, and other chemicals), 2) disturbance to the benthic ecosystem as the vessel hits the sea floor, and 3) pollution to the marine environment through the spread of debris.

The discharge of oil has largely been addressed in **Section 5.5.1**; hence, the focus here is on disturbance to the seafloor and the introduction of debris pollution into the marine environment.

Large pieces of wreckage from a sinking or collision event are likely to descend and settle onto the sea floor. This has the potential to damage benthic habitat and crush individual animals (e.g. demersal fish and epibenthic organisms).

The introduction of debris into the marine environment could result in:

- The entanglement of marine fauna in debris;
- The ingestion of man-made objects by marine mammals, seabirds, fish and marine reptiles which can lead to health issues from gastric impactions;
- A reduction in habitat quality for marine fauna; and
- Creation of navigational hazards from floating of semi-submerged debris.

Mitigations:

- A Notice to Mariners will be issued and a vigilant watch will be maintained throughout the survey;
- The survey operations will comply with the COLREGS, in terms of obligatory radio communications, navigation lights, day shapes, and appropriate navigational practices;
- During the survey, support vessels will assist with navigation safety (particularly with regard to alerting other marine users to the approaching seismic survey vessel) and the implementation of any non-interference zone;
- Tail buoys will mark the end of each streamer which will also have radar reflectors and lights fitted to assist with navigation; and
- The Operational Area lies within the Taranaki Offshore Precautionary Area which requires all ships to navigate with particular caution in order to reduce the risk of maritime casualty and resulting marine pollution.

The likelihood of a collision or sinking is considered to be very low, and although some risks are can be managed through the mitigations listed above, the significance of this unplanned event is considered to be **moderate**.

5.5.4 Biosecurity Incursion

International vessel movements are generally considered the main causes of the spread and introduction of exotic marine species, with transportation of organisms usually occurring as part of biofouling on hulls, anchor chains and in sea chests, or in ballast and bilge water (Bax et al., 2003; Fletcher et al., 2017). An exotic species is considered to be 'invasive' once it begins to cause negative consequences in the new environment (Bax et al., 2003). A chain of events must occur in order for pest establishment to take place, starting with the colonisation of a vessel by a non-indigenous species in its source region, followed by the survival of that species during transit, and finally the subsequent release and establishment of that species within New Zealand waters. Once established in the marine environment, invasive species are difficult to manage or eradicate (Fletcher et al., 2017). Potential effects of the introduction of invasive species include:

- Ecological impacts - changes in function and composition of native biological communities; and
- Economic impacts on economically important sectors (e.g. aquaculture, tourism, and fisheries) (Fletcher et al., 2017).

In order to mitigate the risk discussed above, the Ministry for Primary Industries standards are required to be met by all incoming vessels into New Zealand waters. These standards are in the form of the 'Import Heath Standard for Ships' Ballast Water from all Countries', and the 'Craft Risk Management Standard – Biofouling on Vessels Arriving to New Zealand'.

The Import Heath Standard for Ships' Ballast Water from all Countries prohibits the discharging of ballast water loaded in another country's water inside New Zealand territorial waters without permission. A vessel must show that its ballast water was, or will, be exchanged adequately with mid-ocean water in order to gain permission from the Ministry for Primary Industries to enter New Zealand territorial waters. All vessels used by Shell Taranaki Limited during this marine seismic survey will comply with the Import Heath Standard for Ships' Ballast Water from all Countries and in addition to this the vessels will not be new arrivals into New Zealand waters.

The Craft Risk Management Standard – Biofouling on Vessels Arriving to New Zealand comes into force on 15 May 2018 and requires all vessels to arrive in New Zealand territorial waters with 'clean hulls'. This Craft Risk Management Standard has been developed in line with the 2011 International Maritime Organisation Guidelines for Biofouling Management. It includes measures to be used by vessels in order to comply with the Standard, and the Ministry for Primary Industries will work with operators to help decide which measures are most suitable for them. The vessels that will be contracted to complete this marine seismic survey will be required to comply with the Craft Risk Management Standard – Biofouling on Vessels Arriving to New Zealand even though it is currently voluntary through to May 2018. In addition to this the vessels will not be new arrivals into New Zealand waters.

Mitigations

- The implementation of management measures to ensure the vessel meets the clean hull requirement of the Craft Risk Management Standard – Biofouling on Vessels Arriving to New Zealand;
- Adherence to the Import Standard for Ballast Water Exchange; and
- The survey vessels will not be new arrivals into New Zealand waters.

Based on the Shell Taranaki Limited commitment to comply with both the Import Heath Standard for Ships' Ballast Water from all Countries, and the Craft Risk Management Standard – Biofouling on Vessels Arriving to New Zealand; the risk of a biosecurity incursion from the Māui 4D Seismic Survey is considered to be **negligible**.

5.6 Cumulative Effects

Cumulative effects result when the effects of an activity are added to or interact with other effects in a particular place and within a particular time. In accordance with the 'Cumulative Effects Assessment Practitioner Guide' (CEA, 1999) the following conditions must be met in order for a cumulative effect to occur in relation to an activity:

- There must first be an environmental effect from the singular activity; and
- That effect must be demonstrated to operate cumulatively with the environmental effects from other activities, either past, existing or those planned for the future.

Because low frequency acoustic energy from seismic surveys travels large distances underwater the zone of influence associated with a seismic survey is typically extensive (see **Section 5.3.2**).

Based on the sound transmission loss modelling, the physiological and behavioural effects will most likely be limited to the immediate 1,000 m surrounding the acoustic source array. However, the long-range modelling predicts that the seismic source will be audible underwater for tens of kilometres. Without knowing the background underwater noise levels in the Taranaki there is no way of knowing at what distance the propagating seismic sound matches that of background levels, but it is fair to predict that a degree of masking could occur outside the Operational Area during the survey.

To assess the cumulative effects of the Māui 4D Seismic Survey, other marine activities that might also have an impact on environmental receptors in the zone of influence also need to be identified in order to ascertain any potential for impact overlap.

The following activities have been identified which could, or will, occur in the vicinity of the Operational Area:

- Oil and gas related operations;
- Commercial fishing; and
- Commercial shipping.

Each of these activities is described briefly below. As acoustic disturbance is unequivocally the most likely significant effect from the Māui 4D Seismic Survey, the discussions below focus on the acoustic characteristics of the concurrent activities.

Oil and Gas Related Operations

The Taranaki Basin is the only hydrocarbon producing basin in New Zealand and therefore is a primary focus of oil and gas related activity. No drilling is scheduled to occur in early 2018; however, production activities will be ongoing.

The Māui A and B Platforms are located within the Operational Area and produce natural gas and condensate 24 hours per day. The noise produced by the platforms has not been specifically characterised, but during standard day to day production activities this noise is most likely dominated by the movements of support vessels and machinery noise associated with pumping.

In addition to production activities, other seismic surveys could occur in the Taranaki Basin early in 2018; however, only one seismic vessel is likely to be present which eliminates any potential for temporal overlap of seismic operations in the Taranaki Basin. It is however possible that this single seismic vessel will conduct a series of consecutive surveys; hence could be operational in the Taranaki Basin for a longer period than the 40 day operational window for the Māui 4D Seismic Survey. In particular Shell Taranaki Limited is aware of a preceeding survey which will also be conducted from the *MV Amazon Warrior* and will occur during December 2017 and January 2018. On this basis it is possible that seismic operations will be ongoing from December to April within the Taranaki Basin.

In order to predict the potential cumulative effects of these consequetive surveys is to assume that 1) all surveys are Level 1 surveys under the Code of Conduct; 2) all surveys will have acoustic source levels similar to those which will be used for the Māui 4D Seismic Survey; and 3) the zone of influence will be over 10 km for each survey.

On this basis there is the potential for prolonged acoustic disturbance in the Taranaki Basin, but behavioural and physiological effects will be sufficiently managed through the MMIA process that DOC oversees. There is however the potential for auditory masking and a reduction in zooplankton abundance to occur throughout the cumulative period of seismic operations.

Another seismic survey vessel will be operating in New Zealand waters throughout the duration of the Māui 4D Seismic Survey. This vessl (the R/V Marcus Langseth) will be operating from the Bay of Plenty to Cape Palliser through November/December 2017; and Fiordland to the Puysegur Trench in early 2018. Based on the relative geographical isolation of these areas from the Operational Area, there is unlikely to be any overlap in the sound fields of the surveys.

Commercial Fishing

Commercial fishing activities in the offshore Taranaki were discussed in **Section 4.4.2**. The act of fishing itself will not contribute significantly to the noise profile in the area and the movement of fishing vessels is considered along with other commercial shipping traffic below.

Cumulative effects of fishing (the removal of fish stocks) and the potential for fish to be displaced from habitat during seismic operations could result in an overall decrease in the density of some fish species in offshore Taranaki. Any cumulative effects of this nature would be limited to those fish species targeted by commercial fisheries, e.g. jack mackerel and barracouta.

Commercial Shipping

The low frequency nature of shipping noise, like seismic operational noise, means that it travels long distances underwater. Many commercial vessels use the offshore area regularly and hence it is likely that background shipping noise is virtually constant in this region. The low intensity/low frequency background noise generated by shipping could mask some low frequency cetacean calls in the area. This coupled with the potential masking effects of the Māui 4D Seismic Survey most likely increases the likelihood of masking in the offshore Taranaki for the duration of seismic operations.

There is growing evidence to suggest that in the presence of noise, marine mammals can change their vocalisations (intensity/frequency) so that their calls are less likely to be masked showing some adaptation to increased noise levels (McGregor et al. 2013); however energetic costs to individuals that compensate in this manner are unknown.

Mitigations

The primary mitigations associated with acoustic disturbance for the Māui 4D Seismic Survey are outlined at the end of **Section 5.3.2**. No additional mitigations are recommended to address the potential cumulative effects outlined above.

Despite the proposed mitigations, some additional masking of marine fauna calls can be expected, as well as a possible decrease in zooplankton abundance. The cumulative masking potential associated with the interaction of the Māui 4D Seismic Survey with other marine activities is predicted to cease immediately at the completion of the survey and reductions in zooplankton abundance are predicted to be localised with recovery to pre-survey abundances occurring relatively quickly (days to weeks); hence cumulative effects are considered to have a **moderate** residual effect.

5.7 Summary

Table 27 provides a summary of the potential effects associated with the Māui 4D Seismic Survey and the predicted significance of residual effects as per the criteria presented in **Table 19**. Note that the significance of residual effects describes the significance of any predicted effects assuming all mitigation actions are being taken.

Table 27: Summary of Potential Residual Effects and Significance

	Potential Residual Effects	Significance
Planned Activities	**Physical Presence of Seismic Vessel, Towed Gear and Support Vessels**	
	Ship strike - marine mammals	Negligible
	Collision – seabirds	Negligible
	Displacement of marine fauna from Operational Area	Minor
	Displacement of existing interests from Operational Area	Minor
	Indirect effects	Minor
	Acoustic Disturbance	
	Physiological injury for Species of Concern (detected)	Moderate
	Physiological injury for Species of Concern (undetected)	Major/Severe*
	Physiological injury for Other Marine Mammals	Major/Severe*
	Physiological injury for Fish	Minor
	Physiological injury for Seabirds	Minor
	Physiological injury for Non-Planktonic Invertebrates	Negligible
	Physiological injury for Plankton	Moderate
	Auditory Masking	Moderate
	Behavioural impacts for Species of Concern with calves	Moderate
	Behavioural impacts for Species of Concern	Moderate
	Behavioural impacts for Other Marine Mammals	Moderate
	Behavioural impacts for Fish	Minor
	Behavioural impacts for Seabirds	Minor
	Behavioural impacts for Non-Planktonic Invertebrates	Minor
	Indirect effects	Moderate
	Solid and liquid waste discharges	
	Sewage, greywater, galley waste & garbage	Negligible
	Atmospheric emissions	Minor
Unplanned Events	Fuel oil spill	Minor
	Loss of towed gear	Minor
	Vessel collision or sinking	Moderate
	Biosecurity incursion	Negligible
	Cumulative effects	
	Interaction - impacts of seismic and unrelated activities	Moderate
Key:	** Depending on approach distance to acoustic source*	

6 MONITORING AND REPORTING

6.1 Marine Mammal Mitigation Plan

Under the Code of Conduct and as part of this MMIA, a MMMP is required for proposed Level 1 seismic surveys in New Zealand fisheries waters. An MMMP has been developed for the Māui 4D Seismic Survey and is included as **Appendix D**. The MMMP becomes the standard operating procedure to be followed at sea during seismic survey operations and guides crew and MMOs of their duties and obligations in accordance with the Code of Conduct and any additional mitigation measures outlined in the MMIA.

Monitoring and reporting are key components of the MMMP, whereby:

- All sightings of marine mammals during the survey period will be recorded in a standardised format (both 'on-survey' and 'off-survey');
- A written trip report shall be submitted to DOC within 60 days of the survey completion date;
- MMO raw datasheets will be submitted directly to DOC within 14 days of the survey completion; and
- The voluntary provision of weekly reports to DOC and EPA outlining 1) monitoring effort (visual and PAM); 2) source operations and mitigation actions; and 3) a summary of marine mammal detections and any resulting actions following these detections.

6.2 Research

Once lodged with DOC, MMO data resulting from the Māui 4D Seismic Survey is available at the discretion of DOC for the purposes of research. This research may be undertaken by DOC or other research groups and may assist with both understanding of distributional patterns of marine mammals in New Zealand and the behaviour of marine mammals in relation to active seismic operations. Shell Taranaki Limited recognises and supports this commitment to increase the understanding of these topics.

7 STAKEHOLDER ENGAGEMENT

Shell Taranaki Limited is committed to ongoing engagement with the local Māui community as part of their broader community engagement programme. The Māui Community includes iwi and hapū, the Māui Community Advisory Group (CAG), close onshore neighbours, commercial and recreational fishing groups and other interested parties.

Engagement was initiated with a number of local and national groups during the preparation of this MMIA who were identified as having an interest in the Māui field area. Consultation in relation to this activity builds on the existing and ongoing community engagement programme that Shell Taranaki Limited operates.

Identification of parties with an interest in Shell Taranaki Limited activities has occurred through processes which have evolved over the past 60 years of engagement with Taranaki communities. The Māui community has been established since the very early stages of field development some 40 years ago, and has evolved and grown significantly through time. Shell Taranaki Limited has sophisticated mechanisms for identifying and communicating with the community, including;

- The Māui Community Advisory Group (CAG), made up of representatives from the communities near the Māui field. Members were originally invited and new members are now elected through a voting process, with membership ranging from school teachers to neighbours and farmers. The CAG has an appointed chairperson and meets with Shell Taranaki Limited representatives once a quarter for an update on activities and an opportunity to provide any feedback. An agenda is sent out prior and minutes are taken of the discussion and actions. Special CAG meetings are convened for matters that require a particular focus.
- Hui are held with iwi and hapū who are kaitiaki (guardians) of the Māui rohe (area). Shell Taranaki Limited acknowledges that the Te Kahui o Taranaki Trust and Ngāti Tara hapū have existing interests through their exercise of mana whenua and mana moana of this area. Ongoing discussions will continue with the Te Kahui o Taranaki Trust and Ngāti Tara hapū throughout the Māui 4D Seismic Survey, as part of a broader meaningful relationship. In 2015 Shell and the Te Kahui o Taranaki Trust signed a Relationship Agreement which sets out the framework for an ongoing relationship. This document represents the commitment, from both Shell Taranaki Limited and the iwi, to continue to develop and build upon a meaningful and engaging relationship.
- Neighbours who are not part of the CAG are engaged via face to face visits or written updates. Communication methods include a text message system that provides instant assurance regarding activities in the area and community newsletters that are sent to regulators, schools, emergency services, fishing groups, iwi, hapū, neighbours and local businesses.

In addition to the approach described above, the engagement scope for the Māui 4D Seismic Survey was broadened to a wide range of potentially interested stakeholders based on the requirements of the Code of Conduct and indications from other applications. This included a number of additional iwi and hapū within the Taranaki Region, fishing groups, technical experts and regulators.

Stakeholders were encouraged to contact Shell Taranaki Limited at any time with further questions, concerns or for more information. A consultation register, along with consultation related correspondence and material is included in **Appendix A**.

8 CONCLUSION

Marine seismic surveys are common within the oil and gas sector in New Zealand with well-established standard procedures to mitigate the associated potential effects. In accordance with the EEZ Act – Permitted Activities Regulations, Shell Taranaki Limited will comply with the mitigation actions described in the Code of Conduct to manage both behavioural and physiological effects to marine mammals during the Māui 4D Seismic Survey.

Sound transmission loss modelling has been conducted and predicts that the standard mitigation measures outlined in the Code of Conduct are sufficient to mitigate adverse effects associated with this survey. In addition, Shell Taranaki Limited have offered to implement a suite of other management actions to further reduce potential environmental effects.

The potential environmental effects, associated mitigation measures and additional management actions which Shell Taranaki Limited will implement to minimise such effects have been thoroughly described in this MMIA. In summary, the potential effects of the Māui 4D Seismic Survey are assessed to be mostly minor or moderate whereby recovery is predicted within 24 hours. Moderate effects include 1) potential temporary behavioural changes for marine mammals; 2) a reduction in zooplankton abundance within 2.5 km from the source; 3) the potential masking of low frequency baleen whale calls; and 4) indirect effects associated with changes in prey availability. More significant effects (major or severe) could potentially occur for other marine mammal species (i.e. those not considered to be Species of Concern) that make close approaches to the acoustic source during full seismic operations or for Species of Concern that go undetected within the designated Mitigation Zones.. However, it is envisaged that the use of delayed starts and soft starts will minimise the direct effects on marine mammals which is indeed their intended purpose under the Code of Conduct.

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Consultation Register

Stakeholder	Engagement	Date	Feedback
NZ Petroleum & Minerals	Notification of possible survey (letter)	18/9/17	Receipt acknowledged
Department of Conservation	Notification of possible survey (letter)	18/9/17	Receipt acknowledged
Department of Conservation (DoC) Environmental Protection Authority (EPA)	Meeting	17/11/17	Provided overview of survey including objectives, area and timing. Discussed compliance with Code of Conduct including MMIA, modelling, ground-truthing and stakeholder engagement.
Te Kahui o Taranaki Trust	Phone call Email update	1/12/17 6/12/17	Thanks for information. Te Kahui to confirm Shell's attendance at next trustee meeting scheduled for January.
Ngāti Tara hapū	Phone call Email update	5/12/17 6/12/17	Questions around current survey being undertaken in the area. Continue to keep informed.
Te Korowai o Ngāruahine Trust	Phone call Email update	5/12/17 6/12/17	Te Korowai's submission to NZPAM provided to Shell for consideration. Concerns around the number of surveys happening this summer. More information and MMIA to be provided.
Te Atiawa Iwi	Email update	6/12/17	
Ngāti Rāhiri hapū	Email update	6/12/17	Trained hapū MMOs to be considered for this survey.
Ngāti Te Whiti hapū	Email update	6/12/17	
Māui Community Advisory Group	Phone call to CAG chair Email update	5/12/17 6/12/17	CAG meeting schedule for 22nd January to provide an update.
Ngāti Ruanui	Email update	6/12/17	Request information on environmental protection measures and compliance with all necessary regulations.
Taranaki Regional Council	Phone call & email	6/12/17	Provided overview of survey. Draft MMIA to be provided. Discussed likely status of Proposed Regional Coastal Plan at time of survey.
Cape Egmont Boat Club	Email update	6/12/17	
• Egmont Seafoods • Taranaki Recreational Fisheries	Email update	6/12/17	Continue to keep informed. Request a copy of MMO and PAM reports if survey proceeds.
Deepwater Group	Email update	6/12/17	
Southern Inshore Fisheries	Email update	6/12/17	
• Talleys/Sealord • NZ Federation of Commercial Fishermen	Email update	6/12/17	
NZ Marine Farmers	Email update	6/12/17	
Te Ohu Kaimoana	Email update	6/12/17	
Ministry for Primary Industries	Email update	6/12/17	
Port Taranaki	Email update	6/12/17	
NZ Rock Lobster Industry Council	Email update	6/12/17	
Forest and Bird	Email Phone call	6/12/17 6/12/17	Specific queries around: - Survey design details - Air gun array size - 24/7 operations - Timing - Species detection and mitigation measures - Modelling and ground truthing - Use of multi-beam echo sounders Concerns around: - Code of conduct adequately detecting elusive species

			- Blue whale detection at night - Cumulative impacts - Consultation process regarding input into the MMIA
NIWA	Email	6/12/17	Receipt acknowledged, no hydrophones currently deployed
Oregon State University	Email	6/12/17	Concerns around cumulative impacts from consecutive surveys, also indicated a high number of blue whale sightings in recent months
Auckland University	Email	6/12/17	
Massey University	Email Phone	6/12/17 21/12/17	Discussion about upcoming stranding research
Project Jonah	Email	6/12/17	

Passive Acoustic Monitoring Specifications

PAM Specifications

Cetacean Detection Capability

The vocalisations made by the full range of marine mammal species can be detected by our PAM systems. Typical system configuration has the capability of detecting sounds within a frequency range of 200 Hz to 200 kHz. This frequency band covers most marine mammal vocalisations. The system sensitivity may be extended to 10 Hz to 200 kHz for surveys in which it is necessary to monitor for baleen whales that vocalise at very low frequencies. However, in some circumstances, vessel noise at low frequencies can mask marine mammal vocalisations and limit the performance of PAM. The frequency response of some hydrophone channels is set to counter this (e.g. lower frequency response of 2 kHz for channels designed to detect the majority of species vocalisations). Seiche can readily tailor the frequency sensitivity of the hardware to suit the project application and the range of marine mammal species likely to be encountered. Additionally, PAMGuard software can be configured to focus on the detection of the vocalisations of particular species of interest or concern.

PAMGuard Software

PAMGuard software is integrated into all our PAM systems. PAMGuard is industry-standard software for the acoustic detection, localization and classification of vocalizing marine mammals. It is a sophisticated and extendible software package that assists trained operators in robust decision-making during real-time mitigation operations. As an open source development, PAMGuard is publicly owned and freely available. PAMGuard development is led by a team of specialists at the University of St Andrews, U.K. This has to date been funded by industry via the IOGP Sound and Marine Life Joint Industry Program. Funding is now transitioning to a self-funding mechanism operated through voluntary user contributions.

Table 1. Hydrophone elements frequency range

Hydrophone Elements	
H1	10 Hz to 200 kHz (-3 dB points)
H2	10 Hz to 200 kHz (-3 dB points)
H3	2 Hz to 200 kHz (-3 dB points)
H4	2 Hz to 200 kHz (-3 dB points)

Table 2. Hydrophone sensitivity

Hydrophone sensitivity	
Broadband channel sensitivity	-166 dB re 1V/μPa (nominal)
Standard channel sensitivity	-157 dB re 1V/μPa (nominal)

Summary of NZ Threat Classification System

Criteria for Threatened Taxa as described by the New Zealand Threat Classification System (following Townsend et al. 2008) and as applied to marine mammals (see Baker et al. 2016).

Classification		**Criteria**
Nationally Critical	A	**Very small population (natural or unnatural)** • There are fewer than 250 mature individuals; or • There are ≤ 2 sub-populations *and* ≤ 200 mature individuals in the largest sub-population; or • The total area of occupancy is ≤ 1 ha (0.01 km2).
	B	**Small population (natural or unnatural) with a high ongoing or predicted decline** • There is an ongoing or predicted decline of 50–70% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer; and • The population comprises 250–1000 mature individuals; or • There are ≤ 5 sub-populations *and* ≤ 300 mature individuals in the largest sub-population; or • The total area of occupancy is ≤ 10 ha (0.1 km2).
	C	**Population (irrespective of size or number of sub-populations) with a very high ongoing or predicted decline (> 70%)** • A taxon is 'Nationally Critical' when the population has an ongoing trend or predicted decline of > 70% in the total population due to existing threats taken over the next 10 years or three generations, whichever is longer.
Nationally Endangered	A	**Small population (natural or unnatural) that has a low to high ongoing or predicted decline** • There is an ongoing or predicted decline of 10–50% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer; and • The total population size is 250–1000 mature individuals; or • There are ≤ 5 sub-populations *and* ≤ 300 mature individuals in the largest sub-population; or • The total area of occupancy is ≤ 10 ha (0.1 km2).
	B	**Small stable population (unnatural)** • The population is stable (± 10%) and is predicted to remain stable over the next 10 years or three generations, whichever is longer; and • The total population size is 250–1000 mature individuals; or • There are ≤ 5 sub-populations *and* ≤ 300 mature individuals in the largest sub-population; or • The total area of occupancy is ≤ 10 ha (0.1 km2).
	C	**Moderate population and high ongoing or predicted decline** • There is an ongoing or predicted decline of 50–70% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer; and • The total population size is 1000–5000 mature individuals; or • There are ≤ 15 sub-populations *and* ≤ 500 mature individuals in the largest sub-population; or • The total area of occupancy is ≤ 100 ha (1 km2).

Nationally Vulnerable	A	**Small, increasing population (unnatural)** The population is increasing (> 10%) and is predicted to continue to increase over the next 10 years or three generations, whichever is longer; and The total population size is 250–1000 mature individuals; or There are ≤ 5 sub-populations *and* ≤ 300 mature individuals in the largest sub-population; or The total area of occupancy is ≤ 10 ha (0.1 km2).
	B	**Moderate, stable population (unnatural)** • The population is stable (± 10%) and is predicted to remain stable over the next 10 years or three generations, whichever is longer; and • The total population size is 1000–5000 mature individuals; or • There are ≤ 15 sub-populations *and* ≤ 500 mature individuals in the largest sub-population; or • The total area of occupancy is ≤ 100 ha (1 km2).
	C	**Moderate population, with population trend that is declining** • There is an ongoing or predicted decline of 10–50% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer; and • The total population size is 1000–5000 mature individuals; or • There are ≤ 15 sub-populations *and* ≤ 500 mature individuals in the largest sub-population; or • The total area of occupancy is ≤ 100 ha (1 km2).
	D	**Moderate to large population and moderate to high ongoing or predicted decline** • There is an ongoing or predicted decline of 30–70% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer; and • The total population size is 5000–20 000 mature individuals; or • There are ≤ 15 sub-populations *and* ≤ 1000 mature individuals in the largest sub-population; or • The total area of occupancy is ≤ 1000 ha (10 km2).
	E	**Large population and high ongoing or predicted decline** • There is an ongoing or predicted decline of 50–70% in the total population or area of occupancy due to existing threats, taken over the next 10 years or three generations, whichever is longer; and • The total population size is 20 000–100 000 mature individuals; or • The total area of occupancy is ≤ 10 000 ha (100 km2).

Marine Mammal Mitigation Plan

global environmental solutions

Māui 4D Seismic Survey

Marine Mammal Mitigation Plan

Report Number 740.10033.00200

8 December 2017

Shell Taranaki Limited

167 Devon Street West

New Plymouth

Version: v0.1

Māui 4D Seismic Survey

Marine Mammal Mitigation Plan

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Reference	Status	Date	Prepared	Checked	Authorised
740.10033.00200	v0.1	8 December 2017	Helen McConnell	Dan Govier	Dan Govier

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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 'Māui 4D Seismic Survey'.

This MMMP will be used by observers and crew to guide operations in accordance with the Department of Conservations (DOC) *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* ('Code of Conduct') and the Māui 4D Seismic Survey Marine Mammal Impact Assessment.

1.2 Survey Outline

Shell Taranaki Limited is proposing to acquire a four dimensional (4D) marine seismic survey in the Taranaki Basin. The 'Survey Area' outlined in **Figure 1**, represents the area for which full-fold seismic data will be acquired. The Survey Area lies primarily within Petroleum Mining Licence (PML) 381012, with extensions into Petroleum Exploration Permit (PEP) 51906. Surrounding the Survey Area is a larger Operational Area which is all encompassing and provides a buffer for run in/out, line turns, acoustic source testing and soft start source initiation. No seismic operations during the Māui 4D Seismic Survey will occur outside this Operational Area. The coordinates of the Operational Area are provided in **Appendix 1.**

The Operational Area does not approach or enter any Marine Mammal Sanctuary. The closest marine mammal sanctuary is the West Coast North Island Marine Mammal Sanctuary which is located approximately 6.7 km to the northeast of the Operational Area. Water depths within the Operational Area range from 80 to 150 m.

The seismic survey is predicted to take up to 40 days to complete, and is scheduled to begin in mid-February 2018.

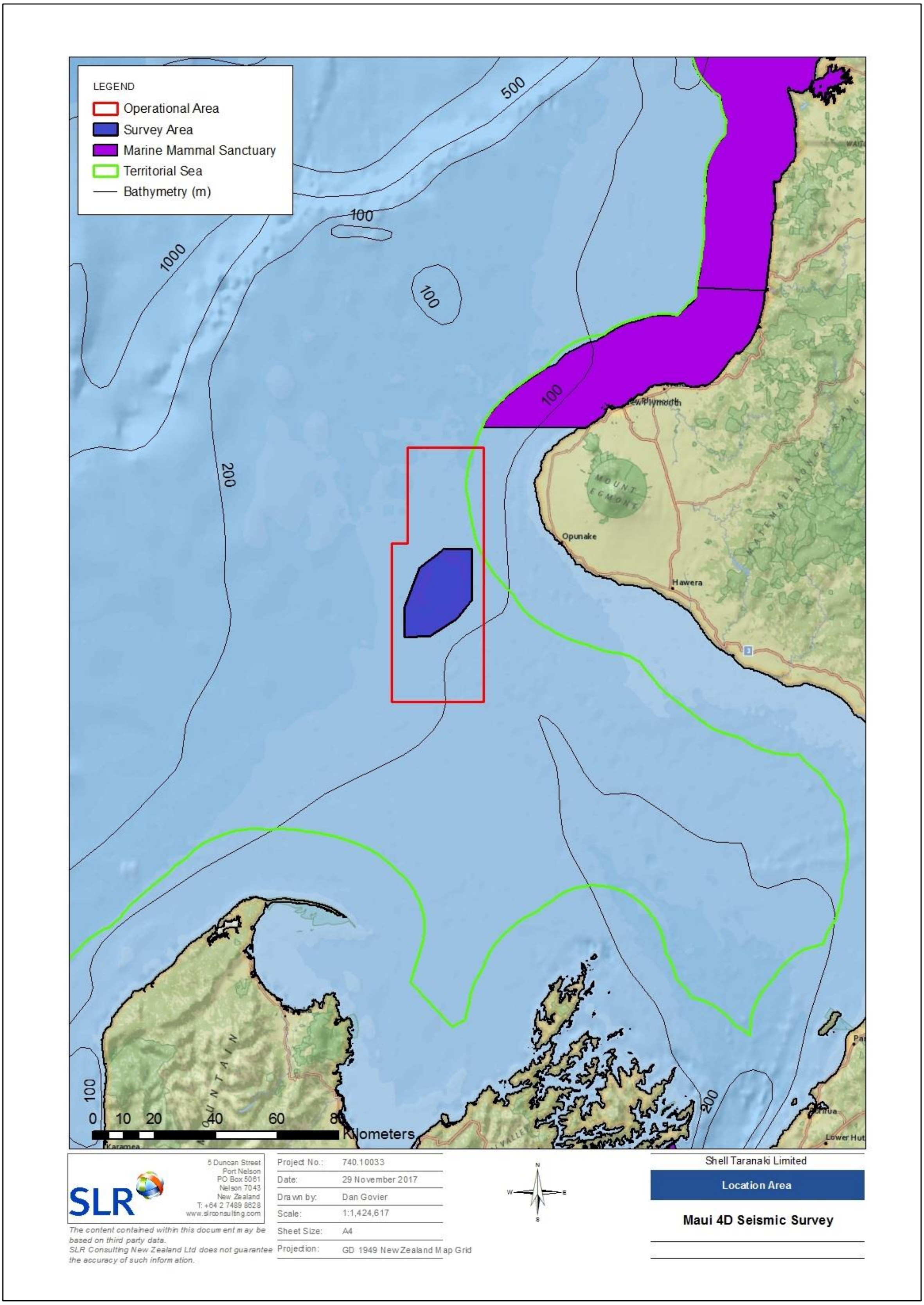
The *MV Amazon Warrior* will undertake the survey with an acoustic source volume of 3,147 in^3. The acoustic source will be activated at a source-point interval of 18.75 m. For a vessel speed of 4.5 knots, this equates to source activation every 8 seconds. According to the Code of Conduct, the Māui 4D Seismic Survey is classified as a Level 1 survey on account of the acoustic source being greater than 427 in^3.

The seismic vessel will tow 8 streamers that extend for approximately 3 km behind the vessel. Each streamer will be separated by 100 m; equating to an overall lateral span of 700 m. The streamers will remain deployed for the duration of the survey.

The seismic vessel will be accompanied by a support vessel (*Mermaid Searcher*) which will serve to ensure a clear path for the seismic vessel, by alerting other marine users of the on-coming seismic vessel and its limited manoeuvrability. An additional chase vessel (*MV Sea Ranger*) will also be present.

The objective of the Māui 4D Seismic Survey is to continue the existing time-lapse series of seismic datasets to monitor changes in the Māui reservoir since the last 4D survey in 2002.

Figure 1 Operational Area for the Māui 4D Seismic Survey



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. **Section 2.2** describes the procedures that are over and above the standard mitigations and represent variations that are specific to the Māui 4D Seismic Survey.

2.1.1 Notification

The notification requirements of the Code of Conduct have been adhered to. A letter was received by the Director-General of the Department of Conservation on 18 September 2017 notifying DOC of Shell Taranaki Limited's intentions to carry out seismic operations in the Taranaki Basin.

2.1.2 Marine Mammal Impact Assessment

Under normal circumstances, a Marine Mammal Impact Assessment (MMIA) must be submitted to the Director-General not less than one month prior to the start of a seismic survey. The MMIA for the Māui 4D Seismic Survey was submitted to DOC on 8 December 2017.

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 2** lists these species.

2.1.3 Observer Requirements

All Level 1 seismic surveys require the use of Marine Mammal Observers (MMOs) in conjunction with Passive Acoustic Monitoring (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 1**;
- 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. This includes reporting and any other duties not required by the Code (i.e. safety reports, etc.), not just on-watch time.

MMOs and PAM operators must schedule their shifts and breaks in such a way as to manage their fatigue levels appropriately so 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 1 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.
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 measures taken.	Record general environmental conditions, acoustic source power output while in operation, and any mitigation measures taken.
Communicate with DOC (+64 27 201 3478 or email at kramm@doc.govt.nz) to clarify any uncertainty or ambiguity in application of the Code of Conduct.	Communicate with DOC (+64 27 201 3478 or email at kramm@doc.govt.nz) 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.

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;

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

- Two MMOs maintain watch at all times during seismic operations when PAM is not operational. This means that operations cannot continue at night if the PAM system malfunctions;
- DOC is notified via email (kramm@doc.govt.nz) 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

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 trip report must also be provided to DOC at the earliest opportunity, but no later than 60 days after the completion of the project.

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 Department 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 (+64 27 201 3478 or email at kramm@doc.govt.nz) and the EPA (seismic.compliance@epa.govt.nz). 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, from the bridge (or preferably even higher vantage point) using both binoculars and the naked eye, and no marine mammals (other than fur seals) have been observed in the relevant 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 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 observer has not detected any vocalising cetaceans in the relevant mitigation zones.

New Location:

In addition to the above normal pre-start observation requirements, when arriving at a new location in the survey programme for the first time, or when returning to the Operational Area following a port call, the initial acoustic source activation must not be undertaken at night or during poor sighting conditions unless either:

- MMOs 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 (1,500 m for Species of Concern with calves, 1,000 m for Species of Concern without calves and 200 m for Other Marine Mammals) in the two hours immediately preceding proposed operations;
  - No fur seals have been sighted during visual monitoring in the relevant mitigation zone (200 m) 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 (200 m) 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 (3,147 in^3) 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 vessel.**

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. No repetition of the less than 10 minute break period in the commencement of a soft start is allowed under the Code of Conduct.

2.1.8 Mitigation Zones for Delayed Starts and Shutdowns

The results of the sound transmission loss modelling (STLM) predicted that the sound exposure levels (SELs) from the Māui 4D Seismic Survey will not exceed the SEL thresholds outlined in the Code of Conduct. Hence the standard mitigation zones (as outlined in the Code of Conduct) will be used during the Māui 4D Seismic Survey as outlined below:

Species of Concern (with calves) within a mitigation zone of 1,500 m

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 1,500 m 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 1,500 m from the source; or
- Despite continuous observation, 30 minutes has elapsed since the last detection of the group within 1,500 m of the source, and the mitigation zone remains clear.

Species of Concern (without calves) within a mitigation zone of 1,000 m

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 within 1,000 m of the source, start-up will be delayed or the source will be shut down and not reactivated until:

- A qualified observer confirms the animal has moved to a point that is more than 1,000 m from the source; or
- Despite continuous observation, 30 minutes has elapsed since the last detection of the animal within 1,000 m 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.

A summary of the mitigation zones that will be adopted for the Māui 4D Seismic Survey is provided in **Appendix 3**, and the required mitigation actions are summarised in the 'Operational Flowchart' in **Appendix 4.**

2.1.9 Line turns

Activation of any seismic source solely for mitigation purposes during line turns is not supported by the Code of Conduct.

2.1.10 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.

2.1.11 Ground Truthing of Sound Transmission Loss Modelling

As per the Code of Conduct requirements, Shell Taranaki Limited will conduct ground-truthing during the survey to verify the results of the STLM.

During the Māui 4D Seismic Survey ground–truthing will be undertaken by isolating the acoustic sound trace received from the streamer hydrophones at the mitigation distances relevant to the mitigation zones outlined in the Code of Conduct (200 m, 1000 m and 1500 m). The streamer hydrophones record across the frequency range 1 – 250 Hz.

As the bathymetry within the Survey Area does not change markedly, the ground-truthing will occur at an approximate depth of 100 m. However, if the opportunity arises, ground-truthing will also occur at a water depth of 80 m (in the southeast portion of the Operational Area) to match the depth on which the short-range STLM was based.

The undertaking of this ground truthing is the responsibility of the on-board seismic data technicians; however, they may seek input from the qualified observers during this process with regards to understanding the mitigation zones and the acoustic thresholds outlined in the MMIA.

2.1.12 Key contacts and communication protocols

The key contact for DOC is Kris Ramm who can be contacted by phone on +64 27 201 3478 or email at kramm@doc.govt.nz. Kris is the primary point of contact for all DOC enquiries or notifications except for those regarding Maui's or Hector's dolphins (see additional contacts provided in **Section 2.2.1** below). Note that if Kris cannot be reached, DOC's secondary point of contact is Dave Lundquist (phone +64 27 201 3529, email dlundquist@doc.govt.nz).

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

2.2 Variances or Additions to the Code of Conduct

This section outlines the agreed variances to the Code of Conduct or additional procedures above and beyond the Code of Conduct. These variances and additions have been adopted by Shell Taranaki Limited for the purpose of the Māui 4D Seismic Survey and agreed by 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 Māui 4D Seismic 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 (during daylight hours and good sighting conditions).

  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 to notify DOC immediately of any Hector's/Maui's dolphin sightings. Extra vigilance for this species should be maintained on approach and departure to Port Taranaki (if port visits here occur). These sightings will be made via telephone to Callum Lilley on +64 27 206 5842, with a follow up email sent to clilley@doc.govt.nz; and
- Weekly MMO reports will be provided to DOC (Kris Ramm) and the EPA. Suggested headings for these reports are as follows:
  - Report information (date and distribution list);

- Summary of operations (seismic operations, weather, observer effort);
- Marine mammal detections (date, species, number, closest distance, array status);
- Interruptions to seismic operations (shut downs, delayed starts);
- Other notable fauna; e.g. turtles, threatened shark species, penguins etc. (date, species, number, closest distance, array status etc); and
- Compliance issues (description of any compliance issues and method of address).

Weekly reports should also note any streamer loss incidents during the survey.

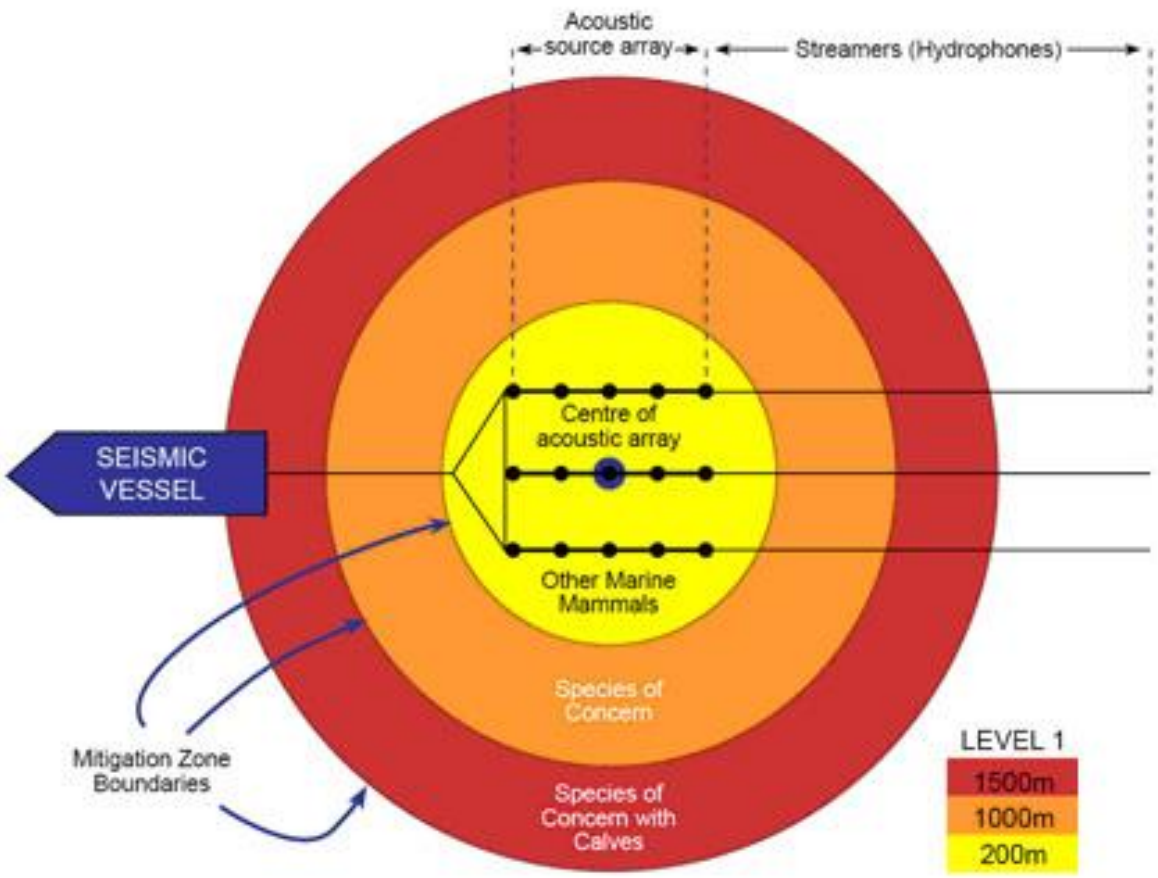
APPENDIX 1: COORDINATES OF OPERATIONAL AREA

Longitude (X Coordinates)	Latitude (Y Coordinates)
1623292.376	5631969.08
1623278.192	5663226.73
1648278.193	5663228.846
1648315.857	5580228.855
1618315.86	5580215.241
1618292.376	5631966.812
1623292.376	5631969.08

APPENDIX 2: SPECIES OF CONCERN

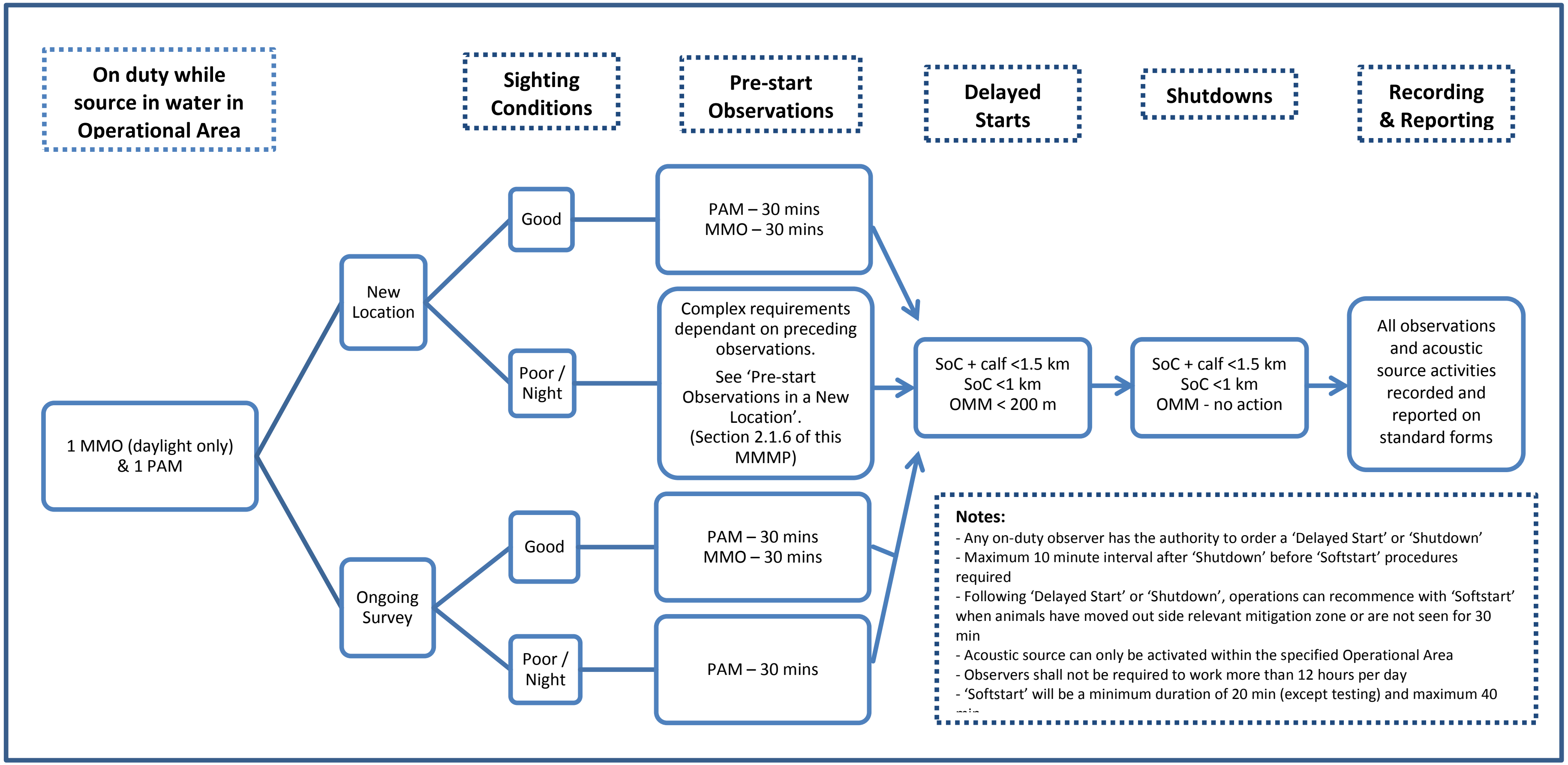
LATIN NAME	COMMON NAME
Megaptera novaengliae	Humpback Whale
Balaenoptera borealis	Sei Whale
Balaenoptera edeni	Bryde's Whale
Balaenoptera bonaerensis	Antarctic Minke Whale
Balaenoptera acutorostrata subsp.	Dwarf Minke Whale
Balaenoptera musculus	Blue Whale
Balaenoptera physalus	Fin Whale
Balaenoptera 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 3: SUMMARY OF MITIGATION ZONES FOR THIS SURVEY



(Source: www.doc.govt.nz)

APPENDIX 4: OPERATIONAL FLOWCHART



Adapted from the Code of Conduct (DOC, 2013); Key: SoC = Species of Concern, OMM = Other Marine Mammal

Sound Transmission Loss Modelling Results

Māui 4D Seismic Survey

Taranaki Basin

Sound Transmission Loss Modelling

Report Number 740.10033.00100

30 November 2017

Shell Taranaki Limited
167 Devon Street West
New Plymouth
New Zealand

Version: Final

Māui 4D Seismic Survey

Taranaki Basin

Sound Transmission Loss Modelling

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740.10033.00100	Draft 1	24 November 2017	Binghui Li	Helen McConnell	Helen McConnell

Executive Summary

Shell Taranaki Limited (Shell Taranaki) has proposed to undertake a 4D seismic survey within the Taranaki Basin. SLR Consulting New Zealand Pty Ltd (SLR) has been engaged by STOS to provide Sound Transmission Loss Modelling (STLM) services for the proposed seismic survey, to assist STOS in achieving relevant regulatory approval for the completion of the survey.

This report details the sound transmission loss modelling study that has been carried out for the proposed survey, which includes the following three modelling components:

- Array source modelling, i.e. modelling the sound energy emissions from the array source, including its directivity characteristics,
- 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 regulatory mitigation zone requirements, and
- Long range modelling, i.e. prediction of the received SELs over a range of up to 150 km from the array source location, in order to assess the noise impact from the survey on the relevant far-field marine mammal sanctuaries or other areas of marine importance.

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

The proposed acoustic source for this survey is the Boltgun 3,147 cubic inch array. The source array comprises 3 subarrays, and each subarray has a number of source elements, arranged as single elements or in clusters. The average towing depth for the source array is 6m, and an operating pressure of 2000 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 arrays, as a result of interference between signals from different array elements, particularly the three sub-arrays.

The location with the shallowest water depth within the 4D Operational Area was selected for the short range modelling, and the location with the closest distance to the adjacent sanctuary area was selected for the long range modelling. The worst case environmental conditions, i.e. autumn seasonal sound speed profile and fine sand seabed sediment, have been assumed for the modelling cases.

The short range modelling prediction demonstrates that the highest SELs occur in the in-line and cross-line directions, as a result of the directionality of the source array. The maximum received SELs over all azimuths are predicted to be below 186 dB re 1µPa^2·s at 200 m and below 171 dB re 1µPa^2·s at 1.0 km.

The long range modelling shows that the received SELs at long range vary significantly at different angles and distances from the source. This directionality of received levels is due to a combination of the directionality of the source array, and propagation effects caused by bathymetry and sound speed profile variations. The southern boundary of the West Coast North Island Marine Mammal Sanctuary has the shortest distance of approximately 6.7 km to the source location. The maximum SELs at the sanctuary boundary are predicted to be around 148 dB re 1µPa^2·s.

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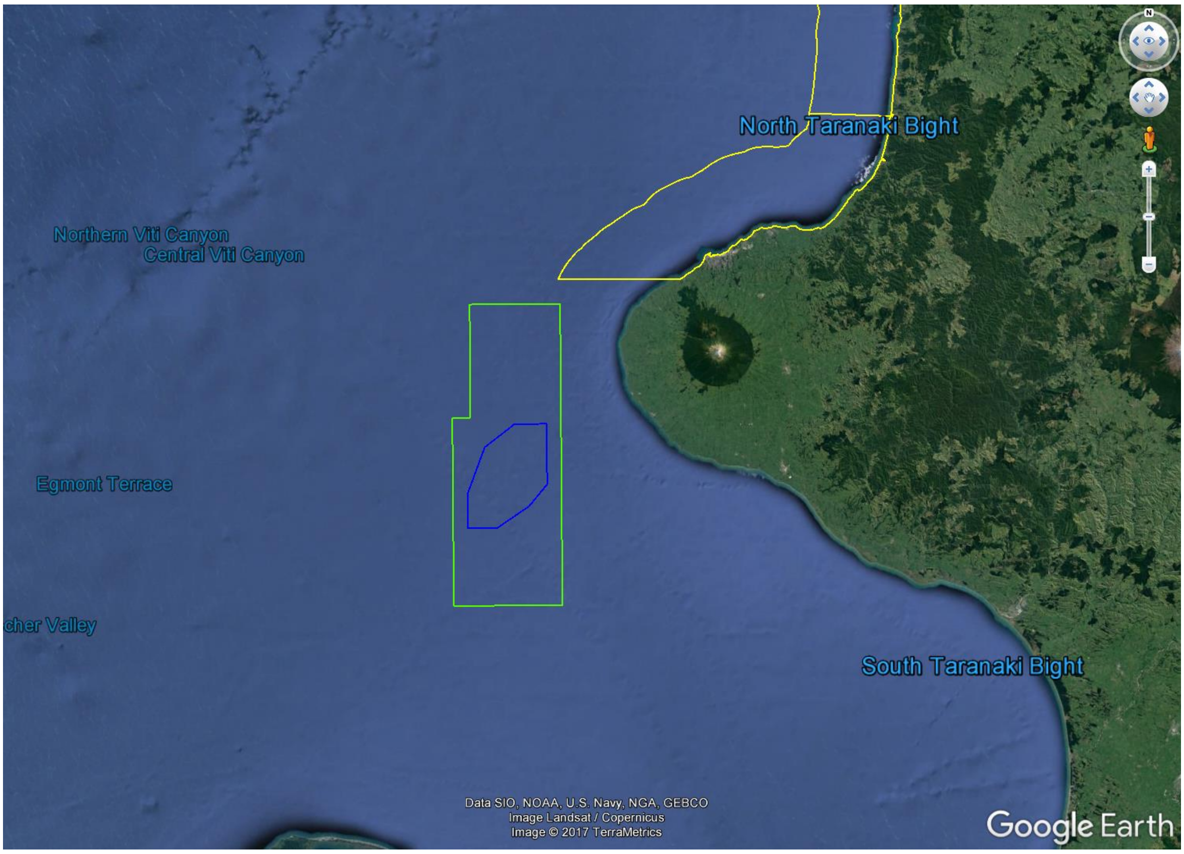
1 INTRODUCTION

1.1 Project description

Shell Taranaki Limited (Shell Taranaki) proposes to undertake a 4D seismic survey within the proposed Māui Seismic Survey Operational Area, as shown in **Figure 1**.

SLR Consulting NZ Ltd (SLR) has been engaged by STOS to undertake sound transmission loss modelling for the proposed surveys, in order to predict the received sound exposure levels (SELs) from the survey, and to demonstrate whether the survey complies with the sound exposure level statutory requirements within the *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* (the Code).

Figure 1 The proposed Māui Seismic Survey Operational Area overlaying Google Earth images. Yellow polygon indicates the boundaries of the marine mammal sanctuaries. Green polygon the 4D survey operational area, and blue polygon the full-fold coverage boundary.



1.2 Statutory requirements for sound transmission loss modelling (STLM)

In New Zealand, the *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* (the Code) was developed by the Department of Conservation (DOC) in consultation with a broad range of stakeholders in marine seismic survey operations. The Code came into effect on 29 November 2013.

The Code requires sound transmission loss modelling to be undertaken to determine whether received SELs exceed 171 dB re 1µPa^2.s (the behavioural threshold) at ranges of 1.0 km and 1.5 km from the source or 186 dB re 1µPa^2.s (the injury threshold) at a range of 200 m from the source.

1.3 Structure of the report

This sound transmission loss modelling study includes the following three modelling components:

- Array source modelling, i.e. modelling the sound energy emissions from the array source, including its directivity characteristics;
- Short range modelling, i.e. prediction of the received SELs over a range of a few kilometres from the array source location, in order to assess whether the proposed survey complies with the near-field mitigation zone requirements imposed by the Code, and
- Long range modelling, i.e. prediction of the received SELs over a range of tens to hundreds of kilometres from the array source location, in order to assess the noise impact from the survey on the relevant far-field marine mammal sanctuaries.

Section 2 of this report details the modelling methodology, procedure and results for the array source modelling. **Section 3** of the report outlines the methodologies and procedures associated with the short and long range transmission loss modelling, with the major modelling results presented in **Section 4**.

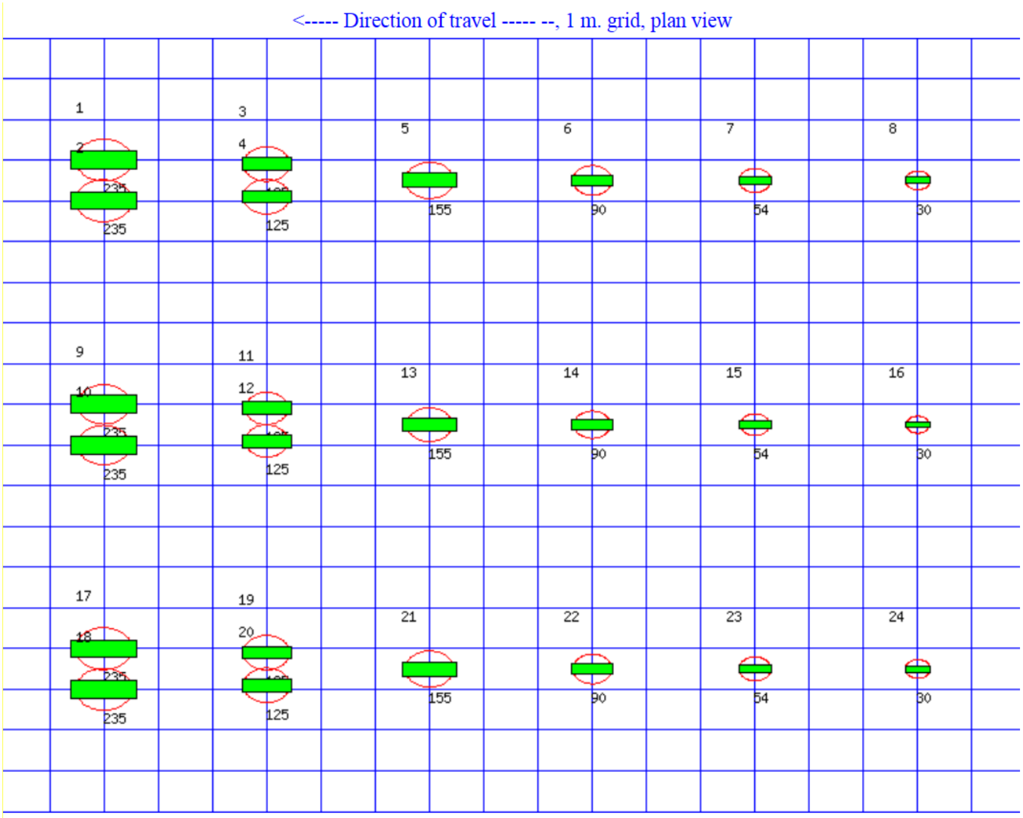
2 AIRGUN ARRAY SOURCE MODELLING

2.1 Airgun array configuration

The airgun array proposed for this survey is the Boltgun 3,147 cubic inch array. The array configuration is shown in **Figure 2**.

The source array comprises 3 subarrays, and each subarray has a number of elements, arranged as singless or in clusters. The element types are 1500LL and 1900LLX airguns. The average towing depth for the source array is around 6 m. The source array has an operating pressure of 2000 pounds per square inch (PSI).

Figure 2 The configuration of the Boltgun 3,147 cubic inch array.



2.2 Modelling methodology

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

- A set of “notional” signatures for each of the array element;
- The far-field signature of the airgun array and its directivity/beam patterns.

2.2.1 Notional signatures

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

Notional signatures are modelled using the Gundalf Designer software package (2015). The Gundalf source model is developed based on the fundamental physics of the oscillation and radiation of air bubbles as described by Ziolkowski (1970), taking into account non-linear pressure interactions between source elements (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 elements and interacting cluster elements at a wide range of deployment depths.

2.2.2 Far-field signatures

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

- The distances from each individual source element to nominal far-field receiving location are calculated. A 9.0 km receiver set is used for the current study;
- The time delays between the individual elements 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 element is calculated with the appropriate time delay. These received signals are summed to obtain the overall array far-field signature for the direction of interest.
- The far-field signature also accounts for ocean surface reflection effects by inclusion of the "surface ghost". An additional ghost source is added for each 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:

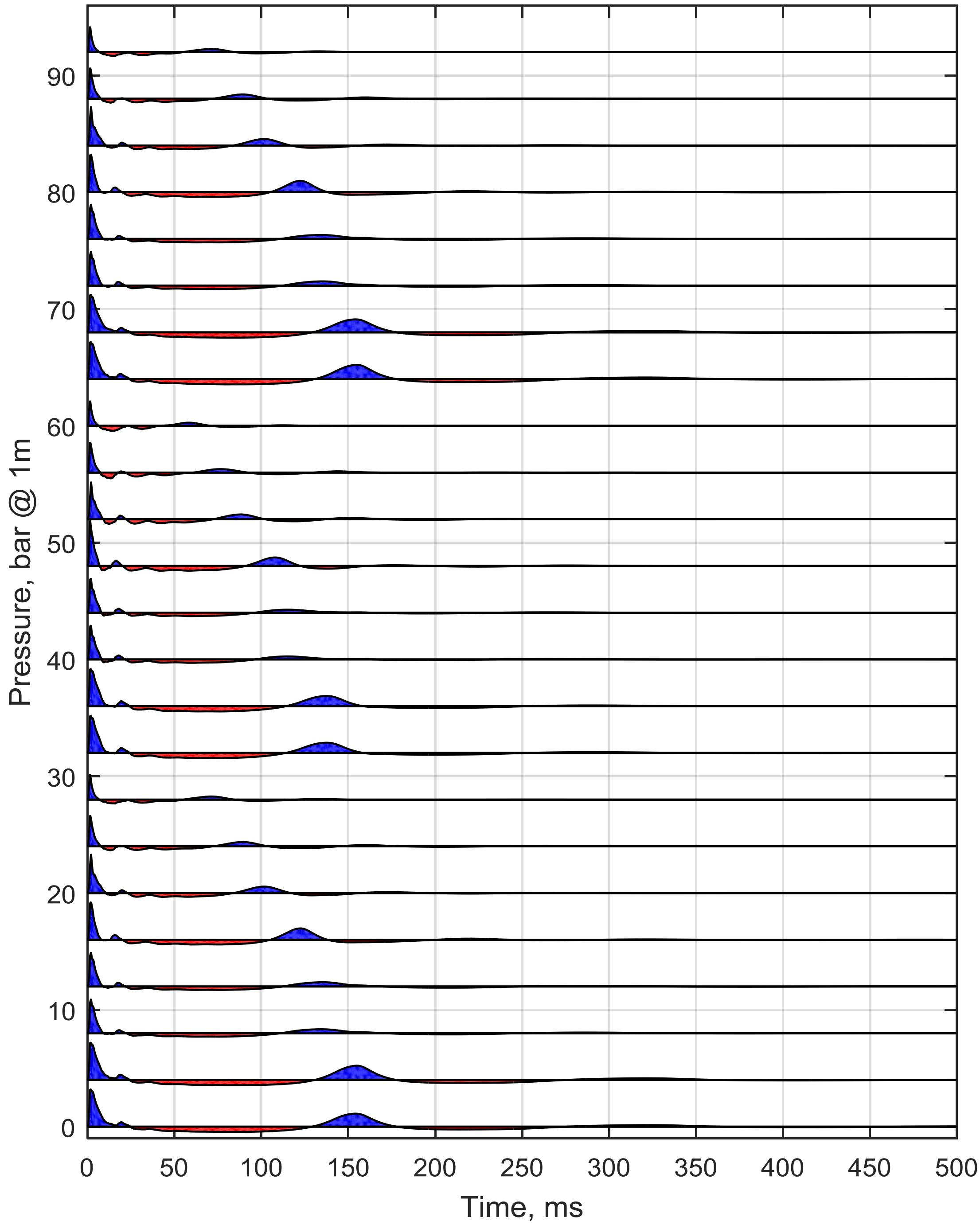
- The far-field signatures are calculated for all directions from the source using azimuthal and dip angle increments of 1-degree;
- The power spectral density (PSD) (dB re 1 $\mu Pa^2 s/Hz$ @ 1m) for each pressure signature waveform is calculated using a Fourier transform technique.
- The PSDs of all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

2.3 Modelling results

2.3.1 Notional signatures

The notional signatures for the Boltgun 3,147 cubic inch array (24 elements) are shown in **Figure 3**.

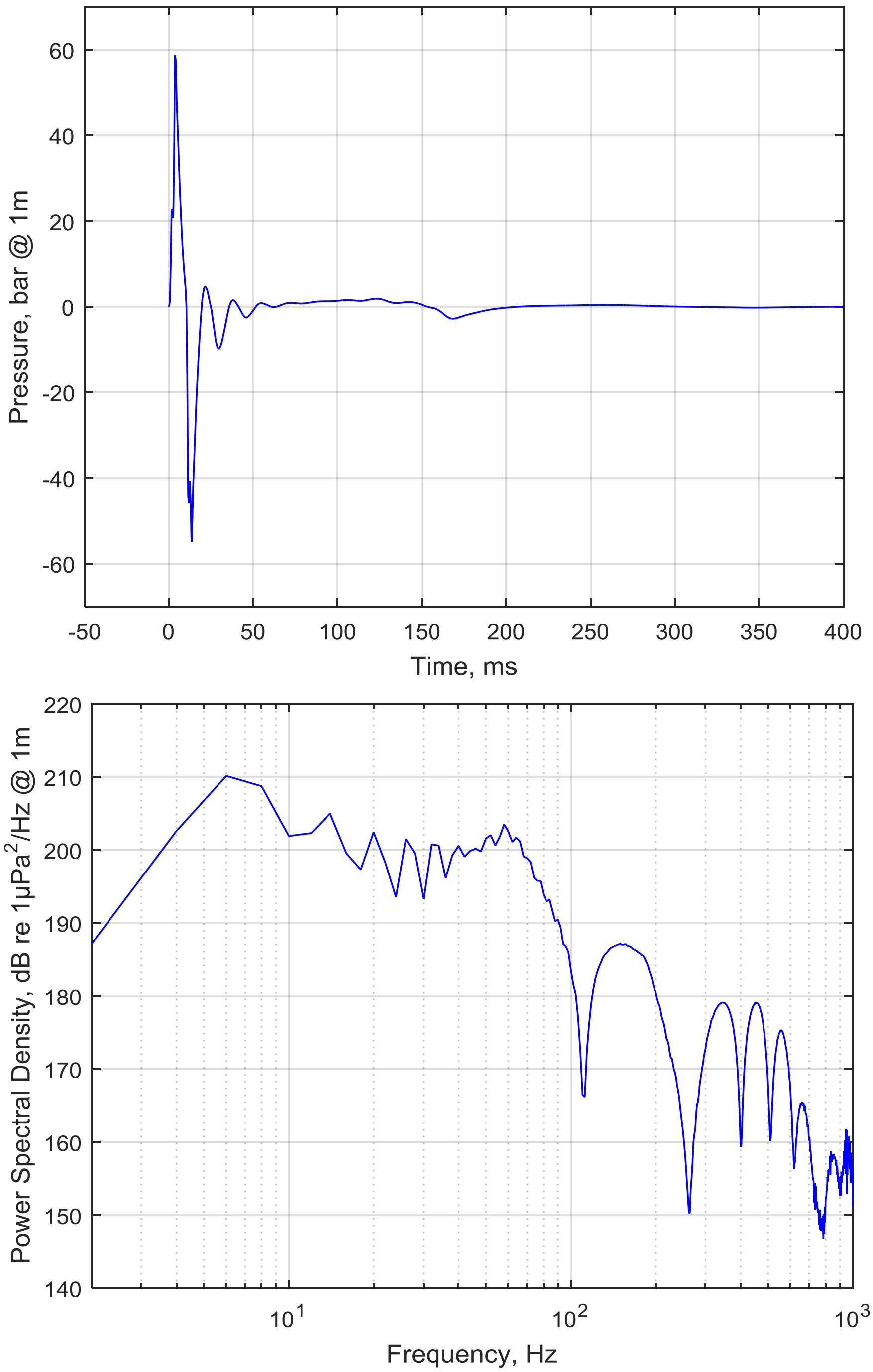
Figure 3 **Notional signatures for individual elements (3 sub-arrays) of the Boltgun 3,147 cubic inch array. Time series of positive pressure and negative pressure indicated by blue fill and red fill respectively. The scale is the same for the signatures from all elements.**



2.3.2 Far-field signatures

Figure 4 shows the simulated signature waveform based on Gundalf Designer software and its corresponding power spectral density for the Boltgun 3,147 cubic inch array. The signature is for the vertically downward direction with surface ghost included.

Figure 4 The far-field signature in vertically downward direction (top) and its power spectral density (bottom) for the Boltgun 3,147 cubic inch array.



2.3.3 Beam patterns

Array far-field beam patterns of the following three cross sections for the source array 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 in-line direction;

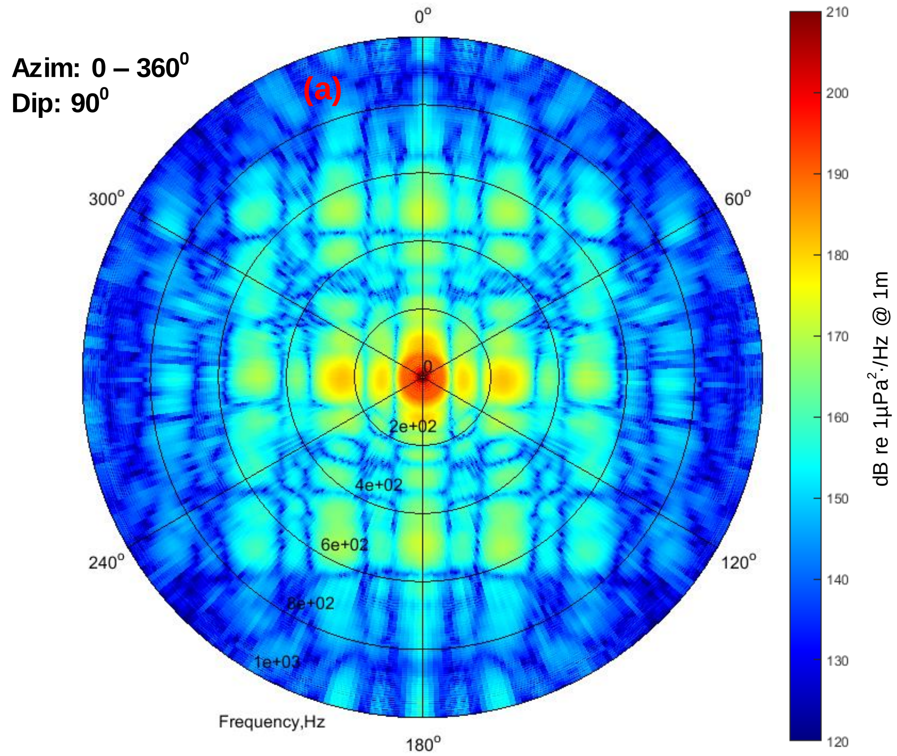
b) The vertical plane for the in-line direction (i.e. azimuthal angle of 0 degree) with dip angle of 0 degree corresponding to the vertically downward direction;

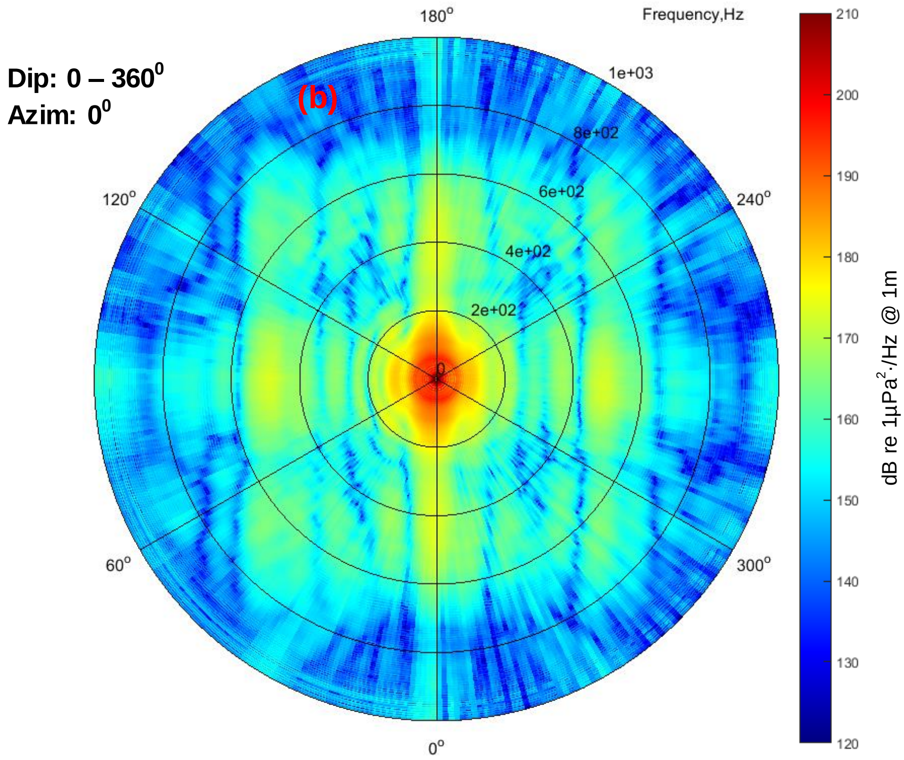
c) The vertical plane for the cross-line direction (i.e. azimuthal angle of 90 degrees) with dip angle of 0 degree corresponding to the vertically downward direction.

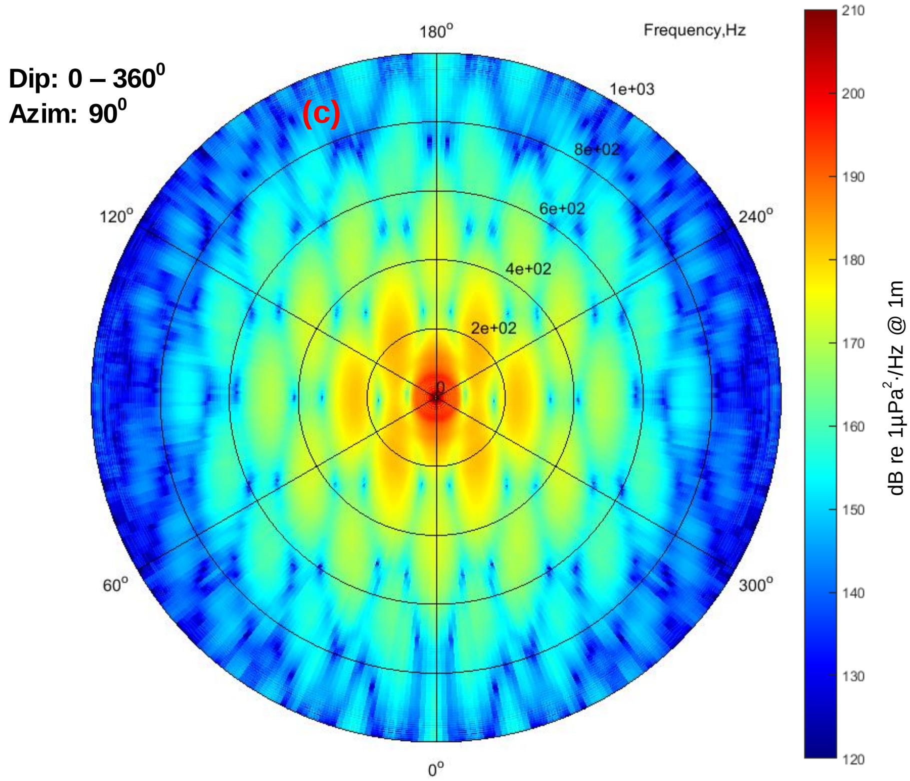
These beam patterns illustrate the strong angle and frequency dependence of the energy radiation from the array. The beam pattern of the horizontal plane shows relatively stronger energy radiation in the cross-line direction than in the in-line direction. The beam patterns of the in-line and cross-line vertical planes have the strongest radiation in the vertical direction.

The predominant frequency variation characteristics of these beam patterns are a result of interference between signals from different array elements, particularly from the three sub-array elements.

Figure 5 Array far-field beam patterns for the Boltgun 3,147 cubic inch array, as a function of orientation and frequency. (a) - The horizontal plane with 0 degree corresponding to the in-line direction; (b) – The vertical plane for the in-line direction; (c) – The vertical plane for the cross-line direction. 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°
210
200
190
180
170
160
150
140
130
120
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°
210
200
190
180
170
160
150
140
130
120
dB re 1µPa²·/Hz @ 1m

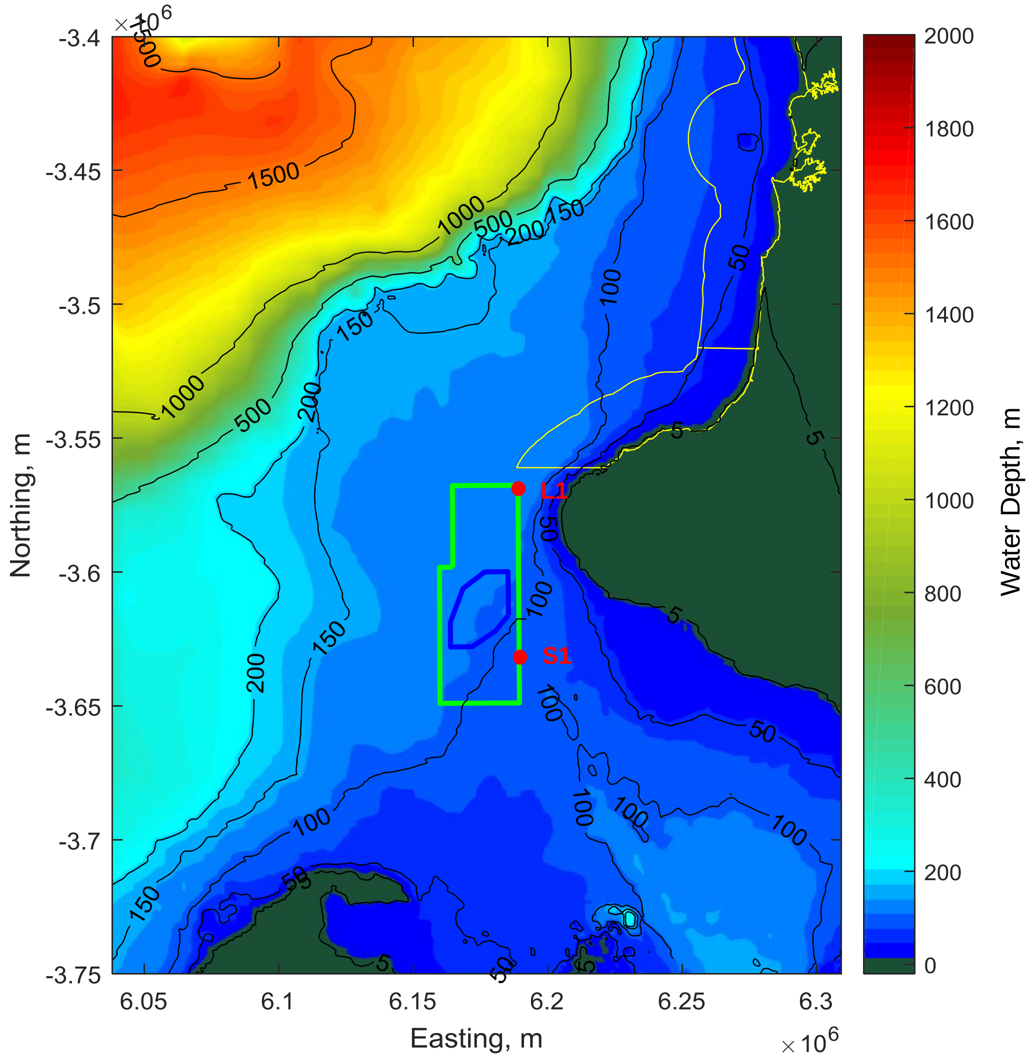
3 TRANSMISSION LOSS MODELLING

3.1 Modelling input parameters

3.1.1 Bathymetry

The bathymetry data used for the sound propagation modelling are the Shell Taranaki/LINZ merged gridded bathymetry dataset provided by Shell Taranaki, with the corresponding bathymetric imagery presented in **Figure 6**.

Figure 6 The bathymetry contour covering the proposed Operational Area. Yellow polygon indicates the boundaries of the marine mammal sanctuaries. Green polygon the 4D survey Operational Area, and blue polygon the full-fold coverage boundary. Red dots indicate the selected source locations for the modelling scenarios. The coordinate system is based on WGS84 Web Mercator Map Projection.



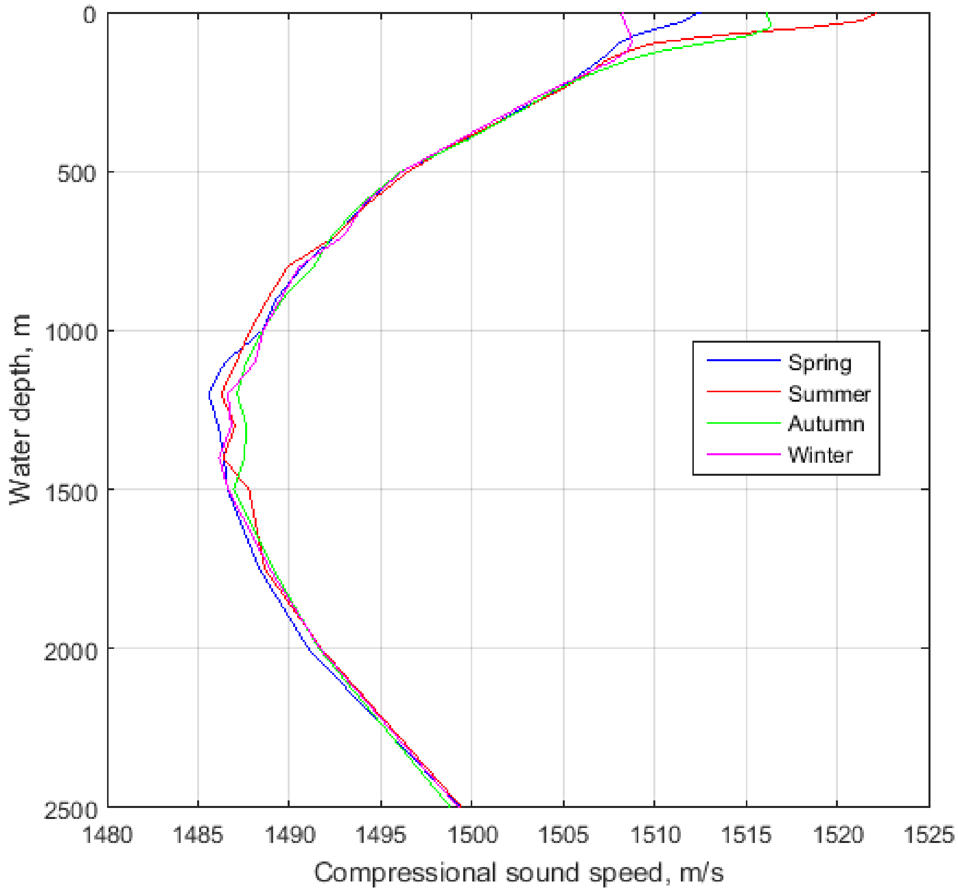
3.1.2 Sound speed profiles

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 7 demonstrates typical seasonal sound speed profiles within the project area for four austral seasons. The most significant distinctions for the four profiles occur within the mixed layer near the surface. The spring and summer seasons have downwardly refracting near-surface profiles, with the summer profile having the stronger downwardly refracting feature. Both the autumn and winter seasons exhibit a surface duct, with the profile in the winter season having a stronger and deeper surface duct than that in the autumn season. Due to the stronger surface duct within the profile, it is expected that the winter season will favour the propagation of sound from a sourcearray as it is a near-surface acoustic source. In a descending order, the autumn, spring and summer seasons are expected to have relatively weaker sound propagation for a near-surface array source.

The Shell Taranaki survey is scheduled to commence in mid February 2018, with the majority of the survey most likely to take place in March 2018. Therefore, the autumn sound speed profile is selected as the worst case condition for all sound propagation modelling scenarios.

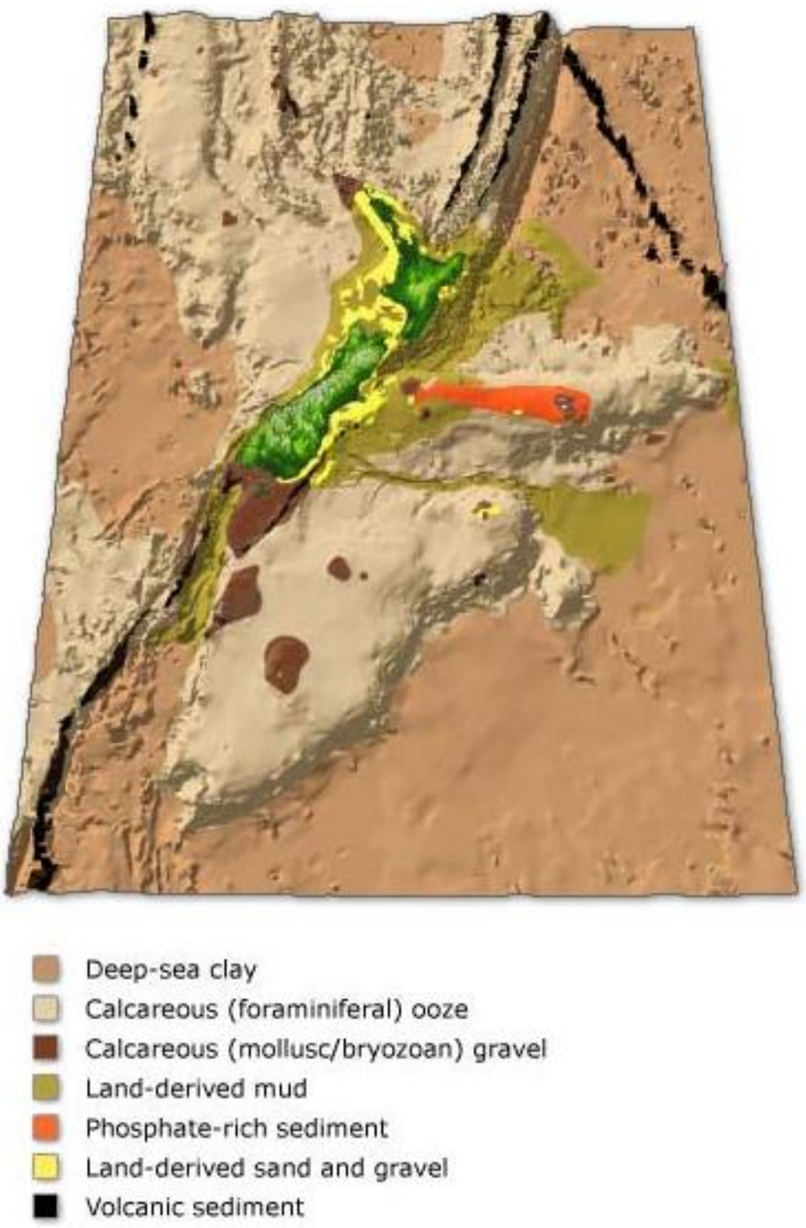
Figure 7 Typical seasonal sound speed profiles west of the North Island for different australseasons.



3.1.3 Seafloor geo-acoustic 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 8** 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 8 The distribution of the main types of marine sediment on the seafloor within coastal and offshore regions around New Zealand



The continental shelf is 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. Within the project area, off the western North Island, areas of black iron-rich sand have been formed by wave action on volcanic rock.

The detailed sediment types for various relevant coastal and offshore regions are referred to the NZ marine sediment charts and some technical reports (e.g. such as Matthew et al (2014) and Galindo-Romero et al (2014)). A summary of sediment types in and around the Taranaki Basin is provided in **Table 1**.

Table 1 Detailed sediment types within the coastal and offshore regions covering the Operational Area.

Region - West NZ	Sediment Type
Taranaki – Northland Continental Shelf	Dominant fine sand sediment with coarse sand sparsely scattered
Taranaki – Northland Continental Slope	Silt - clay
Southern New Caledonia Basin, Reinga Basin and Challenger Plateau	Pelagic sediments (mud – oozes, equivalent to silty clay)
Cook Strait	Fine sand

The geoacoustic properties for the various possible sediment types within the coastal and offshore regions around the project area are presented in **Table 2**. The geoacoustic properties for sand, silt and clay are as described in Hamilton (1980), with attenuations referred to Jensen et al (2011). The elastic properties of sand, silt and clay are treated as negligible. The reflection coefficients for sediments of sand, silt and clay are presented in **Figure 9** and **Figure 10** respectively.

Table 2 Geoacoustic properties for various possible sediment types within the coastal and offshore regions in the Taranaki Basin.

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	2035	1835	0.8
Fine Sand	1940	1750	0.8
Very Fine Sand	1855	1700	0.8
Silt - Clay			
Silt	1740	1615	1.0
Sand-Silt-Clay	1595	1580	0.4
Clayey Silt	1490	1550	0.2
Silty Clay	1420	1520	0.2

The reflection coefficients for sediments of sand, silt and clay are presented in **Figure 9** and **Figure 10** respectively. As can be seen, the sandy seafloor sediments are more reflective than the silt and clay sediments, particularly at low grazing angles.

Figure 9 **The reflection coefficients (magnitude - top panel and phase – bottom panel) for sand sediments (coarse sand, fine sand and very fine sand)**

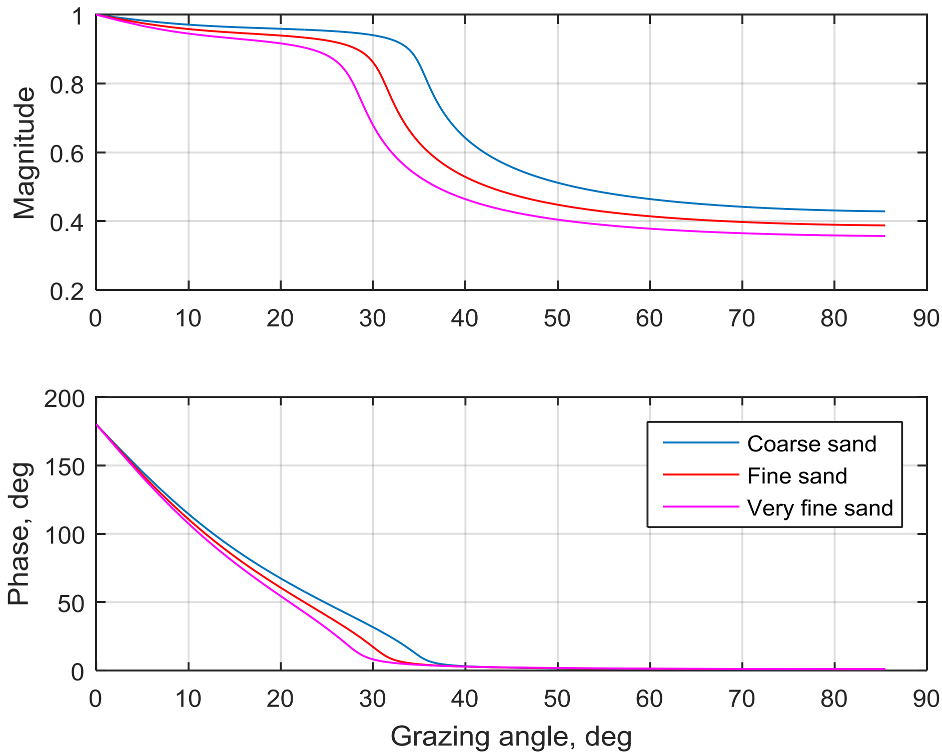
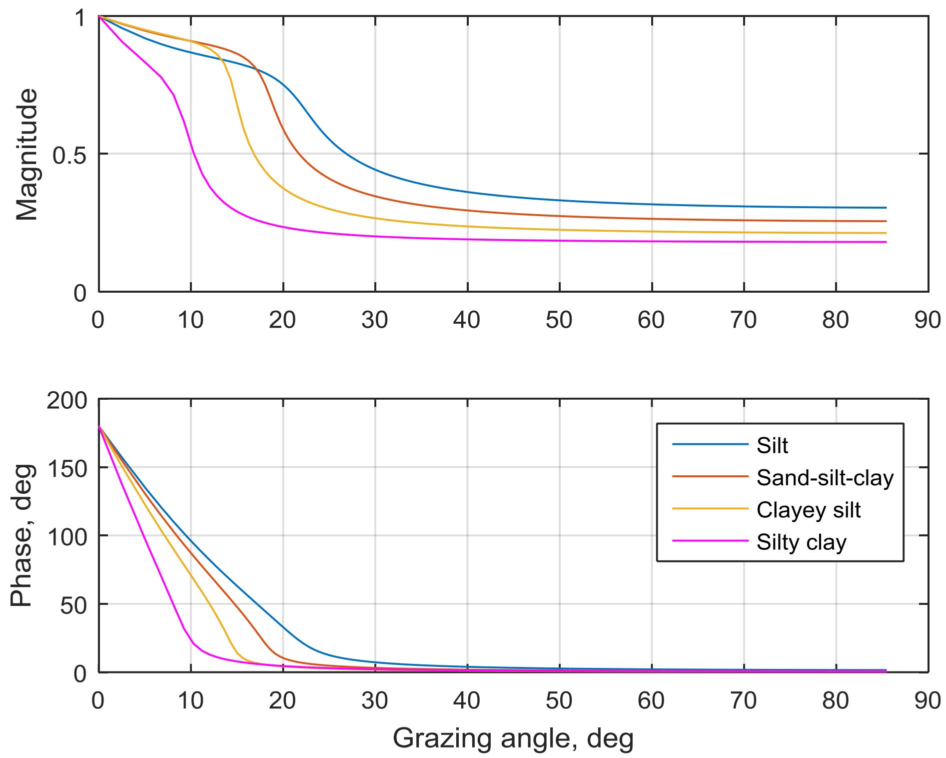


Figure 10 **The reflection coefficient (magnitude - top panel and phase – bottom panel) for silt-clay sediments (silt, sand-silt-clay, clayey silt, silty clay)**



3.2 Detailed modelling methodologies and procedures

The modelling accuracy requirements, source directivity characteristics and computational cost of the short range and long range modelling cases are different. The following sections describe the different modelling methodologies and procedures employed for the short range and long range modelling cases.

3.2.1 Short range modelling

3.2.1.1 Modelling methodology and procedure

The short range modelling is used to verify mitigation zones in relatively close proximity to the array source, and requires modelling predictions with high accuracy. In addition, interference between the signals arriving at any receiving location from different elements 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 reconstructing and synthesizing 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 procedure is followed to calculate received sound exposure levels:

1) The modelling algorithm SCOOTER is executed for frequencies from 1 Hz to 1 kHz, in 1 Hz increments. The source depth is set as 6 m for the Boltgun 3,147 cubic inch array. A 1-m receiver grid in both range and depth with a maximum range up to 4 km is applied for the selected water depth. For each 1-m gridded receiver, the received sound exposure level is calculated by following steps 2) – 5);

2) The range from each element in the array to each receiver is calculated, and the transfer function between each element 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 transfer function;

3) The complex frequency domain signal of the notional signature waveform for each 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 that particular element;

4) The waveform of received signal from each element is reconstructed via Inverse Fourier Transform. The received signal waveforms from all elements in the array are summed to obtain the overall received signal waveform;

5) The overall signal waveform is squared and integrated to obtain the received SEL. Alternatively, the SEL value can also be calculated via integration of the energy power density over frequency in Step 3).

3.2.1.2 Modelling scenarios

One location with the shallowest water depth within the 4D Operational Area is selected for the short range modelling. The location is marked up in **Figure 6** with relevant details listed in **Table 3**.

The worst case modelling conditions for underwater noise propagation applicable to the proposed survey, i.e. fine sand seabed sediment and autumn sound speed profiles, have been assumed for the short range modelling.

Table 3 Details of the selected source location for the short range modelling

Source Location	Water Depth	Source Array Configuration	Coordinates [Easting, Northing]	Locality
S1	80	the Boltgun 3,147 cubic inch array	[6.1894 x 10^6, - 3.6489 x 10^6]	Southeast corner of the 4D Operational Area

3.2.2 Long range modelling

3.2.2.1 Modelling methodology and procedure

The long range modelling case requires reasonable accuracy of prediction as it generally involves complex and variable environmental factors such as sound speed profiles and bathymetric variations. Therefore, the modelling prediction for the long range case is carried out using the far-field source levels of octave frequency bands and their corresponding transmission loss calculations.

The fluid parabolic equation (PE) modelling algorithm RAMGeo (Collins, 1993) is used to calculate the transmission loss between the source and the receiver. RAMGeo is an efficient and reliable PE algorithm for solving range-dependent acoustic problems with fluid seabed geo-acoustic properties.

The received sound exposure levels are calculated following the procedure as below:

1) One-third octave source levels for each azimuth to be considered are obtained by integrating the horizontal plan source spectrum over each frequency band, and these levels are then corrected to SEL levels;

2) Transmission loss is calculated using RAMGeo at one-third octave band central frequencies from 8 Hz to 1 kHz, with a maximum range of 120 km and at 5 degree azimuth increments. The bathymetry variation along each modelling track is obtained via interpolation from the bathymetry dataset;

3) The one-third octave source SEL levels and transmission loss are combined to obtained the received SEL levels as a function of range, depth and frequency;

4) The overall received SEL levels are calculated by summing all frequency band SEL levels.

3.2.2.2 Modelling scenarios

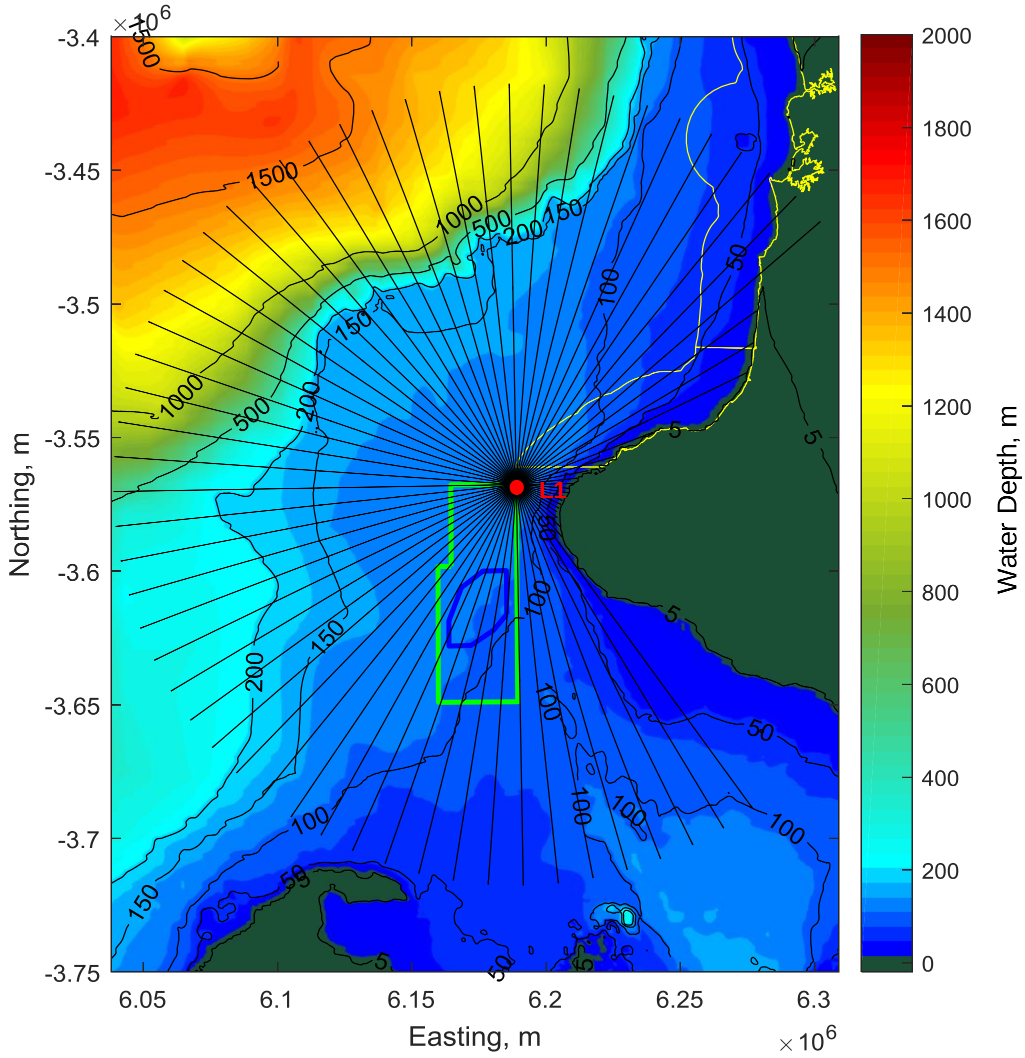
One long range modelling scenario is proposed for the Boltgun 3,147 cubic inch array. The source location as described in **Table 4** is selected for the long range modelling.

Shell Taranaki have advised that the survey operation will be in a North-South orientation.

Table 4 Details of the selected single source location for the long range modelling

Source Location	Water Depth, m	Coordinates [Easting, Northing]	Locality
L1	124	[6.189 x 10^6, - 3.568 x 10^6]	Northeast corner of the Operational Area, closest to adjacent marine mammal sanctuary area

Figure 11 Long range modelling source location (L1), with modelling sound propagation paths (black lines) overlaying local bathymetry. The coordinate system is based on WGS84 Web Mercator Map Projection.



4 RESULTS

4.1.1 Short range modelling

The received SEL levels have been calculated for the Boltgun 3,147 cubic inch array at the source location S1. The modelling scenario is with the worst-case autumn season sound speed profile and the fine sand seabed sediment. 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 12**. The figure illustrates higher SEL levels in both the in-line and cross-line directions as a result of the directionality of the source array.

The scatter plots of the predicted maximum SELs across the water column from the source array for all azimuths are displayed in **Figure 13**, 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 1 µPa^2·S) and mitigation ranges (i.e. 200m, 1.0km and 1.5km).

As can be seen from the figures below, the maximum received SEL levels over all azimuths are predicted to be below 186 dB re 1µPa^2·s at 200 m and below 171 dB re 1µPa^2·s at 1.0 km. The predictions of the maximum SEL levels received at three mitigation ranges are listed in **Table 5**. **Table 6** presents the ranges from the centre of the source array to the ranges where the predicted maximum SEL levels are expected to equal the threshold levels (186 dB and 171 dB re 1µPa^2·s).

Table 5 Predicted maximum SEL for all azimuths at ranges of 200 m, 1 km and 1.5 km from the center of the array for the Boltgun 3,147 cui array at source location S1.

Source location	Water depth, m	Seafloor	SEL at different ranges, dB re 1µPa^2·s		
			200 m	**1.0 km**	**1.5 km**
S1	80	Fine sand	180.0	169.4	166.2

Table 6 Ranges from the center of the array where the predicted maximum SEL for all azimuths equals the SEL threshold levels for the Boltgun 3,147 cui array at source location S1.

Source location	Water depth, m	Seafloor	Ranges complying with the following SEL thresholds, m	
			SEL < 186 dB re 1µPa^2·s	**SEL < 171 dB re 1µPa^2·s**
S1	80	Fine sand	74	800

Figure 12 The predicted maximum received SEL across the water column as a function of azimuth and range from the centre of the array. 0 degree azimuth corresponds to the in-line direction. The modelling scenarios are for the Boltgun 3,147 cui array at source location S1. Dark blue circles represent the mitigation zones of 200 m (solid), 1.0 km (dash) and 1.5 km (dash-dot).

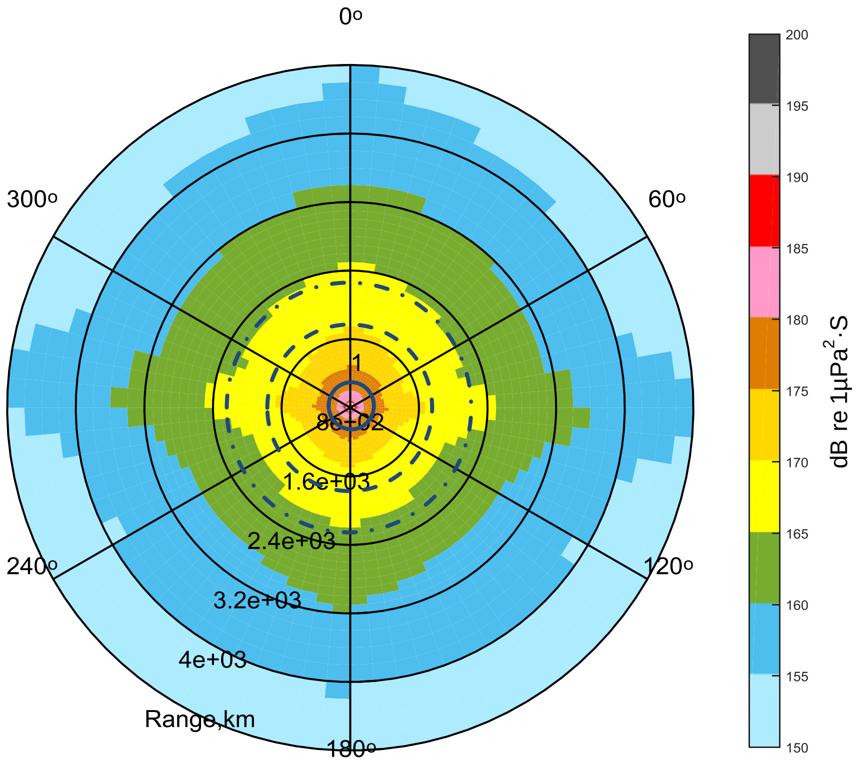
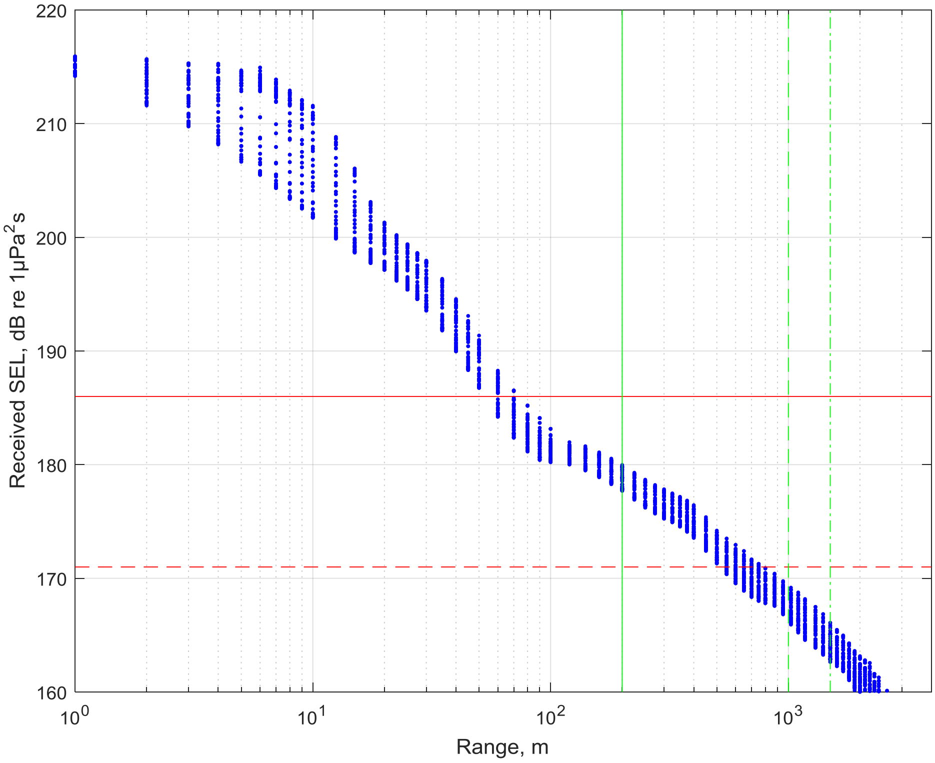


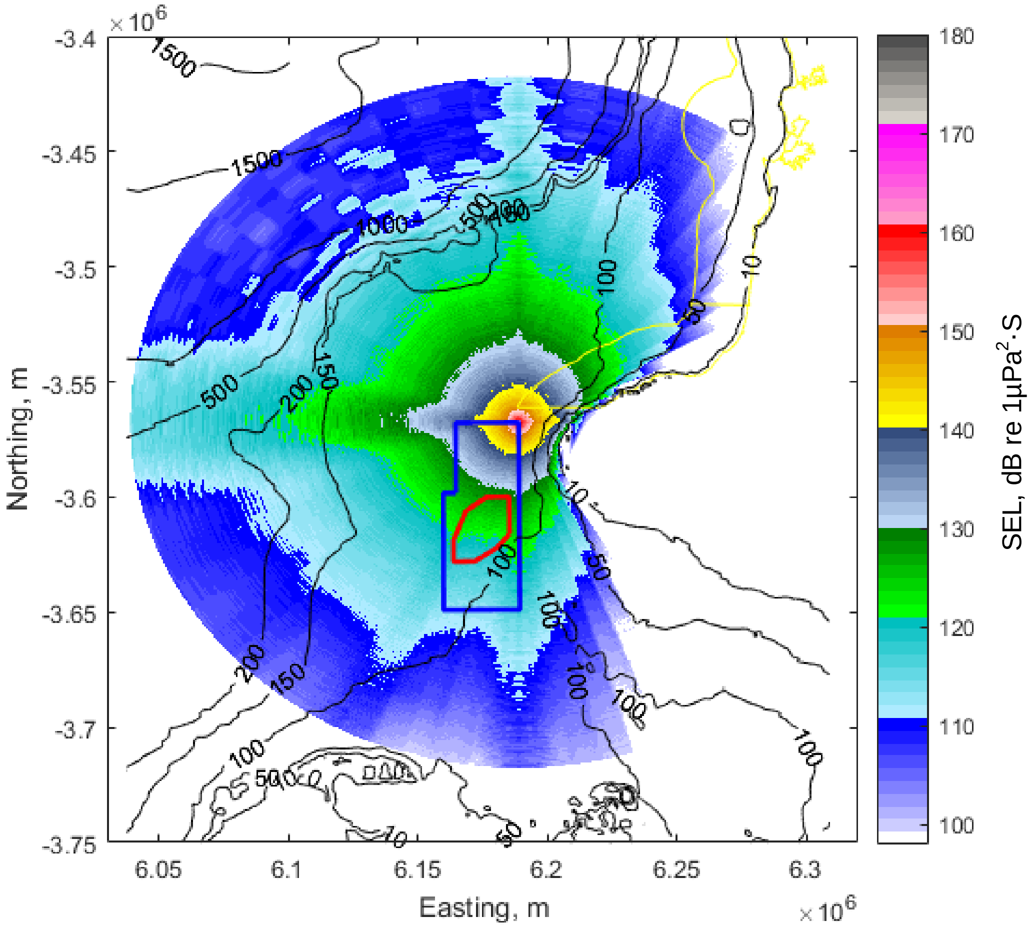
Figure 13 Scatter plot of predicted maximum SELs across the water column for all azimuths as a function of range from the center of the source array for the Boltgun 3,147 cui array at source location S1. Horizontal red lines show mitigation thresholds of 186 dB re 1µPa2·S (solid) and 171dB re 1µPa2·S (dash). Vertical green lines show mitigation ranges of 200 m (solid), 1 km (dash) and 1.5 km (dash-dot).



4.1.2 Long range modelling

Figure 14 shows the contour image of the predicted maximum SELs received at locations up to 150 km from the source location L1, overlaying the local bathymetry contours.

Figure 14 Modelled SEL (maximum level at any depth) contour (for source location L1 to a maximum range of 150 km), overlaying with bathymetry contour lines.



As can be seen from **Figure 14**, the received noise levels at far-field locations vary significantly at different angles and distances from the source. This directionality of received levels is due to a combination of the directionality of the source array, and propagation effects caused by bathymetry and sound speed profile variations.

The southern boundary of the West Coast North Island Marine Mammal Sanctuary has the shortest distance of approximately 6.7 km to the the source location L1. The maximum SELs received from the source location S1 at the sanctuary boundary are predicted to be around 148 dB re 1µPa^2·S. The SELs are predicted to be approximately 130 - 148 dB re 1µPa^2·S over the southwest corner of the sanctuary area that the propagation paths overlap with. The SELs are predicted to drop below 100 dB re 1µPa^2·S when the sound propagation reaches the sanctuary area off the Kawhia coast over 140 km away from the source location.

Figure 15 and **Figure 16** show the modelled SELs vs range and depth along the propagation path in South-North and North-South direction from the source location L1 respectively. As a result of the downward-refracting sound speed profiles along the path (as shown in **Figure 7**) and relatively reflective sandy seabed at low grazing angles (as shown in **Figure 9**), the received SELs are predicted to be slightly above 110 dB re 1µPa^2·S at a distance of 150 km in South-North direction from the source location. The North-South direction has slightly more attenuation due to its shallow water depths across the entire propagation path, and the received SELs are predicted to be slightly above 100 dB re 1µPa^2·S at a distance of 150 km from the source location.

Significant attenuations are predicted for the shallow water area with upslope bathymetry profiles in the West-East direction, with an example shown in **Figure 17**. The upslope bathymetry profile within the area causes strong interaction between the sound signal and seabed, and consequently causes strong acoustic attenuation.

The modelled SELs vs range and depth along the propagation path in the East-West direction is presented in **Figure 18**. Due to the higher array source directivity at the cross-line directions as shown in **Section 2.3.3**, coupled with the downward-refracting sound speed profile and reflective sandy seabed, the received SELs along the East-West direction are relatively higher compared with other directions, and are predicted to be slightly above 120 dB re 1µPa^2·S at a distance of 150 km from the source location.

Figure 15 Modelled SELs vs range and depth along the propagation path in South-North direction from the source location L1. Black line shows the seabed depth variation.

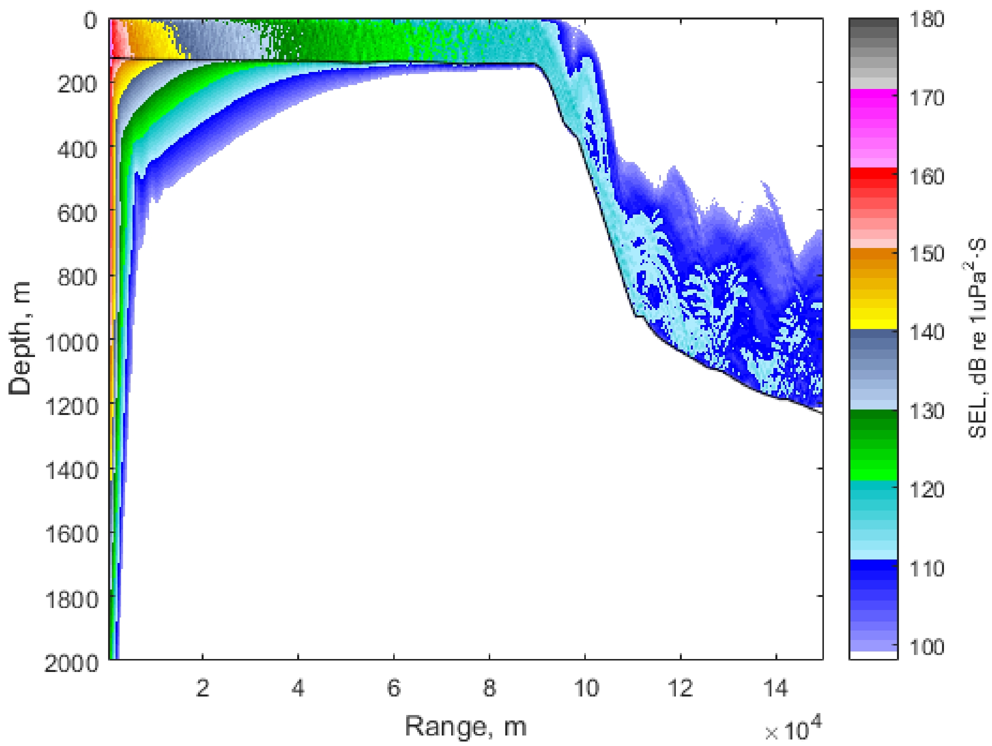


Figure 16 Modelled SELs vs range and depth along the propagation path in North-South direction from the source location L1. Black line shows the seabed depth variation.

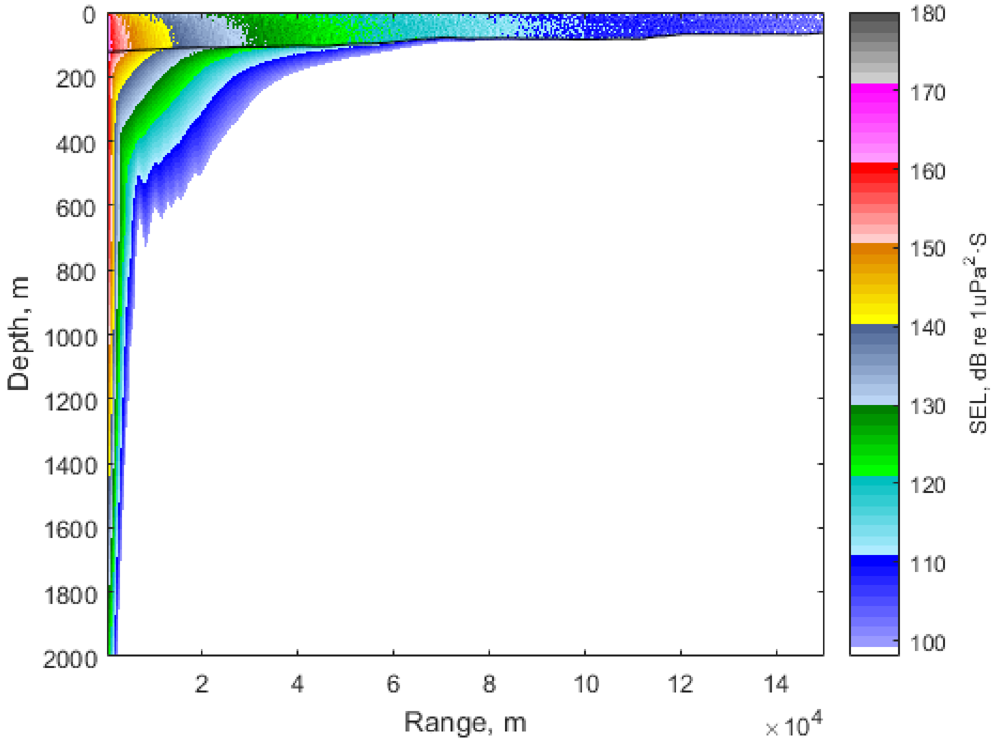


Figure 17 Modelled SELs vs range and depth along the propagation path in West-East direction from the source location L1. Black line shows the seabed depth variation.

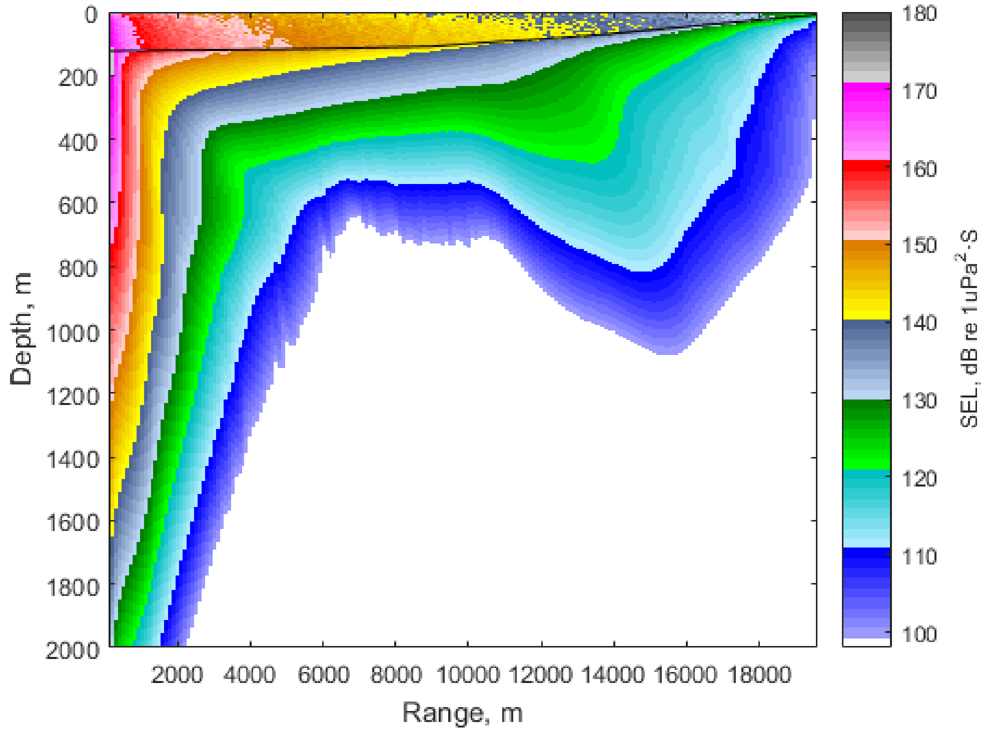
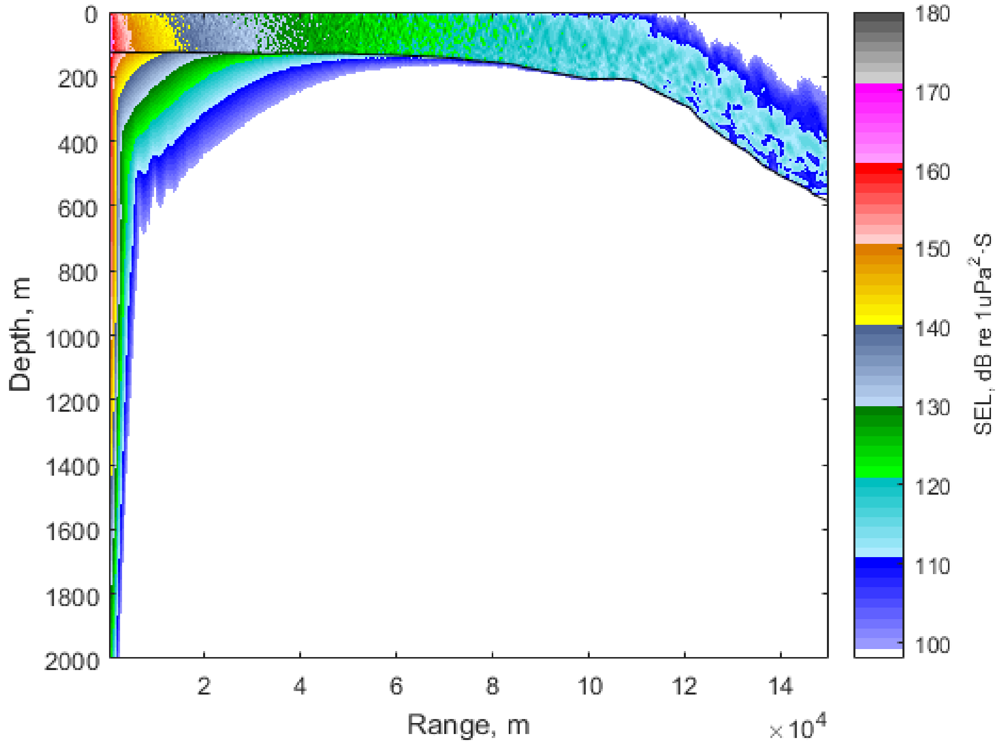


Figure 18 Modelled SELs vs range and depth along the propagation path in East-West direction from the source location L1. Black line shows the seabed depth variation.



5 CONCLUSIONS

Shell Taranaki has proposed to undertake a 4D seismic survey within the Taranaki Basin. This report details the sound transmission loss modelling study that has been carried out for the proposed survey, which includes three modelling components, e.g. array source modelling, short range modelling and long range modelling. The detailed modelling methodologies and procedures for the three components are described in **Section 2** and **Section 3** of the report.

The proposed acoustic source for this survey is the Boltgun 3,147 cubic inch array. The location with the shallowest water depth within the 4D Operational Area was selected for the short range modelling, and the location with the closest distance to the adjacent marine mammal sanctuary area was selected for the long range modelling. The worst case environmental conditions, i.e. autumn seasonal sound speed profile and fine sand seabed sediment, have been assumed for the modelling cases.

The short range modelling prediction demonstrates that the highest SELs occur in the in-line and cross-line directions, as a result of the directionality of the source array. The maximum received SEL levels over all azimuths are predicted to be below 186 dB re 1µPa^2·s at 200 m and below 171 dB re 1µPa^2·s at 1.0 km.

The long range modelling shows that the received noise levels at long range vary significantly at different angles and distances from the source. This directionality of received levels is due to a combination of the directionality of the source array, and propagation effects caused by bathymetry and sound speed profile variations. The southern boundary of the West Coast North Island Marine Mammal Sanctuary has the shortest distance of of approximately 6.7 km to the selected source location. The maximum SELs at the sanctuary boundary are predicted to be around 148 dB re 1µPa^2·S.

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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 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 some duration. The root-mean-square sound pressure level is the level of the root of the mean-square pressure against 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

GROUND TRUTHING METHODOLOGY

Ground-truthing Methodology

Ground-truthing Methodology for the Māui 4D Seismic Survey

For surveys taking place in an AEI where sound transmission loss modelling is required, Appendix 1 of the Code requires that this modelling is ground-truthed during the survey by appropriate means.

During the Māui 4D Seismic Survey ground–truthing will be undertaken by isolating the acoustic sound trace received from the streamer hydrophones at the mitigation distances relevant to the mitigation zones outlined in the Code of Conduct (200 m, 1000 m and 1500 m). The streamer hydrophones record across the frequency range 1 – 250 Hz.

As the bathymetry within the Survey Area does not change markedly, the ground-truthing will occur at an approximate depth of 100 m. However, if the opportunity arises, ground-truthing will also occur at a water depth of 80 m (in the southeast portion of the Operational Area) to match the depth on which the short-range modelling was based.