APPENDIX 18

ASSESSMENT OF UNDERWATER NOISE EFFECTS

Styles Group
Underwater Acoustics

ASSESSMENT OF UNDERWATER NOISE EFFECTS

SHIPYARD AND DRYDOCK FACILITY

PREPARED FOR

Ministry of Business, Innovation & Employment

DATE

4 August 2026

Assessment prepared by Styles Group for Ministry of Business, Innovation & Employment.

REVISION HISTORY

Rev:	Date:	Comment:	Version:	Prepared by:	Reviewed by:
1	18/06/26	Draft for client review.	Draft	Matt Pine, Ph.D., MASNZ Principal Styles Group	Jon Styles, MASNZ Director and Principal Styles Group
2	4/08/26		Final	Matt Pine, Ph.D., MASNZ Principal Styles Group	Jon Styles, MASNZ Director and Principal Styles Group

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Executive summary

Styles Group has predicted the underwater noise levels from the construction the proposed Northland shipyard and drydock facility in Whangārei Harbour. This report has been prepared to accompany the resource consent application and Assessment of Environmental Effects for the proposal.

The purpose of this assessment is to set out the general nature and extent of underwater noise levels and to quantify the spatial extent of acoustic-related effects/impacts on the different marine taxa (**animal groups**).

The results of this assessment inform the spatial ecology reports on marine mammals, benthic ecology, and avifauna. Those specialist assessments deal with the potential effects in the context of the overall marine ecology, species populations and ecological communities within Whangārei Harbour.

Noise criteria

We have adopted the thresholds set out in the marine mammal acoustic technical guidance (revised in 2024) from the National Marine Fisheries Service (**NMFS**) of the U.S. Department of Commerce. This guidance has been extensively used around New Zealand and the world for underwater noise assessments. In the absence of specific guidance on underwater noise effects criteria in New Zealand, the adoption of overseas standards and peer-reviewed research is common.

For fish, we relied on the thresholds set by NMFS (2025) for the onset of physical injuries that could lead to fatality and hearing loss. Physical injury effects are noise-related impacts that current research can reliably link to negative effects on an individual or population net fitness.

Physiological effects

Physiological effects include the risk of hearing loss through auditory injury (including permanent threshold shift, PTS) or temporary threshold shift (TTS).

Our modelling demonstrates that there is risk for these effects in all marine mammal species for the percussive piling. The dredging noise is not shown to present a risk for these physiological, including hearing loss, effects in marine mammals.

Large whale species (Bryde's, humpback whales etc) are at particular risk for TTS effects as their onset risk range extends to an absolute maximum of 4.08km from the unmitigated impact piling of the 1622mm OD steel piles along the combi wall. Mitigation using confined bubble curtains can reduce this to an absolute maximum of 3.79km.

For dolphin species (including killer whales), unmitigated piling of the combi wall piles presents a risk for auditory injury out to a maximum range of 183m (38m with confined bubble curtains).

The risk for TTS onset reaches a maximum range of 1.89km (461m with confined bubble curtains).

The spatial extent of the potential onset of auditory injury and TTS in fishes (and invertebrates) and kororā/little penguins were unable to be quantified with specific ranges due to a lack of thresholds in the scientific literature.

Behavioural effects

Behavioural effects/responses include a large range of effects from small changes such as vigilance, brief interruptions to activity and minor changes that will not have a significant impact when intermittent over short time frames, to medium sized behavioural changes that are increasingly likely to have negative consequences on an individual by increasing disruptions to essential behaviours.

Behavioural responses from continuous dredging noise in cetaceans were quantified using dose-response functions based on the recommendations in Southall et al. (2021). Dose-response functions were unavailable for pinnipeds so step-function thresholds were used to predict ranges within which fur seals and leopard seals may show a behavioural change.

For the percussive piling, step-function thresholds from NMFS (2024) were used to predict ranges within which all marine mammal species may show a behavioural change.

The modelling shows minor behavioural responses can be expected in marine mammals within 4.05km from unmitigated percussive piling. Confined bubble curtains are estimated to reduce that range to approximately 2.95km. Care is needed when interpreting those ranges as the simple step-function thresholds do not consider contextual variables, such as age, sex, behavioural states or mother/calf pairs.

When exposed to the loudest dredging noise from a medium sized trailer-suction hopper dredger (TSHD), low behavioural responses can be expected within 1.44km (i.e., risk is greater than 0%), with a 50% probability of a moderate responses by dolphin species occurring within 100m. Again, large whales with their low-frequency hearing can be expected to show low behavioural responses inside 3.04km, which increases to >50% within 1.89km. These ranges are much smaller for a large cutter-suction dredger (CSD) or backhoe dredger (BHD).

Small behavioural responses in fishes and kororā/little penguin were unable to be determined due to an absence of relevant data.

Auditory masking effects

Auditory masking is the interference of a biologically important signal (such as vocalisations) by an unimportant noise (i.e., anthropogenic noise in this case) that prevents the listener from properly perceiving the signal.

Masking release mechanisms are various strategies that allow an animal to continue detecting and discriminating ecologically important signals in noisy environments, thereby allowing them to overcome the effects of masking in some cases.

Our assessment of auditory masking is informed by our own measurements of the ambient sound levels within Whangārei Harbour entrance between June and December 2020.

Baleen whales are generally more sensitive to auditory masking effects compared to some other marine mammals (i.e., delphinids) due to their peak hearing sensitivities and vocalisations overlapping very well with the low-frequency noise from the percussive piling and dredging (all three types of dredging). The lower level (i.e. <25%) of auditory masking effects for all marine mammal species could occur within 6.56km from the unmitigated percussive piling for the combi wall (between 3.40km and 3.78km when using confined bubble curtains). The same lower level of masking could be expected within 3.03km when exposed to loudest form of dredging noise, the TSHD.

Kororā/little penguins are also susceptible to possible masking effects, with low (25% LSR) to medium level (50% LSR) effects occurring within 5.26km and 3.68km, respectively, from unmitigated percussive piling. Confined bubble curtain reduces those ranges to between 2.67km (25% LSR) 4.43km (50% LSR).

Audibility

Audibility of the anthropogenic noise simply means that an animal may hear the noise from the piling or dredging. The simple audibility of an anthropogenic noise does not necessarily mean that there will be detrimental effects on an animal group. The spatial extent of audibility is simply the maximum range at which the piling or dredging noise may be audible.

Inside Whangārei Harbour, these audibility ranges are confined by the narrow harbour. This means the maximum audibility range is approximately 10km before the sound reaches the shoreline across the harbour and very quickly attenuates to well below the local sound levels.

If percussive piling the largest 1622mm OD piles along the combi wall, all marine mammal species had audibility ranges to that maximum range of 10k, while Kororā/little penguins were out to 8.09km. With confined bubble curtains, that audibility range for marine mammals decreases slightly to 9.76km but 6.7km for Kororā/little penguins.

Audibility ranges for dredging were considerably smaller, with the modelling showing loudest type of dredger (the TSHD) being audible within 5.07km and 4.45km for marine mammal species and Kororā/little penguins, respectively.

1.0 Introduction

Styles Group has been engaged by the Ministry of Business, Innovation & Employment (**MBIE**) to undertake an underwater acoustic assessment of the proposed shipyard and drydock facility at Marsden Point, Whangārei Harbour (**the Project**).

The purpose of this underwater noise assessment is:

- To demonstrate the nature and extent of noise emissions,
- To quantify, if any, the spatial extent of various acoustic-related effects on marine mammals, penguins and fish inside Whangārei Harbour.

This assessment is for the purposes of informing the specialist ecology reports, and as such, discussion of the results and conclusions around effects/impact levels on various marine taxa in the context of the Harbour's ecology and literature are contained in those reports.

2.0 The project

The development and operation of a marine maintenance operations facility abutting the western side of the existing Northport port facility at Marsden Point, Whangārei Harbour. The project includes a reclamation, vessel haul-out system, and associated wharf structures, dredging, and supporting infrastructure.

The key components of the project include:

- reclamation of approximately 9.7ha
- a 'cutout' to the reclamation where a vessel haul out system is to be located, being a floating drydock or potentially ship lift or other lifting mechanism
- construction of a piled wharf structure to accommodate vessels either temporarily (before/after haul out), or for extended periods where works not requiring haul out can be undertaken
- dredging stage one: capital and maintenance dredging associated with construction and ongoing operation of the marine maintenance operations facility, including a berth pocket and a vessel turning basin to provide for safe navigation
- dredging stage two: capital dredging to ensure sufficient volume of dredge spoil is available to construct both the Northland Drydock facility and Northport's Vision for Growth development.
- fixed plant and buildings to accommodate marine maintenance activities and materials

- sufficient working & laydown areas for marine maintenance operations, including the ability to transfer vessels to hardstand
- access to and around the marine maintenance operations facility, including a landside area for staff carparking
- public access around the edge of the reclamation to a public fishing platform

The marine maintenance operations facility is to provide vessel maintenance, repairs, and servicing, including but not limited to cleaning, painting, and repair of commercial and naval vessels, including Cook Strait ferries and Royal New Zealand Navy logistics vessels, along with other vessels such as international freight vessels and super yachts. The facility has design capacity to accommodate vessels ~50m to 230m in length with displacement between 500t and 28,000t. The facility will be based on normal working hours of 7am-6pm but the capacity to operate 24/7/365 where required, subject to appropriate restrictions on noise-generating activities.

The location of the facility has been carefully selected for functional and operational requirements, including the need for deep water access, sheltered harbour conditions, proximity to existing port services, sea and land transport links, and integration with established and proposed marine and land-based industrial infrastructure.

The project is listed in Schedule 2 of the Fast-track Approvals Act 2024 as having significant regional or national benefits.

From an underwater noise perspective, the proposed percussive piling and capital dredging works are the two construction activities that pose the highest risk to marine animals. This advice provides a specific assessment of those activities to inform the determination of the appropriate mitigation strategies by the relevant technical specialists.

A full description of the project is provided in the AEE.

3.0 Assessing levels of acoustic-related effects

There is a growing body of evidence that underwater noise can, and does, have detrimental impacts on marine life. Approximately 538 studies have been reviewed in a 2021 review paper, providing a high level of confidence that anthropogenic noise can negatively affect marine fauna (Duarte et al. 2021). Specifically, a significant percentage of quantitative studies report negative impacts across a variety of noise sources, including vessels, sonars, acoustic deterrent devices, energy and construction infrastructure and seismic surveys (Figure 1, taken directly from Duarte et al. 2021). While underwater noise is typically a *point-source pollutant* (Duarte et al. 2021) with effects that decline when the source is removed, it should be included in an assessment of cumulative pressures on marine ecosystems.

This report constitutes a comprehensive assessment of the underwater noise effects associated from the pile driving and capital dredging required during the Project. It is based on advanced computer modelling of the noise propagation field that is generated by the equipment used. The models are then used as the basis for assessing the level of effect on marine mammals, penguins and fishes.

The purpose of the underwater noise assessment is to quantify the spatial extent of various effects related to marine fauna, using the available data from international technical guidance and peer-reviewed studies. A complete discussion of the underwater noise effects on various animal groups in the context of the ecology of Whangārei Harbour are contained within the specialist ecology reports, where the level of impact on the specific area's ecology is assessed.

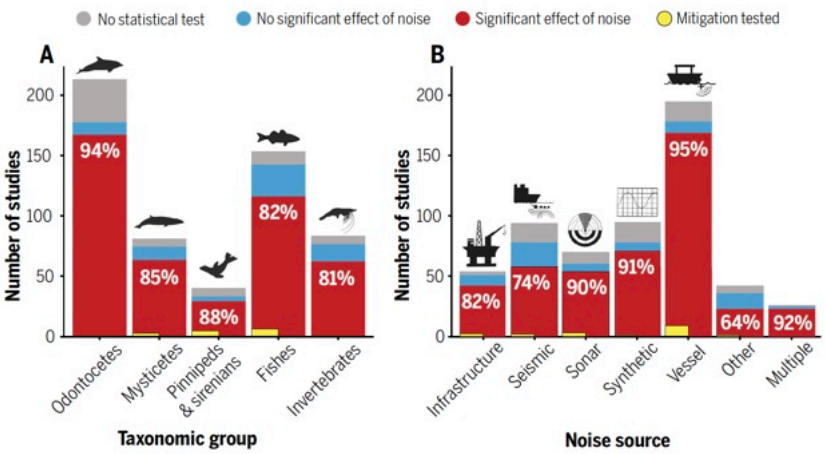

Figure 1: Plot showing the number of studies reviewed in Duarte et al. (2021), broken down by taxa (A) and anthropogenic noise source (B). The percentages represent the proportion of studies that report evidence of impacts (of any magnitude). The plot is taken directly from Duarte et al. (2021).

3.1 Noise criteria and applying international technical guidance and peer-reviewed studies.

This report describes the modelling of underwater noise that has been undertaken to inform the effects on the marine environment using international guidelines for noise effects and peer-reviewed studies on marine mammals, penguins and fishes. Based on the current state of knowledge, there are three key effect categories that are relevant to all marine fauna (including invertebrates to a lesser degree than fishes) in the survey area. These are:

1. Physiological effects: Include auditory injury (**AUD INJ**) that may or may not result in permanent hearing loss (termed permanent threshold shift, **PTS**). Also includes temporary hearing loss (temporary threshold shift, **TTS**).

2. Behavioural effects: Behavioural responses or changes due to the anthropogenic noise exposure.

3. Masking effects: The interruption or interference of a biologically important signal by an invading noise (i.e., a masking noise).

Generally speaking, the severity of effects (as termed in the literature or guidance, for example Southall et al. (2019, 2021)) decreases with increasing range from the noise source (Figure 2). Physiological effects generally occur closest to a noise source and can have direct impacts on an animal's survival, foraging, and reproduction (referred to as *vital tracks* or *vital rates* (Southall et al. 2021))[1]. Behavioural effects can range from minor to major (that can impact an individual's vital rates) depending on many variables, but generally beginning at the higher levels of masking. Masking in and of itself is not necessarily a significant effect if the masking is short-lived and/or mild. However, if masking reaches levels that that are high enough or continuous enough to overwhelm an individual's masking release mechanisms, then animals may alter their behaviours to escape the noise or move away, potentially to a less suitable habitat (which would be a significant effect).

While these effects categories relate to all marine fauna, not all of the effects categories could be specifically predicted (i.e., effects ranges being calculated) for all marine animal groups (being cetaceans, pinnipeds, fishes, and kororā/little penguins) due to data deficiencies in the scientific literature, and therefore exclusion from national or international technical guidance. Table 1 provides details on the overall method used for each effect category and which animal group were included in each effect category.

Figure 2: Effects categories in a generalised order of increasing distance from the noise source. Depending on the thresholds, or metrics used to assess certain effect categories, the true order can be less linear.

[1]Vital tracks/rates are the three parallel categories within the severity scale in field studies for free-ranging (i.e., wild) marine mammals that can be considered, based on their impact on individual fitness and population parameters (Southall et al. 2021).

Table 1: Methods used for assessing effects in this assessment for certain animal groups.

Effects category	Assessment Guidance/Methods used.	Rationale for use	Relevant animal group
Physiological	National Marine Fisheries Service (NMFS), Update 2024 & 2025	International standard for physiological effects threshold	Cetaceans, Pinnipeds, Fishes
	Safe-distance method/ NMFS (2024).	NMFS discussed method for assessment a stable moving source. NMFS (Update 2024) also provide thresholds for fishes.	Cetaceans, Pinnipeds
Lack of thresholds/guidance for invertebrates and seabirds. However, the impact ranges for those animal groups are expected to be less than those for marine mammals and fishes due to their similar or lower hearing ranges.			
Behavioural	Probabilistic dose-response curves (continuous noise).	Dose-response curves recommended where available by Southall et al. (2021).	Cetaceans.
	NMFS Thresholds	NMFS provides methods for assessing onset of Level B harassment.	Cetaceans**, Pinnipeds, Fishes**.
Masking	Active listening space reduction (LSR)***	LSR is based on environmental conditions that is better understood and more robust for this application (see Figure 5 for recommendation in Pine et al. 2020).	Cetaceans, Pinnipeds, Kororā little penguins.

**For cetaceans, these are used for comparative reasons, since the dose-response function contains assumptions. No dose-response functions available for fishes or penguins in relation to piling or dredging.

***An animal's listening space is the immediate area surrounding it within which it can detect and perceive a biologically important signal. As an animal receiver moves around an area while construction activities are underway, such as piling or dredging, the animal's listening space will decrease to a new, smaller listening space. The difference between the original and the smaller listening space under masking conditions is termed the listening space reduction, LSR.

3.2 Species assessed

Specific species within and around the investigation area are not specifically, or individually, assessed throughout this assessment. Instead, they are grouped/pooled into larger, representative groups for the purposes of assessing effects on all species within and around the project area. These groups are referred to as animal groups[2] and the assessment of different effect categories is provided for each animal group. This approach was adopted because:

- Technical guidance provide data that represent functional hearing groups based on overlapping hearing capabilities, hearing anatomies and acoustic ecologies between certain species. For example, the National Marine Fisheries Service (NMFS (2024)) in the U.S. provide composite audiogram functions for each functional hearing group of marine mammals that represent the various species within the project area. Or, the frequency range of vocalisations overlap, and/or the role of sound in each species' life history is similar.
- Data on hearing anatomies and hearing thresholds for all species within the survey area do not exist.

Table 2 provides specific details on how the animal groups were defined and the rationale for doing so.

3.3 Scope of this assessment

The purpose and scope of this underwater noise assessment is to:

i. Model the underwater piling and dredging noise associated with the reclamation.

ii. Assess the potential extent of hearing threshold shifts (both permanent and temporary), behavioural responses and/or auditory masking in marine mammals and kororā/little penguins.

iii. Assess the potential extent of auditory injury onset in fishes (including PTS and TTS).

This assessment has been prepared to inform the assessment of effects on fish and marine mammals that have been undertaken by other specialists.

[2] These are cetaceans (whales/dolphins), pinnipeds (seals), penguins (kororā) and fishes.

Table 2: Species/groups used to represent various species in this assessment.

Method	Species or groups that data is from to assess effects category in this assessment	Taxa/Species within the Project area represented.	Rationale
Physiological Effects			
AUD INJ/TTS Thresholds	Functional hearing groups, as defined in NMFS (2024)	Cetaceans, Pinnipeds.	Species are grouped into their respective functional hearing groups, or sizes, based on a combination of factors related to their hearing capabilities, auditory anatomy and acoustic ecology. Species that overlap in these three general areas are pooled together for quantifying effects ranges.
Physical Injury Thresholds	General, from NMFS (2025)	Fishes	NMFS summary documents provide one of the only regulatory-provided thresholds for physical injury in fishes from percussive pile driving.
Behavioural			
Probabilistic dose-response curves (continuous dredging noise)	Killer whales	Cetaceans	Recent peer-reviewed dose response function using empirical data on a delphinid species exposed to continuous noise sources (vessel noise) that is pooled in the same functional hearing group as delphinid species that frequent Whangārei Harbour. Therefore, considered appropriate for representing dolphin species inside Whangārei Harbour.
Single step functions (percussive piling or dredging)	NMFS (2024) threshold used for Behavioural Onset Zones	Cetaceans, Pinnipeds, Fishes	Piling-related dose-response curves unknown for these species/groups, and hearing anatomy substantially differs to cetaceans. Single step function based on the NMFS (2024) thresholds was therefore used to establish behavioural effect zones.
Auditory masking & audibility			

Method	Species or groups that data is from to assess effects category in this assessment	Taxa/Species within the Project area represented.	Rationale
LSR & signal excess (simplified sonar equation)	Functional hearing groups & composite audiograms	Marine mammals, kororā	NMFS (2024) composite audiograms are based on all available audiogram data, which are derived for each functional hearing group after compiling all available hearing threshold data for representative species. These are therefore superior in terms of robustness than using single audiograms for specific species as they can suffer from small sample sizes. Masking ranges for fishes (and invertebrates) fall within the ranges for marine mammals. Therefore, by assessing the auditory masking ranges for marine mammals, the worst-case scenarios are provided for fishes as well.
	Little penguin (*Eudyptula minor*) audiogram	Kororā/little penguins	Estimated audiogram of same species of penguin from microCT (see Wei et al. 2024). This is the best hearing data for *E. minor* at the time of this assessment being undertaken.

4.0 Underwater noise and effects modelling

We prepared underwater noise models of the Whangārei Harbour entrance, centred on the Project. Figure 3 displays the extent of the modelled area.

A full technical discussion of the methodology for the underwater noise modelling, including details on the source levels, propagation models and environmental inputs is set out in Appendix C. We do not replicate that here and instead provide a brief summary below.

The key aspects of the modelling included:

- Source level data were based on a computational model by MacGillivary (2015) and empirical measurements by Austin et al. (2016). The input pile size into the source model was 1622mm OD steel casing piles for the combi walls as they are the largest piles in the construction. Effects ranges from driving all other piles that are smaller will be contained inside the results presented in this assessment.
- The noise models incorporated bathymetry, sound speed and seafloor composition.
- Two propagation codes were used to model the range-dependent sound pressure levels: the parabolic equation method (RAMGeo from the Ocean Acoustics Library) for frequencies below 1.2kHz, and Energy Flux (EF) (Weston et al. 1971; 1976). The EF algorithm is a computationally efficient over range-dependent scenarios (Farcas et al. 2020). As such, very high resolution models can be used to investigate a range of scenarios, in short time frames. It also has been validated in a range of environments (such as in ship noise models (Farcas et al. 2020) or around shallow water fish farms (Findlay et al. 2021) and can produce very good propagation loss predictions (Sertlek & Ainslie 2013; 2014). While caution is needed, its use in modelling pile-driving noise has also been undertaken (for example de Jong et al. (2019); Wood (2016)) and presents several advantages for piling in shallow waters.
- The EF model's limitations are that it presents depth-averaged propagation losses (i.e., it has no depth-dependence) and assumes isovelocity sound channels (Wood 2016).
- The resulting noise field maps were used to assess each effects category, namely physiological, behavioural and auditory masking. General audibility ranges were also considered as the theoretical maximum area for which the potential onset of any noise impact, of any severity, may occur.
- The potential onset of auditory injury (both recoverable and permanent, including TTS) were assessed for fishes exposed to the highest percussive-piling noise. Behavioural impacts and masking effects were not assessed because of the lack of data on the relationship between contextualised behavioural responses and corresponding noise levels for piling or dredging.

Please refer to Appendix C for further detail, including the criteria for the assessment of noise effects on marine mammals and fishes, along with the rationale for why certain impacts were assessed.

Sections 5 through 8 below sets out the noise modelling results for percussive piling and capital dredging using a TSHD, CSD and BHD, providing ranges for:

- Potential onset of auditory injury (AUD INJ), including permanent threshold shift (PTS).
- Potential onset of temporary threshold shift (TTS).
- Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for each the species of interest.
- Distances at which the potential onset of behavioural responses may occur.
- Distances within which audibility of the activity will be possible.
- Cumulative noise effects.

Appendices D through H provide plots and/or contour maps.

The modelling results for the dredging represent effects ranges for both stages of dredging, since the equipment used are the same, and the areas are very close to each other. Additionally, the effects ranges from the dredging are assessed relative to the position of the dredge operating under full production conditions (i.e., worst case).

Figure 3: Map of the Project area

The blue dotted line represents the extent of the underwater noise models.

5.0 Results: marine mammals

5.1 Percussive piling

In this case, the cumulative Sound Exposure Levels ($L_{E,24hr}$) levels were above the peak levels (L_{pk}) for all functional hearing groups assessed. The $L_{E,24hr}$ thresholds were therefore used to assess threshold shift in marine mammal groups.

Table 3 below summaries the ranges within which temporary threshold shifts (TTS) for marine mammals can be expected. The ranges within which AUD-INJ (including PTS) can be expected are substantially smaller than those for TTS. Exclusion zones based on the TTS ranges (as a mitigation measure) will, therefore, afford all marine mammals protection from AUD-INJ effects, including PTS.

5.1.1 Effects category: physiological

Table 3: Ranges (m) for the potential onset of permanent threshold shift (PTS) for the four functional hearing groups of cetaceans from **unmitigated** percussive piling.

Species	Critical Range (m)
Bryde's Whales, Humpback whales, southern right whales (LF)	1400
Killer Whales, Bottlenose Dolphins, Common Dolphins (HF)	183
Leopard Seals (PW)	1400
Fur Seals (OW)	433

Table 4: Ranges for the potential onset of temporary threshold shift (TTS) for the four functional hearing groups of cetaceans from **unmitigated** percussive piling.

Species	Critical Range (m)
Bryde's Whales, Humpback whales, southern right whales (LF)	4081
Killer Whales, Bottlenose Dolphins, Common Dolphins (HF)	1888
Leopard Seals (PW)	4088
Fur Seals (OW)	4005

5.1.2 Effects category: behavioural

Table 5: Distances at which the potential onset of behavioural responses may occur from the **unmitigated** percussive piling.

The use of these two threshold values, their origin, and meaning are provided in the methods, contained in Appendix D.

Species	Threshold	
	140dB	**160dB**
All Species	4052m	568m

5.1.3 Effects category: auditory masking

Table 6: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) during **unmitigated** percussive piling occurs for each functional hearing group during the quietest noise conditions.

Functional hearing group	Species	Distances (m) at which some percentage of an individual's active listening space during piling			
		75%	**50%**	**25%**	**0%**
Low Frequency	Bryde's, humpback, southern right	3555	3891	6559	10000
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer	2312	3891	6559	10000
Phocid Pinnipeds	Leopard seals	3547	3891	6559	10000
Otariid Pinnipeds	New Zealand fur seals	3182	3891	6559	10000

5.1.4 Effects category: audibility

Table 7: Distances within which audibility of the **unmitigated** percussive piling is possible during the median noise conditions over the daytime.

Functional hearing group	Species	Estimated Audibility Range (m)
Low Frequency	Bryde's, humpback, southern right	10000
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer	10000
Phocid Pinnipeds	Leopard seals	10000

Functional hearing group	Species	Estimated Audibility Range (m)
Otariid Pinnipeds	New Zealand fur seals	10000

5.2 Trail-suction-hopper dredging

5.2.1 Effects category: physiological

A noise model of the operation of the TSHD while dredging was prepared to understand the noise levels from the noisiest activities. The noise sources present during the TSHD operation are water pumps, engines, propellors, pipes and the draghead extracting sandy/gravel sediments.

Noise levels beyond 1m from the source are not expected to induce TTS within any of the functional hearing groups of marine mammals during dredging.

5.2.2 Effects category: behavioural

Table 8: Distances at which 75, 50, 25 and 0% risk of low and moderate behavioural responses for each of the species of interest may occur.

Species	Behavioural Response	Risk isopeth (m)			
		75%	50%	25%	0%
Killer Whale Bottlenose Dolphin Common Dolphin	Low (minor changes in respiration rates, swimming speeds/direction)	317	434	598	1438
	Moderate (moderate to extensive changes in swimming speeds/direction and/or diving behaviours, moderate or prolonged cessation of vocalisations, and/or avoidance)	52	100	200	634
Bryde's Whale Humpback Whale Southern Right Whale	Low (minor changes in respiration rates, swimming speeds/direction)	1438	1892	2154	3037
Fur Seal Leopard Seal	Low (minor changes in respiration rates, swimming speeds/direction)	Potential Onset: 1892m			

Species	Behavioural Response	Risk isopeth (m)			
		75%	**50%**	**25%**	**0%**
	Moderate (moderate to extensive changes in swimming speeds/direction and/or diving behaviours, moderate or prolonged cessation of vocalisations, and/or avoidance)	Potential Onset: 415m			

5.2.3 Effects category: auditory masking

Table 9: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for each functional hearing group during the quietest noise conditions.

Functional hearing group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced by when the TSHD is actively extracting			
		75%	**50%**	**25%**	**0%**
Low Frequency	Bryde's, humpback, southern right.	753	1460	3026	5070
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer.	72	1031	3026	5070
Phocid Pinnipeds	Leopard seals	884	1470	3026	5070
Otariid Pinnipeds	New Zealand fur seals	581	1283	3026	5070

5.2.4 Effects category: audibility

Table 10: Distances within which audibility is possible during the median noise conditions over the daytime.

Functional hearing group	Species	Estimated Audibility Range (m)
Low Frequency	Bryde's, humpback, southern right.	5070
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer.	5070
Phocid Pinnipeds	Leopard seals	5070
Otariid Pinnipeds	New Zealand fur seals	5070

5.3 Cutter-suction dredging

5.3.1 Effects category: physiological

Noise emissions from a complete dredging production cycle were evaluated. A noise model of the operation of the cutter head and dredging was prepared to understand the noise levels from the noisiest activities.

Noise levels beyond 1m from the source are not expected to induce TTS within any of the functional hearing groups of marine mammals during dredging.

5.3.2 Effects category: behavioural

Table 11: Distances at which 75, 50, 25 and 0% risk of low and moderate behavioural responses for each of the species of interest may occur.

<table>
<tr><th rowspan="2">Species</th><th rowspan="2">Behavioural Response</th><th colspan="4">Risk isopeth (m)</th></tr>
<tr><th>75%</th><th>50%</th><th>25%</th><th>0%</th></tr>
<tr><td rowspan="2">**Killer Whale**
Bottlenose Dolphin
Common Dolphin</td><td>Low (minor changes in respiration rates, swimming speeds/direction)</td><td>127</td><td>200</td><td>329</td><td>716</td></tr>
<tr><td>Moderate (moderate to extensive changes in swimming speeds/direction and/or diving behaviours, moderate or prolonged cessation of vocalisations, and/or avoidance)</td><td>35</td><td>49</td><td>86</td><td>417</td></tr>
<tr><td>**Bryde's Whale**
Humpback Whale
Southern Right Whale</td><td>Low (minor changes in respiration rates, swimming speeds/direction)</td><td>619</td><td>748</td><td>1401</td><td>2154</td></tr>
<tr><td rowspan="2">**Fur Seal**
Leopard Seal</td><td>Low (minor changes in respiration rates, swimming speeds/direction)</td><td colspan="4">Potential Onset: 748m</td></tr>
<tr><td>Moderate (moderate to extensive changes in swimming speeds/direction and/or diving behaviours, moderate or prolonged cessation of vocalisations, and/or avoidance)</td><td colspan="4">Potential Onset: 184m</td></tr>
</table>

5.3.3 Effects category: auditory masking

Table 12: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for each functional hearing group during the quietest noise conditions.

Functional hearing group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced by when the CSD is extracting			
		75%	**50%**	**25%**	**0%**
Low Frequency	Bryde's, humpback, southern right.	251	587	1364	4376
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer.	36	383	1364	4376
Phocid Pinnipeds	Leopard seals	283	587	1364	4376
Otariid Pinnipeds	New Zealand fur seals	180	504	1364	4376

5.3.4 Effects category: audibility

Table 13: Distances within which audibility is possible during the median noise conditions over the daytime.

Functional hearing group	Species	Estimated Audibility Range (m)
Low Frequency	Bryde's, humpback, southern right.	4376
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer.	4376
Phocid Pinnipeds	Leopard seals	4376
Otariid Pinnipeds	New Zealand fur seals	4376

5.4 Backhoe dredging

5.4.1 Effects category: physiological

We evaluated the noise emissions from the backhoe dredging, including operation of the BHD engine/generator, hydraulic rams, bucket impact and loading on the seafloor, barge loading and anchoring the spuds. A noise model of the bucket impact and loading was prepared to understand the noise levels of the noisiest activity.

TTS effects are not expected to incur beyond 1m of the source for any of the functional hearing groups of marine mammals. No TTS (or any injury) guidelines from aggregate dredging exist for fishes.

5.4.2 Effects category: behavioural

Table 14: Distances at which 75, 50, 25 and 0% risk of low and moderate behavioural responses for each of the species of interest may occur

Species	Behavioural Response	Risk isopeth (m)			
		75%	50%	25%	0%
Killer Whale Bottlenose Dolphin Common Dolphin	Low (minor changes in respiration rates, swimming speeds/direction)	102	134	215	423
	Moderate (moderate to extensive changes in swimming speeds/direction and/or diving behaviours, moderate or prolonged cessation of vocalisations, and/or avoidance)	38	63	93	280
Bryde's Whale Humpback Whale Southern Right Whale	Low (minor changes in respiration rates, swimming speeds/direction)	404	498	573	773
Fur Seal Leopard Seal	Low (minor changes in respiration rates, swimming speeds/direction)	Potential Onset: 498m			
	Moderate (moderate to extensive changes in swimming speeds/direction and/or diving behaviours, moderate or prolonged cessation of vocalisations, and/or avoidance)	Potential Onset: 130m			

5.4.3 Effects category: auditory masking

Table 15: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for each functional hearing group during the quietest noise conditions.

Functional hearing group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced by when the BHD is actively extracting			
		75%	50%	25%	0%

Functional hearing group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced by when the BHD is actively extracting			
Low Frequency	Bryde's, humpback, southern right.	32	320	841	2446
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer.	19	77	405	2446
Phocid Pinnipeds	Leopard seals	33	320	841	2446
Otariid Pinnipeds	New Zealand fur seals	28	227	694	2446

5.4.4 Effects category: audibility

Table 16: Distances within which audibility is possible during the median noise conditions over the daytime.

Functional hearing group	Species	Estimated Audibility Range (m)
Low Frequency	Bryde's, humpback, southern right.	2446
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer.	2446
Phocid Pinnipeds	Leopard seals	2446

6.0 Results: Kororā Little Penguin

This section presents a series of tables for the effects categories for kororā/little penguins. Physiological effects (AUD INJ (including PTS), and TTS) are not quantified due to a lack of thresholds data in the scientific literature.

6.1 Percussive piling

6.1.1 Effects category: auditory masking

Table 17: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for kororā/little penguins during the median noise conditions over the daytime.

Group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced during piling			
		75%	**50%**	**25%**	**0%**
Little Penguin	Kororā	1164	3679	5263	8088

6.1.2 Effects category: audibility

Table 18: Distances within which audibility is possible during the median noise conditions over the daytime.

Animal	Species	Estimated Audibility Range (m)
Little Penguin	Kororā.	8088

6.2 Trail-suction-hopper dredging

6.2.1 Effects category: auditory masking

Table 19: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for kororā/little penguins during the median noise conditions over the daytime.

Group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced by when the TSHD is actively extracting			
		75%	**50%**	**25%**	**0%**
Little Penguin	Kororā	21	269	1034	4448

6.2.2 Effects category: audibility

Table 20: Distances within which audibility is possible during the median noise conditions over the daytime.

Animal	Species	Estimated Audibility Range (m)
Little Penguin	Kororā.	4448

6.3 Cutter-suction dredging

6.3.1 Effects category: auditory masking

Table 21: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for kororā/little penguins during the median noise conditions over the daytime.

Group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced by when the CSD is actively extracting			
		75%	50%	25%	0%
Little Penguin	Kororā	---	64	511	4376

6.3.2 Effects category: audibility

Table 22: Distances within which audibility is possible during the median noise conditions over the daytime.

Animal	Species	Estimated Audibility Range (m)
Little Penguin	Kororā.	4376

6.4 Backhoe dredging

6.4.1 Effects category: auditory masking

Table 23: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for kororā/little penguins during the median noise conditions over the daytime.

Group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced by when the BHD is actively extracting			
		75%	50%	25%	0%
Little Penguin	Kororā	NaN	46	604	2446

6.4.2 Effects category: audibility

Table 24: Distances within which audibility is possible during the median noise conditions over the daytime.

Animal	Species	Estimated Audibility Range (m)
Little Penguin	Kororā.	2446

7.0 Results: Fish

7.1 Percussive piling

For fishes, the cumulative sound exposure levels, $L_{E,p,12h}$, levels were above the L_{pk} and were therefore relied upon for determining the critical ranges for injury.

Table 25: Ranges for the potential onset of noise impacts from the percussive piling in fishes, based on the NMFS (2025) thresholds for fishes </> 2g in mass

Size	Critical Range (m)
<2g	1402
>2g	773

8.0 Mitigation

The underwater noise modelling identifies that without mitigation a large shut down and marine mammal observation zone is required to protect marine mammals from TTS onset risk. Due to the practical challenges of implementing such a large observation zone, mitigation will be required to reduce the impact zone to one that is more manageable. Methods to achieve this for piling driving fall into two areas:

1. Operationally. These methods mitigate sound exposure to animals/environments by modifying the piling operational method. For example, slow starts, restricted hammer strikes per day, timing activity to certain tidal levels, etc.

2. Reducing underwater radiated noise. These methods mitigate sound exposure on animals by reducing the radiated noise from the immediate area around the source. For example, timber dollys, bubble curtains, restricting hammer/ram energies, etc.

A range of standard mitigation options have been considered for this project and are recommended. These include the use of cushions between the top of the pile and hammer/ram, soft starts and use vibratory piling methods over impact piling whenever possible.

However, these strategies are likely to not be sufficient on their own at reducing the risk for physiological effects to a more manageable range. We understand that the use of cofferdams, or double jacketed piles, are not practicable for this project due to the design of the combi wall. Bubble curtains have therefore been identified as the most practicable option to reduce the underwater radiated noise levels during the percussive piling.

Single or double bubble curtains have been used in New Zealand and internationally with as much as 10-14dB reductions being reported[3] (Bellman 2014). However, the performance of open bubble curtains inside Whangarei Harbour is very likely to be hindered due to the high currents (~3knots) that pass Northport and the 14-16m depth that the piling will be in.

Confined bubble curtains, however, circumvent the issue of high currents as an outer casing pile is inserted around the inner pile, with the bubble curtain operating between the pile a. The inner pile is the 1622mm OD pile that is to be driven for the combi walls, while the outer pile is likely to be up to 2032mm OD. Between the inner pile and outer casing are ‘injection’ rings at set depths that pump air through a porous tube into the annulus (the space between the two steel piles).

This type of bubble curtain is a commonly used mitigation strategy overseas, for example at the Port of Anchorage in Alaska during a modernisation project in 2016 (Austin et al. 2016). For this assessment, a similar confined bubble curtain setup was modelled.

To assess the levels of abatement from a confined bubble curtain during the large 1622mm OD piles for the combi wall, the MacGillivary (2015) source model was expanded to include a bubble layer and outer casing piles. Mitigated source levels were then used in the noise propagation model to obtain the new, smaller, effects ranges during the impact piling of the 1622mm OD piles.

A detailed description of how this was achieved is provided in Appendix C.

8.1 Confined bubble curtain results: marine mammals

8.1.1 Effects category: physiological

Table 26: Ranges for the potential onset of permanent threshold shift (PTS) for the four functional hearing groups of cetaceans.

Species	**Critical Range (m)**
Bryde’s Whales, Humpback whales, southern right whales (LF)	451

[3] German Federal Maritime and Hydrographic Agency, BHS.

Species	Critical Range (m)
Killer Whales, Bottlenose Dolphins, Common Dolphins (HF)	38
Leopard Seals (PW)	368
Fur Seals (OW)	183

Table 27: Ranges for the potential onset of temporary threshold shift (TTS) for the four functional hearing groups of cetaceans.

Species	Critical Range (m)
Bryde's Whales, Humpback whales, southern right whales (LF)	3785
Killer Whales, Bottlenose Dolphins, Common Dolphins (HF)	461
Leopard Seals (PW)	3335
Fur Seals (OW)	1888

8.1.2 Effects category: behavioural

Table 28: Distances at which the potential onset of behavioural responses may occur from the percussive piling.

The use of these two threshold values, their origin, and meaning are provided in the methods, contained in Appendix D.

Species	Threshold	
	140dB	**160dB**
All Species	2950m	227m

8.1.3 Effects category: auditory masking

Table 29: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for each functional hearing group during the quietest noise conditions.

Functional hearing group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced during piling			
		75%	**50%**	**25%**	**0%**

Functional hearing group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced during piling			
Low Frequency	Bryde's, humpback, southern right.	2911	3776	5603	9759
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer.	1632	3402	5603	9759
Phocid Pinnipeds	Leopard seals	2902	3776	5603	9759
Otariid Pinnipeds	New Zealand fur seals	2533	3776	5603	9759

8.1.4 Effects category: audibility

Table 30: Distances within which audibility is possible during the median noise conditions over the daytime.

Functional hearing group	Species	Estimated Audibility Range (m)
Low Frequency	Bryde's, humpback, southern right.	9759
High Frequency	Common, bottlenose dolphins. Killer, LF pilot, false killer.	9759
Phocid Pinnipeds	Leopard seals	9759
Otariid Pinnipeds	New Zealand fur seals	9759

8.2 Confined bubble curtain results: kororā/little penguins

8.2.1 Effects category: auditory masking

Table 31: Distances at which 75, 50, 25 and 0% listening space reduction (LSR) occurs for kororā/little penguins during the median noise conditions over the daytime.

Group	Species	Distances (m) at which some percentage of an individual's active listening space is reduced during piling			
		75%	50%	25%	0%
Little Penguin	Kororā	506	2664	4428	6700

8.2.2 Effects category: audibility

Table 32: Distances within which audibility is possible during the median noise conditions over the daytime.

Animal	Species	Estimated Audibility Range (m)
Little Penguin	Kororā.	6700

8.3 Confined bubble curtain results: fishes

Table 33: Ranges for the potential onset of noise impacts from the percussive piling in fishes, based on the NMFS (2025) thresholds for fishes </> 2g in mass

Fish size	Critical Range (m)
<2g	489
>2g	314

9.0 Cumulative noise effects from both in-project and concurrent consents

We understand that there is potential for percussive piling and dredging to be undertaken simultaneously. Piling and/or dredging as part of the neighbouring Northport Limited or Channel Infrastructure consents may also occur, should they choose to give effect to the series of extant resource consents for piling and dredging.

We have therefore assessed the potential for cumulative noise resulting from these activities occurring simultaneously. The assessment modelled noise from percussive piling in the project area operating concurrently with dredging (including a TSHD, CSD, or BHD) inside the turning basin.

Cumulative levels were determined by summing the linear sound levels from individual sound exposure maps and converting them back to decibels:

$$L_{\mathrm{cum}}(x,y) = 10\log_{10}\left(\sum_{i=1}^{N} 10^{L_i(x,y)/10}\right) \qquad \text{eq. 1}$$

where $L_i(x,y)$ was the noise level (dB) of the activity, i, at location (x,y), and N is the number of concurrent activities.

The combined levels, $L_{\mathrm{cum}}(x,y)$, were then compared with the loudest single activity (i.e., the percussive piling) at 18 receiver points around Whangārei Harbour entrance (Figure 4). At each receiver points (rp), the relative cumulative increase above the primary controlling activity was calculated using:

$$\Delta(rp) = L_{\mathrm{cum}}(rp) - max_i\, L_i(rp) \qquad \text{eq. 2}$$

A negligible $\Delta(rp)$ value indicated that the acoustic environment is generally dominated by a single source. Consequently, the effects ranges presented above and recommended marine mammal observation zones (MMOZ) would remain effective in managing sound exposure.

Our assessment showed that concurrent dredging and percussive piling will not materially produce cumulative noise effects, even when the activities occur in close proximity (see Figure 15 in Appendix D). Specifically:

- Because proximal dredging adds no appreciable acoustic energy above the primary piling noise, concurrent dredging from adjacent consents will not materially increase or change effects ranges.
- Similarly, if neighbouring consent holders undertake percussive piling simultaneously, spatial separation means that received sound levels at any given location are dominated by the closer operation. A distant piling source add minimal sound energy to the overall linear intensity received by an animal listener.
- Each consent holder's conditioned or recommended mitigation measures (by way of MMOZs) and monitoring requirements will remain effective at protecting marine mammals from TTS effects.

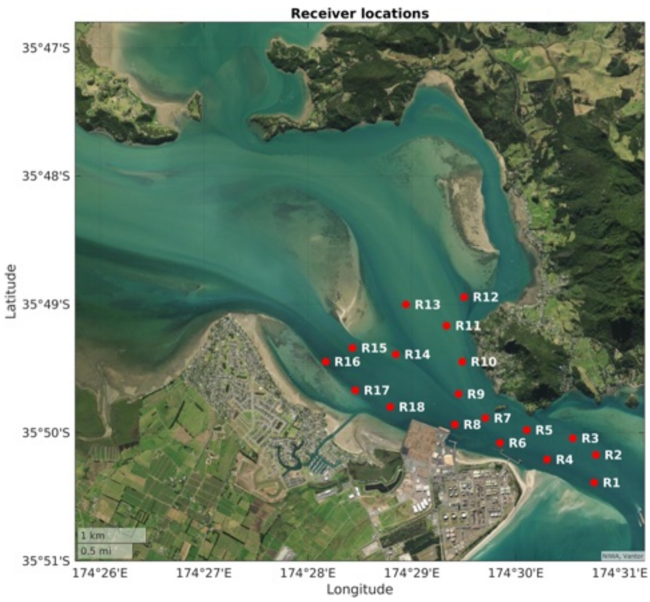

Figure 4 Locations of the percussive piling and dredger used in the cumulative noise modelling. The receiver location is where the modelled spectra were taken to test if any cumulative effects.

10.0 Conclusion

The construction of the proposed shipyard and drydock facility inside the Whangārei Harbour entrance will expose marine mammals, penguins and fish to acoustic-related disturbances that, depending on location, are either physiological or behavioural. Mitigation is required to reduce the spatial extent of the more concerning effects, namely auditory injury and temporary threshold shift. This is particularly relevant to HF cetaceans (that include bottlenose dolphins and killer whales) that are known to frequent the harbour entrance several times a month. Due to the currents and depths of the Project area, confined bubble curtains are the recommended form of noise abatement when driving the very large combi wall piles.

Acoustic effects are not expected to extend beyond the harbour entrance and into Bream Bay due to the substantial attenuation in noise levels from diffraction around the very shallow Mair Bank.

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Appendix A Glossary of Terms

Acoustic waveguide	A medium or structure that guides sound waves by restricting the wave movement in one of more dimensions, resulting in the efficient transmission of the sound wave.
Ambient sound	Ambient sound is the total of all noise within a given environment, comprising a composite of sounds from sources near and far.
Biologically important signal	An acoustic signal that, once detected and perceived, provides the receiving animal some information that is important to its survival and/or reproductive output.
Critical band	The frequency band of sound, contained within a broadband noise spectrum, that contains the energy equal to that of a pure tone centred in the critical band and just audible in the presence of broadband noise (Erbe et al. 2016).
dB (decibel)	The basic measurement unit of sound. The logarithmic unit used to describe the ratio between the measured sound pressure level and a reference level of 1 micropascals (0 dB) (or 20 micropascals for airborne sound).
Detector	A detector is a computer program that automatically detects the presence or absence of a particular signal that the algorithm is trained to detect.
Halocline	A strong change in salinity in a body of water with depth, where the salinity is markedly different above and below the layer in which the salinity change occurs.
Power spectral density (PSD)	The dB level of the power spectrum, presented every 1 Hz.
Permanent Threshold Shift (PTS)	An increase in the threshold of hearing (i.e. the minimum sound intensity required for the receiver to detect a signal) at a specific frequency that does not return to its pre-exposure level over time., i.e., it is permanently altered.
Sub-lethal	Sub-lethal effects are biological (including ecological), physiological or behavioural effects on individuals that survive exposure to the invasive noise.
Sound pressure level (SPL)	The logarithmic unit used to describe the ratio between the measured sound pressure level and a reference level of 1 micropascals (0 dB) (or 20 micropascals for airborne sound). Unless stated otherwise, the SPL refers to the root-mean-square (rms) sound pressure.
Soundscape	Similar to ambient sound, the acoustic soundscape is the sum of multiple sound sources arriving at a receiver (whether animal or hydrophone).
SoundTrap (ST)	An autonomous underwater acoustic logger used in marine science research from Ocean Instruments New Zealand.
Sound exposure level	The dB level of the time integral of the squared pressure over the duration of the sound event, expressed as dB re 1 $\mu Pa^2 \cdot s$.
Source level	The sound pressure level transmitted by a point-like source that would be measured at 1 metre distance, and expressed as dB re 1 μPa @ 1m.
Temporary Threshold shift (TTS)	An increase in the threshold of hearing (i.e. the minimum sound intensity required for the receiver to detect a signal) at a specific frequency that returns to its pre-exposure level over time.

Appendix B The existing underwater soundscape

Marine mammals, fish and invertebrates depend on underwater sound for critical life processes. These processes include, but are not limited to, keeping group members together while navigating turbid coastal waters, communication between family members, locating prey during feeding, mediating mating behaviours, and avoiding predation (Duarte et al. 2021). Their ability to communicate and perceive biologically important sounds are directly related to the surrounding acoustic environment as signals must be audible over the background soundscape within some critical bandwidth. Coastal activities, including pile-driving, dredging, shipping, drilling, etc, can cause ambient sound levels over a wide frequency range to rise to the point where marine animals are unable to detect signals that are important to them. This masking effect can induce a range of sub-lethal impacts, from increased stress hormones and behavioural responses to total habitat avoidance and exclusion (Southall et al. 2007; Nowacek et al. 2007; Duarte et al. 2021). Underwater noise pollution can therefore degrade marine mammal habitats within sites where offshore activities take place.

Notwithstanding, not all areas/environments/regions are as suspectable to noise impacts because the physical environment changes. Generally, noise effects can only occur if the invading noise source is audible (audibility being a function of both the ambient soundscape and hearing thresholds of the listener). Therefore, to properly assess the maximum spatial extent of possible acoustic disturbance, the ambient soundscape must be fully considered and incorporated into the effects modelling (in the context of the species' hearing thresholds and critical bandwidths).

For this reason, among others, underwater noise monitoring at four locations near Northport Limited (**NPL**) has been occurring since June 2020.

Methodology

Monitoring sites and data acquisition

A SoundTrap recorder (ST300HF) was deployed near Passage Island opposite NPL. This location is one of four marine mammal monitoring sites maintained by NPL. This location was selected for the acoustic assessment because it was the closest to the proposed works. The sampling rate was 96 kHz and deployed at depths over 8m.

The hydrophone component of the SoundTrap recorders was calibrated by the manufacturer. Field-calibration checks before the initial deployment were undertaken using a calibrated piston phone (GRAS Type 42AA, SPL 114 dB re 20 µPa, nominal frequency range 250 Hz), and calibrated (using a Brüel & Kjaer Type 4231 Sound Calibrator) sound level meter (Brüel & Kjaer 2250 Type 1 SLM with a Brüel & Kjaer ½ inch condenser microphone Type 4189) and specialist acoustic software. Electronic calibration of the recorder component was undertaken at the start of every recording event by comparing a set of automated tones of known frequency and voltage amplitude to the full-scale response level provided by the manufacturer for the appropriate gain setting and verified using the piston phone.

Overview of analysis procedure

Ambient sound recordings were processed sound pressure levels *(SPL*s), power spectral densities (*PSD*s) and third octave level (*TOL*s). The equations for those are detailed by Merchant et al. (2015). For this assessment, the median *SPL*s in the third octave bands were needed for the behavioural, masking and audibility effects assessments. A full characterisation of the ambient soundscape was outside the scope of this assessment.

The levels used in the effects assessment are provided in Figure 19 in Appendix C.

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Appendix C Marine mammal acoustic monitoring

Northport Limited (NPL) has maintained a Cetaware™ real-time acoustic buoy inside since 28 September 2024. The buoy hosts a hydrophone that is constantly listening for the burst pulses, whistles and echolocation clicks from dolphin species (including killer whales) that enter Whangārei Harbour. The hydrophone is connected to Cetaware™'s AI module that transmits live detection of dolphin vocalisations to a web interface, as well as storing raw detection audio snippets and metadata on a Cetaware™ server in Auckland. Since late January 2025, the buoy also detects and monitors vessel passbys for monitoring how vessels (both recreational and commercial) reduce dolphins active listening space inside the harbour (as a proxy for how vessel noise reduces acoustic habitat inside the harbour).

Figure 5: Plot showing the void fraction profile in the CBC modelling.

The main way that the buoy quantifies marine mammal presence inside the harbour is through detection events (i.e., acoustic encounters). Detection events were defined as the time between the first and last detected vocalisation that was within 20 minutes of the previous vocalisation. For example, if a vocalisation was detected at 10:00hrs and another at 10:10hrs, that would count as the same detection event (lasting 10 minutes). However, if no whistles/burst-pulses/buzzes were detected within 20 minutes of the last (i.e., at 10:10hrs), then the detection event was concluded, and the duration would be 10 minutes. All detection events have been validated by an experienced and qualified bioacoustician.

In October 2025 the buoy was hauled out of the water for an annual service (reapplying antifoul coatings and checking connectors etc). However, during that time the mooring line's surface marker came loose and the mooring line had to retrieved via SCUBA. This delayed the redeployment of the buoy until 14 January 2025.

Dolphin species are relatively regular visitors to the harbour. Since September 2024 and 4 August 2026 (excluding the time when the buoy was not in the water during the annual service), there have been 230 acoustic encounters of dolphins (primarily bottlenose dolphins) and 28 orca encounters.

Month	Proportion
Dolphins	
January	9.7
February	8.9
March	16.1
April	30.0
May	17.7
June	18.3
July	32.3
August	39.2
September	23.3
October	22.6
November	26.7
December	35.5
Orca	
January	0.0
February	0.0
March	1.6
April	3.3
May	1.6
June	3.3
July	1.6
August	1.6
September	16.7
October	5.3
November	6.7
December	0

Season	DaysRecording	MinutesDetected	NumEvents	DaysWithDetection
Dolphins				
Summer	135	400	41	22
Autumn	184	500	55	39
Winter	156	1392	86	46
Spring	115	767	48	27
Orca				
Summer	135	0	0	0
Autumn	184	61	4	4
Winter	156	88	5	4
Spring	115	352	19	10
Seals				
Summer	135	0	0	0
Autumn	184	28	8	6
Winter	156	0	0	0
Spring	115	0	0	0

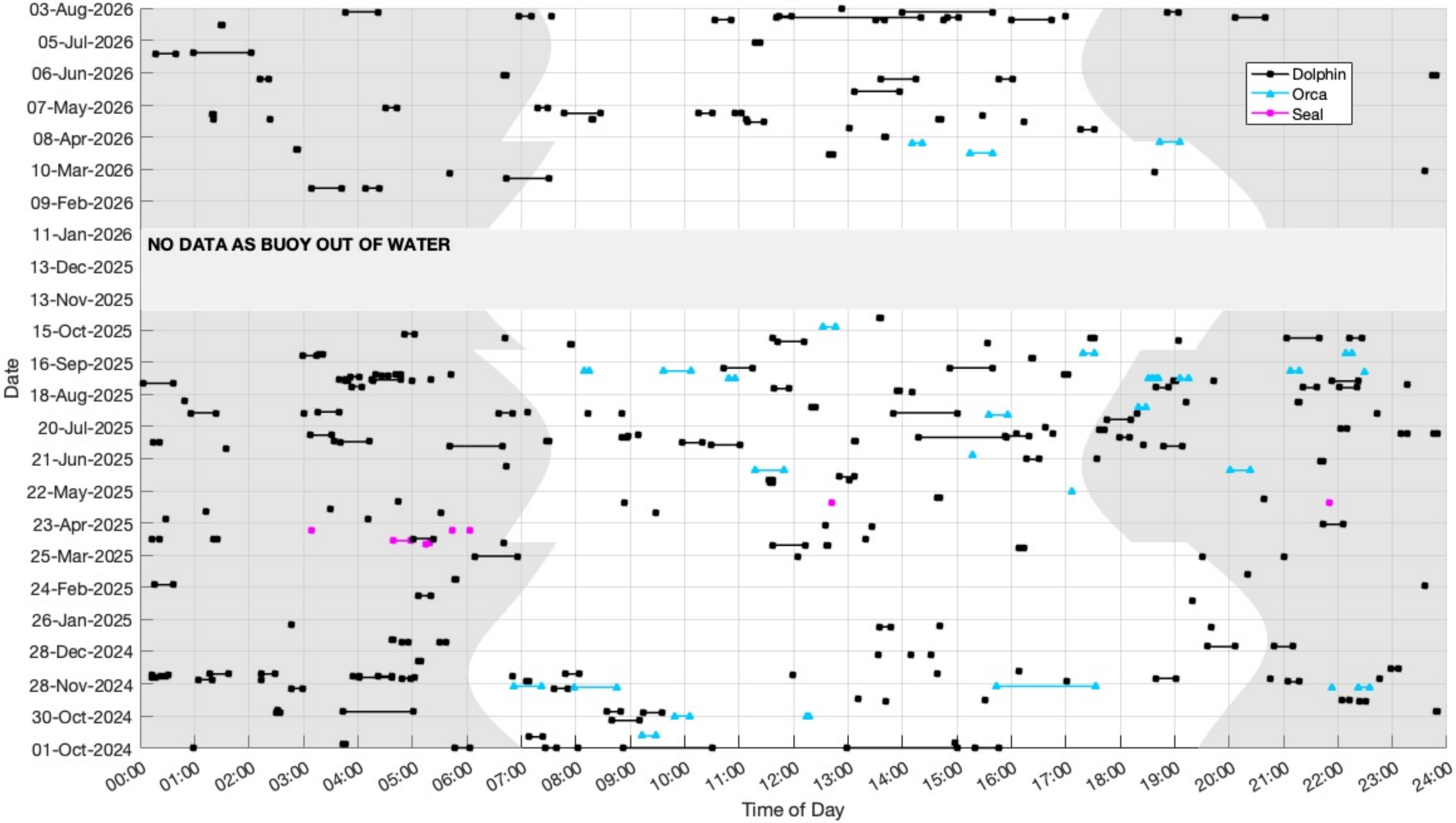

Figure 6: Actogram showing acoustic detections of marine mammals from the Cetaware™ buoy.

Appendix D Methodology: underwater noise modelling

Sound Sources

Percussive piling

The source spectrum used for the effects range calculations was based on a computational model by MacGillivray (2015) and empirical data from Austin et al. (2016). The MacGillivray model simulates the expansion/contraction of the pile as the impact stress wave from the hammer travels down the length of the pile and translates that physical motion into an array of equivalent monopoles. That array of discrete amplitudes essentially replicate the sound radiation pattern of the vibrating pile and are inserted directly into the PE/EF starter for the range-dependent propagation modelling.

The MacGillivray model is easily implementable using known properties of the combi wall piles. It's use for this assessment was because:

a) The input parameters of the model are based on readily available physical properties of the impact hammer and the steel casing pile for the combi wall.

b) MacGillivray (2015) validated the model's output with empirical measurement data. This is particularly helpful in 'calibrating' the source spectra.

A MATLAB implementation based on the equations by MacGillivray (2015) was used to model the source spectrum of the 1.622m OD steel casing piles.

The model input parameters for the largest combi wall piles are provided in Table 34.

Table 34: Input parameters for the piling source model.

Parameter	Value	
Hammer & Pile Parameters		
Hammer energy (E)	400	kJ
Pile length (L)	35.0	m
Pile mid-wall radius (a)	79.83	cm
Pile wall thickness (h)	2.50	cm
Ram mass (m_1)	18	tons (18,000 kg)
Drive head + anvil mass (m_2)	5	tons (5,000 kg)
Impedance ratio (Z_p/Z_h)	0.6	
Pile stress wave speed (c_p)	5	km/s
Pile bulk density (ρ_p)	7.8	g/cm^3
Poisson's ratio (ν)	0.3	
Pile toe reflection coeff. (R)	-0.5	
Environmental & Geometry Parameters		

Water sound speed (c_f)	1.463	km/s
Seawater density (ρ_f)	1.025	g/cm³
Embedment depth	15	m
Above-water length	4	m
Water depth (d)	16	m

The general stages, or phases, of the overall source model are provided in Figure 7.

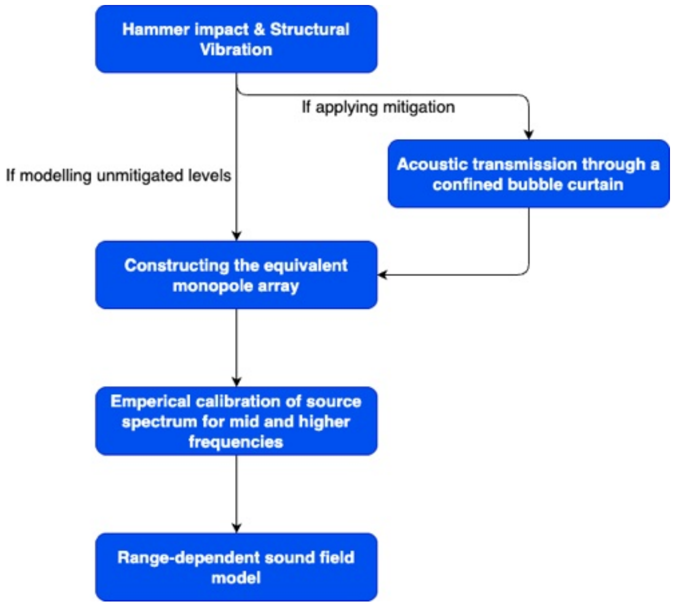

Figure 7: Schematic showing the overall source model pipeline.

The MacGillivray model begins with simulating a hydraulic hammer contacting the top of the steel pile and the stress wave travelling down (then up) the length of the pile inside a layered 2-D fluid medium. The model treats the hydraulic hammer a lumped-mass system separated by a cushion layer (an elastic layer). When the ram drops, the model calculates the force of the impact on the cushion layer and into the pile. Once the pile is hit, the stress wave travels rapidly down the steel pile and which is modelled as a thin cylindrical shell. A finite-difference time-domain (FDTD) solver simulates the compression wave travelling down the pile. The radial loading pushes the water outwards, damping vibration but creating sound waves that propagate outwards. MacGillivray (2015) uses a Hankel transfer function to define how the sound travels from the centre of a discrete monopole source to the outer layer of the cylindrical pile (i.e., the pile's boundary). Finally, the MacGillivray model solves for the frequency-domain amplitudes to recreate the physical movement of the pile wall that can be inputted into standard propagation codes (Figure 8).

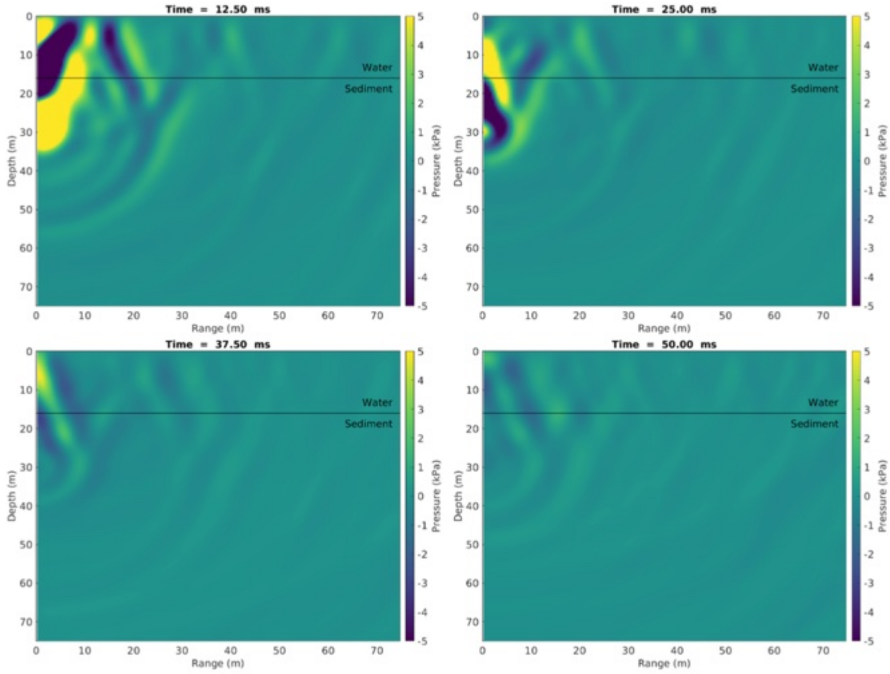

Figure 8: Instaneous sound pressure (kPa) with range and depth, as modelled using the MacGillivray model (no CBC).

The MacGillivray model does, however, include simplifications that are important to note. The first is that the model treats the pile as being in a layered 2-D fluid medium. This means it ignores the physical effects of sediment layers around the embedded part of the pile. For example, the shear wave coupling from the pile to an elastic seabed, as well as non-linear sediment modes are ignored. Instead, the model uses a simplified impedance boundary condition at the pile toe to represent energy dissipation from sediment resistance, while treating the surrounding sediment as a simplified fluid layer. While the Green's function only uses a two layer fluid environment, being the water column and sediment layer, the source model does extend the monopole array along the whole pile (so both the water column and sediment). This means that geoacoustic propagation is handled by the PE model. This simplification does carry a risk of overestimating the source amplitudes that are being handed to the PE/EF starters because varying stiffness and damping of the sediment changes the response of the pile itself. Therefore, the impedance of the seabed has a strong influence on the generated pressure levels being fed into the propagation codes.

11.1.1 Confined bubble curtains

Due to the large pile sizes required for the combi wall, noise abatement systems are required to reduce the range within which physiological effects on marine mammals can be expected.

A range of other abatement technologies for this project have been discussed, such as double-jacket piles and coffers. However, due to the design constraints of the combi wall, we understand that the most reliable noise abatement option available is a confined bubble curtain (**CBC**).

Air bubble curtains are commonly used internationally due to the simplicity of their application and effectiveness at reducing noise (Tsouvalas & Metrikine 2016). Open bubble curtains are unlikely to be effective around Northport due to the high currents around Whangarei Harbour entrance. These currents will cause rising bubbles to dissipate, especially over 14-16m water depths.

Confined bubble curtains consist of an outer casing that surrounds the pile being driven (the inner pile) and air bubbles are released at various depths between the inner and outer piles. This means that the bubble layer can be maintained in high currents. Similar to unconfined bubble curtains, the system generally works by disrupting the acoustic impedance through changes in the density of the seawater around the pile being driven (Tsouvalas & Metrikine 2016).

Confined bubble curtains have been successfully used overseas, and we have based our assessment of the CBC used during the modernisation of Anchorage Port in the U.S. during 2016 (Austin et al. 2016). That system consisted of a telescoping outer casing (as opposed to a single steel casing pile) that allowed them to change the casing length as tidal levels varied, and four vertically spaced aeration/bubble rings (every ~2.74m along the pile). A single air compressor was used that provided a continuous supply of air at 1600 cubic feet per minute (cfm). This was distributed to each bubble ring (referred to as an injection ring) at 160, 320, 560 and 560 cfm respectively at each bubble ring from the first stage (the top ring) to the last stage (the bottom ring).

The effectiveness of bubble curtains has some frequency-dependence, where the volume/flow rate and size of the bubbles has varying effects on the noise attenuation achieved. For example, when the sound energy being emitted from the pile is more concentrated around the resonance frequency of the bubbles (such as smaller piles with higher frequency components), the sound absorption of the bubble curtain itself is most important, and therefore the bubble characteristics (dimeter, rates etc) are important (Tsouvalas & Metrikine 2016).

To model the frequency-dependent insertion loss of the confined bubble curtain, an additional stage was added to the MacGillivray model. This new attenuation stage was based on the linear effective-medium theory by Commander & Prosperetti (1989). Their theory homogenises the water and bubbles and treats the whole curtain as a single fluid with its own complex wavenumber and density. The effective-medium theory is highly effective at modelling pressure waves through a bubble mixture with relatively low void fractions and small bubble sizes with no sharp peaks that lead to massive resonance effects (Commander & Prosperetti 1989).

The software, therefore, incorporated a series of safeguards and assumptions that prevented the mathematical model from 'breaking' (i.e., producing -inf values or exceptionally unrealistic insertion-loss results from extreme scattering cross sections at resonance frequencies of bubbles). The first was how the void fraction was defined in the model. The void fraction was simply the percentage of air, by volume, that makes up the effective-medium (i.e., the air volume in the bubbly mixture), such as:

$$\beta = {}^{4}/_{3}\,\pi R^3 n \qquad \text{eq.2}$$

where β was the void fraction, R was the bubble radius and n was the number of bubbles per unit time. However, as the bubbles are injected into the annulus and rise, the hydrostatic pressure decreases which causes the bubbles to expand. The model dynamically calculated this depth-dependence based on the hydrostatic pressure at each depth point (using atmospheric pressure, water density and gravity). For each injection ring inside the bubble curtain (set as 2.74m along the pile) the model summed the volumetric air flow from all injection rings located below some depth point (dz_m). Because the bubbles expand as they rise, the flow from each ring is multiplied by the ratio of the pressure at the injection ring to the hydrostatic pressure at some depth node. That produces a raw void fraction profile for each depth point. This method did produce non-physical sharp steps in the void fraction profile at each injection ring. The profile was, therefore, smoothed with a moving average window to ensure a smooth continuous profile while still maintaining the overall hydrostatic decrease rates (see Figure 9).

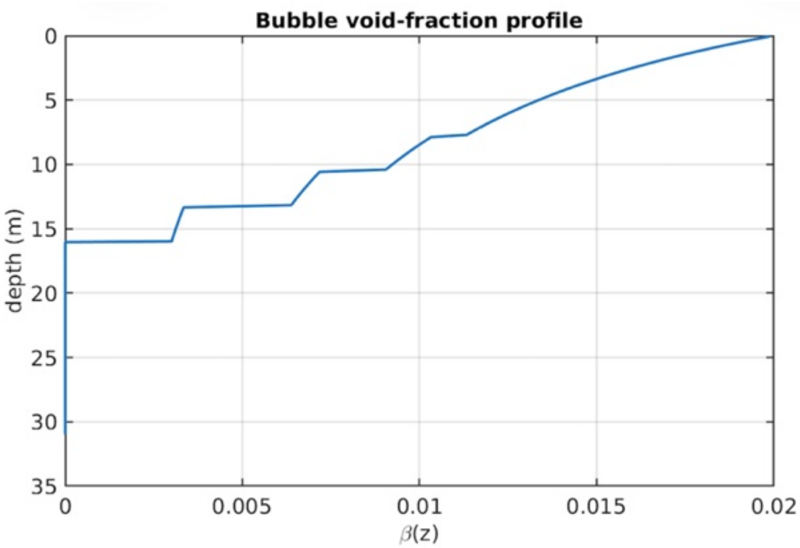

Figure 9: Plot showing the void fraction profile in the CBC modelling.

The conservation of energy as the pressure wave from the inner pile moves through the effective-medium layer was calculated at each void fraction value at each depth node along the pile. The model applied a lognormal distribution of the bubble sizes inside that volume of air (i.e., the individual size of bubbles that make up the void fraction at that depth). It did this by breaking the distributions into 96 different size intervals between 0.1mm and 1cm, centred around a 3mm average. For each of these 96 size bins, the model calculated three types of physical damping that cause the sound to attenuate:

1. Viscous damping. The energy lost as the oscillation of the air bubble creates friction against the denser (more viscous) water molecules.

2. Acoustic radiation damping. As the bubble expands/contracts it disrupts the cohesion of the pressure wave due to scattering.

3. Thermal damping. As the pressure wave causes the air bubbles to contract/expand they heat up (like pumping air into a bike tyre, the pump heats up due to friction) and the surrounding water immediately absorbs that heat. The smaller the bubble, the larger the surface area of air inside the bubble curtain and therefore the greater the thermal damping.

The model summed all these individual damping effects across the entire lognormal distribution to generate a final complex effective wavenumber which dictated the phase speed and acoustic attenuation for that depth node, as the pressure wave moved through the bubble curtain.

When the pressure wave reaches the outer casing, the model then simulated the wave's transmission through the outer steel casing. The model treated the outer casing as a thin elastic shell (like MacGillivray (2015)) that resists movements based on its mass, stiffness and structural damping. An important assumption was that the Young's modulus value for steel was halved for the outer casing. This was done to allow some radial deformation, representing the possibility that the outer casing may not be a single, continuous 16m steel pipe, but rather a system consisting of overlapping steel segments (similar to the Anchorage Port case (Austin et al. 2016)). To calculate the total sound transmission through the effective-medium and outer casing layers, the model employed a 3x3 Transfer Matrix Method (TMM). The method generated an array of complex transmission coefficients for each frequency and depth node. The coefficients were then multiplied by the raw structural pile velocity from the original MacGillivray model, resulting in the attenuated boundary velocities on the outside of the outer casing. Next, the model ran the equivalent monopole array calculations from MacGillivray (2015) to solve for the amplitudes required for a central vertical line of monopole sources to push outward and recreate the attenuated boundary velocity output described by MacGillivray (2015). This final array represented the mitigated acoustic signature from the CBC system (Figure 10), and its complex amplitudes were converted into starting pressures for the PE/EF propagation codes.

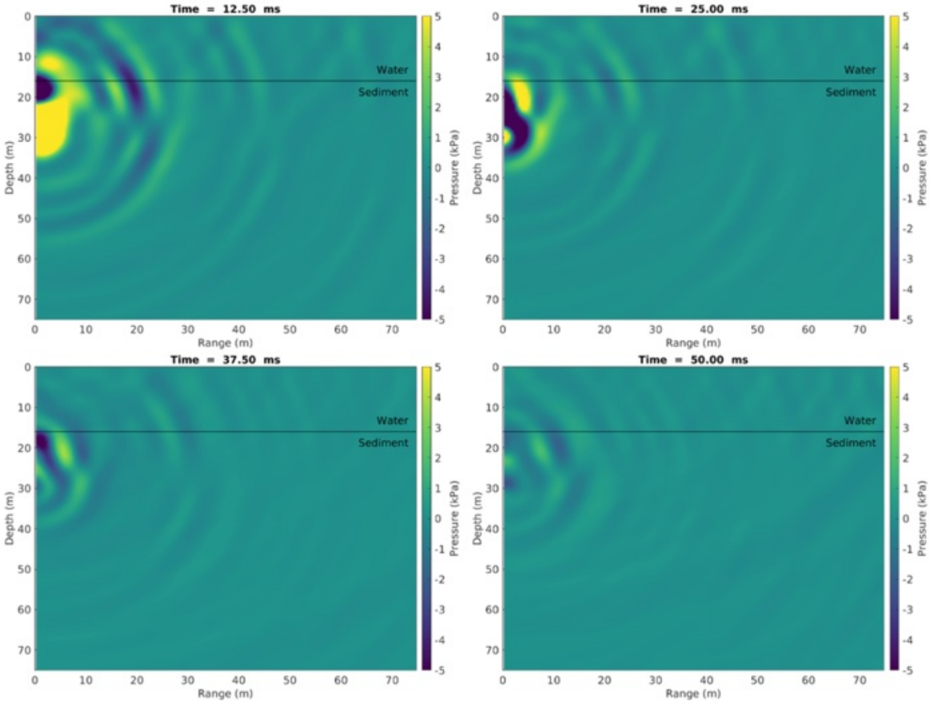

Figure 10: Instaneous sound pressure (kPa) with range and depth, as modelled using the MacGillivray model (with CBC).

The CBC in the source model was parameterized using the values in Table 35.

Table 35: Input parameters for the CBC in the source model.

Parameter	**Value**	**Units**
Curtain Geometry & Outer Casing (Shell)		
Inner boundary radius	0.8108	m
Outer casing inner radius	0.916	m
Outer casing outer radius	0.941	m
Bubble layer thickness	0.1052	m
Casing wall thickness	0.025	m
Effective Young's modulus	105	GPa (half of steel)
Shell Poisson's ratio	0.30	non-dimensional
Shell density	7.8	g/cm^3
Structural loss factor	0.25	non-dimensional
Max transfer coefficient magnitude clamp	0.95	non-dimensional
Bubble Size Distribution		
Distribution type	Lognormal	-
Mean bubble radius	3	mm
Standard deviation	0.30	non-dimensional
Min / Max radius cutoff	0.1 / 10	mm

Number of integration intervals	96	-
Air density	1.2	kg/m³
Damping scale multiplier	1.50	non-dimensional
Void Fraction Profile		
Bubble rise velocity	0.25	m/s
Smoothing method	Linear moving average	-
Starting bottom void fraction	0.003	0.3%
Injection ring vertical spacing	2.74	m
Relative flow profile (top to bottom)	[0.30, 0.60, 1.00, 1.00]	proportional ratio

11.1.2 Source spectrum calibration

When compared to empirical data, MacGillivray (2015) showed his model to be relatively accurate for frequencies below 600Hz. Those low frequencies are generated more by the primary stress wave from the hammer, and the bulk compression of the steel acting on the water was quite well handled by the FDTD solver described by MacGillivray (2015). However, above 600Hz, the MacGillivray model underestimated the mid- and higher frequency components. Increasing the Nyquist frequency of the FDTD solver to capture those shorter wavelengths did not improve the higher-frequency performance of the model (when compared to empirical data) because the lumped-mass force generator assumes that the hammer strikes the pile perfectly on top and generates a uniform stress wave travelling down the pile with only axisymmetric motion being calculated (being a 1D FDTD solver). The model, therefore, it is unable to account for bending modes in the pile's motion generated from off-centred or glancing hammer strikes and those bending and ringing modes are what creates the mid and higher frequencies (Tsouvalas 2015).

In order to account for the mid and upper frequencies for the combi wall piles, the modelled source spectrum was adjusted to incorporate the empirical spectral shape and high-frequency roll-off observed by Austin et al. (2016). Specifically, the measured spectrum at 12m range[4] was used to dictate the target spectral shape for frequencies above 600 Hz. To establish this target spectrum, the following function was used:

$$L_{ori}'(f) = \begin{cases} L_{ori}(f) \, iff < 400\ Hz \\ \left(1 - \frac{f-400}{200}\right) L_{ori}(f) + \frac{f-400}{200} L_{adj}(f) \, if 400 \le f \le 600\ Hz \\ L_{adj}(f) \, iff > 600\ Hz \end{cases}$$

$L_{adj(f)} = L_{ori(500)} + L_{emp(f)} -$ 172 dB re 1 μPa　　　eq. 3

where $L_{ori}'(f)$ was the adjusted level for f frequency (Hz), L_{ori} was the original output level from the MacGillivray model with or without the confined bubble curtain, L_{adj} was the

[4] Based on Pile ID IP6 in Figure D-22, in Appendix D in Austin et al. (2016).

adjustment factor, L_{emp} was the empirical levels from Austin et al., (2016) and the 172dB was an overall reference level. That spectrum was then used as the benchmark in an iterative 'calibration' loop that scaled the original model's equivalent monopole source array output to match that new spectrum.

$$\Delta \mathrm{L}_{\{\mathrm{dB}\}(f)} = \mathrm{L}'_{\{\mathrm{ori}\}(f)} - \mathrm{L}_{\{\mathrm{ori}\}(f)} \quad \text{eq. 4}$$

$$Gain(f) = 10^{\left\{\left(\frac{\Delta L_{\{dB\}(f)}}{20}\right)\right\}} \quad \text{eq. 5}$$

$$C_{\{final\}(f)} = C_{\{ori\}(f)} \times Gain(f) \quad \text{eq. 6}$$

This operates as a continuous loop that repeats the free-field acoustic metric calculations from the model's equivalent monopole array, and applies increasingly smaller gain adjustments while smoothing the residual errors over adjacent frequency bands during each iteration to prevent non-physical high-frequency spikes. The loop terminates only when the model's equivalent monopole array converges within a 0.25 dB tolerance threshold of the target spectrum (see Figure 11).

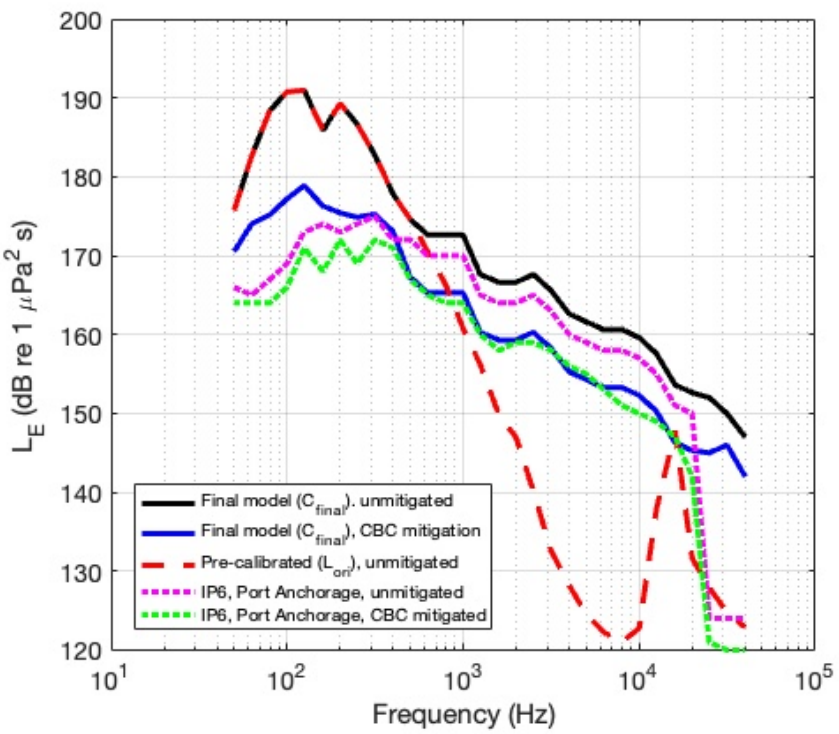

Figure 11: Modelled decidecade bands from the piling source model, showing the unmitigated, emperical and CBC mitigated spectra.

That final adjusted/calibrated monopole source array is then passed node-by-node to the propagation codes, after converting them into effecting starting pressures.

The source location of the piling are provided in Figure 15**.**

Capital dredging

Both dredging stages will potentially use three types of dredgers: a trail-suction-hopper dredger (TSHD), a cutter-suction dredger (CSD) and a backhoe dredger (BHD). We understand that a small or medium sized TSHD will be used.

We have based our modelling on a medium sized TSHD (such as the *Albatros*), but a large CSD and BHD as those specific dredging types have yet to be confirmed. Given the lack of details on the proposed CSD and BHD equipment, it was not possible to model actual acoustic data or recordings of the exact dredgers that will be used. Therefore, the source signal for the CSD and BHD dredger type was based on published source spectra (from actual noise measurements) for similar dredging plant at different stages of their respective production cycles. The TSHD was modelled using an empirical source spectrum. Data were obtained from a single large BHD (BHD New York) and a large CSD (CSD Florida) were selected to represent the largest possible dredgers that could be used for the proposed works (Figure 12). Details on all dredgers used in the modelling are provided in Table 36.

The aim was to model a representative source signal for a complete production cycle (for example, the BHD digging and loading the barge, operating the cutter head of the CSD, or dredging sediment while the TSHD was underway (i.e., in extraction mode) and so the source levels for a range of typical operating configurations were considered. It is important to note that the measurement data obtained for each dredger were the cumulative noise level of all sources for that particular dredger during that particular production stage. For example, the source levels from the BHD under full dredging (i.e., bucket impact and digging) contain noise from the hydraulics and on-board generators, as well as any pumps.

Each dredger-type was modelled as a point source inside the turning basin. The source spectra for the dredging are provided in Figure 13 and Figure 14 and summaries are provided in Table 37.

Table 36: Summary table of the different dredger types incorporated in the acoustic modelling

Dredger Type	Vessel	Length (m)	Capacity (m^3)	Total Power (kW)	Location	Citation
TSHD	Albatros	75	1860	2360	NZ	Dutch Dredging
CSD	Florida	159	-	18938*	US	Reine et al. 2014
BHD	New York	61	18	2565	US	

*Total installed power.

Figure 12: Photographs of each of the dredging plant used to represent the possible dredging equipment for the project.

Table 37: Summary of high-level source characteristics for each dredging type in the acoustic modelling

Dredger Type	Vessel	Dredging Event	L_p Distance (m)	N_{PL} model used to calculate *SL*	L [3]	Peak Frequency (Hz)	Citation
CSD	Florida	Full Dredging[7]	152	15log(r)	175	300	Reine et al. 2014; Robinson 2015
BHD	New York	Engine/Generator noise	75	15log(r)	167	125	Reine et al. 2014
		Hydraulic Rams	60	15log(r)	164	2500	
		Bucket Impact and Filling	60	15log(r)	179	315	
		Barge Loading	60	15log(r)	166	100	
		Anchoring Spuds	75	15log(r)	167	1200	
		Engine/Generator noise	75	15log(r)	167	125	
TSHD	Albatros	Full dredging, pumps on, hopper filling	30	Pine et al. 2014	184	100	Pine 2022

[1]Received sound level (dB re 1 μPa).
[2]Propagation loss model used to back-calculate source level, L_S).
[3]Broadband source level (dB re 1 μPa^2 m^2), un-weighted, averaged over a 1 sec time period.

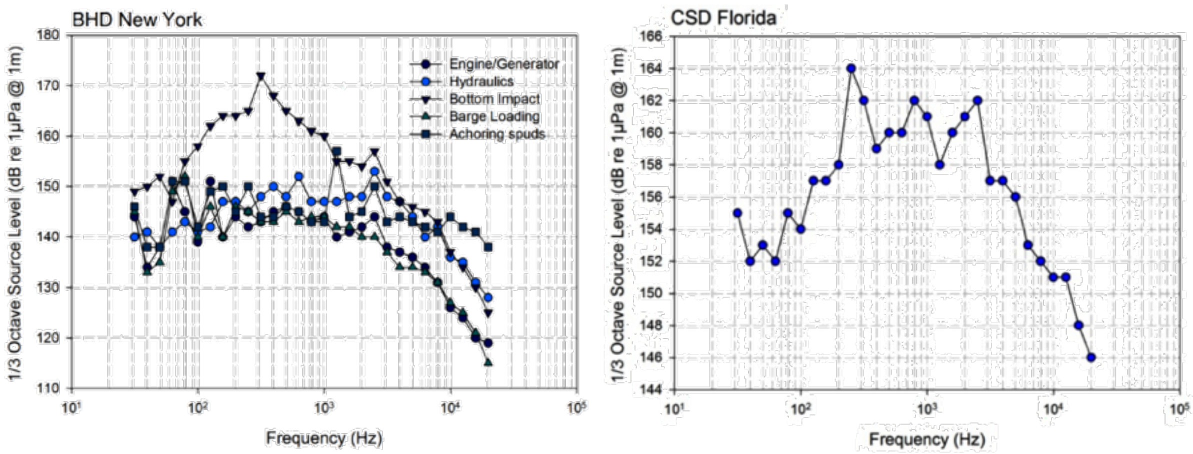

Figure 13: Decidecade source spectra for the CSD and BHD dredgers modelled under different operating stages during a typical production cycle.

Data sourced from Robinson et al. (2011) and Reine et al. (2014).

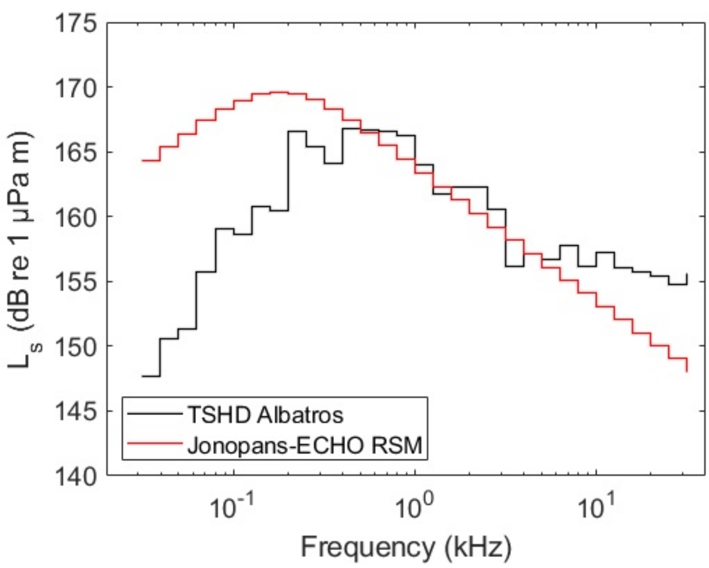

Figure 14 Decidecade source spectrum of the TSHD *Albatros* dredging sand/clay. The red line represents the reference source model for a 75m dredger from MacGillivray & de Jong (2021).

Broadband source level = 184 dB_{rms} re 1 µPa m

Figure 15: Source locations for the percussive piling and dredging for the acoustic model.

Bathymetry

Sound propagation within coastal waters typically follows a normal mode whereby a sound wave of a particular wavelength moves sinusoidally through an acoustic waveguide (i.e., the water column or seafloor) (Jensen 2011). However, sound propagation in shallow water is highly influenced by boundary effects and the extent of those effects is related to water depth, as well as the seafloor and surface roughness. Bathymetry data is therefore critical for range-dependent propagation modelling.

The bathymetry raster used was provided by MetOcean Solutions, but updated to incorporate the latest hydrographic survey data from Northport (Figure 16). A copy of the bathymetry raster was adjusted to better reflect the expected bathymetry when piling starts. This was because the turning basin and dry dock berthing area will be dredged first to their target depths of 14.5m and 16m CD, respectively. This was achieved by creating a polygon mask around the plotted bathymetry over a satellite image and depth values inside were replaced with linearly interpolated values using the polygon's edge depths. A separate polygon mask was generated to change depth values that fell inside to the dredge target depths.

This adjustment was not applied to the bathymetry used in the dredging noise models.

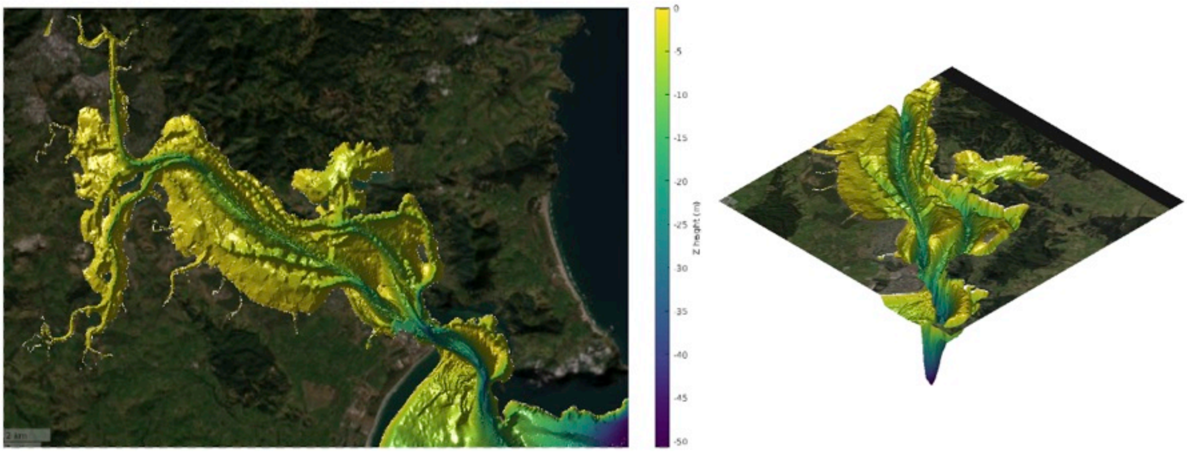

Figure 16: The bathymetry raster uploaded to the acoustic model.

Sea-floor composition

The seafloor composition within Whangarei harbour entrance is relatively well studied compared to most, with a range of investigations being completed for other consent applications in recent years. The geoacoustic properties used in this study was built using sediment data obtained from Initia Geotechnical Specialists in 2019 and Tonkin & Taylor in 2016 using a series of vibrocores up to 10m depth, beyond which consolidated (dense) sands were assumed (since the driven depths of the piles extend beyond 30m). The locations of the vibrocores are provided below (Figure 17 and Figure 18), and were the same positions used in the acoustic model. A simple underlying structure array with the geoacoustic properties at each of those locations were carried forward at all calculation grid points in the propagation model that fell inside a set area around each vibrocore location. The geoacoustic properties used in the modelling for the different sediment types are provided in Table 3.

For the areas west of the Project area where no vibrocores were taken, the same properties were assumed for that area as core BH-02 (as shown in **Figure 8**).

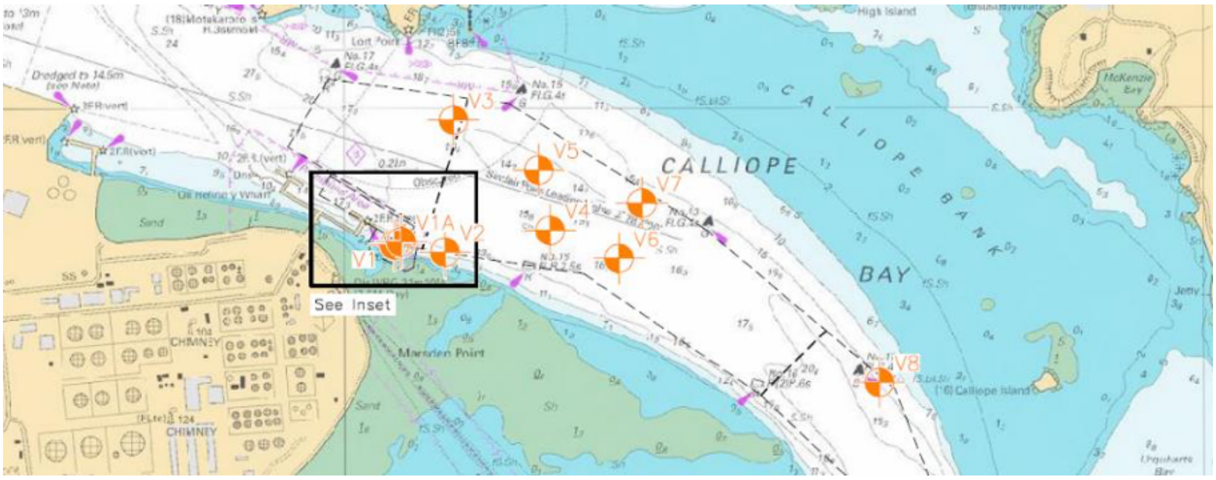

Figure 17: Borehole locations towards the harbour entrance

Borehole log data for these locations were used in the noise model (taken directly from Tonkin & Taylor 2016) and presented in Appendix I.

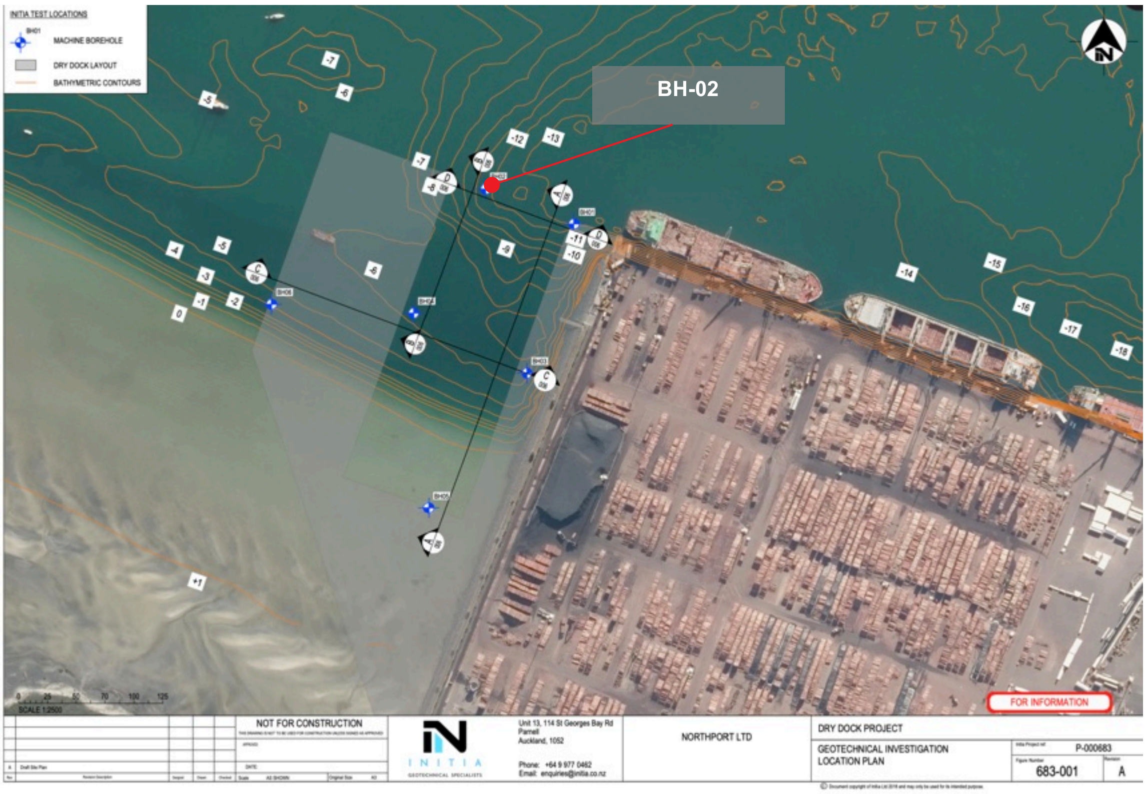

Figure 18: Borehole locations

Borehole log data for these locations were used in the noise model (taken directly from Initia Geotechnical Specialists (2019)) and presented in Appendix I.

Range-dependent propagation model

The underwater propagation loss (N_{PL}) was defined as:

$$L_{p,f}(R) = L_{s,f} - N_{PL,f}(R) \qquad \text{eq.7}$$

where $L_{p,f}$ at distance R was the predicted sound pressure level for some frequency bandwidth, $L_{s,f}$ is the source level at some frequency and $N_{PL,f}$ is the propagation loss over R for that frequency band. This assessment utilised a hybrid approach that combined RAMGeo (Colins 1993 parabolic equation model) and Energy Flux (EF) using the MATLAB routines from the Ocean Acoustics Library[5] (including from AcTUP (Curtin University)). These models are range-dependent and therefore incorporate sound speeds, changing water depths, and seafloor properties along the propagation pathway, with increasing distance from the source.

A simple frequency cutoff at 1.2kHz was used that triggered the software to switch from using the PE routine to the EF routine. While EF models are suitable for modelling low frequencies sounds below 1kHz, the hybrid approach was used because the EF model becomes more sensitive to the seafloor properties, which were largely approximated in this assessment. EF models were also preferred over the Bellhop routine for the omnidirectional piling noise because it is a very computationally efficient approach to underwater sound propagation and they bridge ray and mode theories, depending on the frequency. Developed by Western (1971), the EF models work by dividing the propagation pathway into different regions based on how sound propagates, considering factors like geometric spreading, mode stripping (attenuation of higher-order modes), and potentially a single dominant mode at longer ranges. They can therefore handle the range-dependence required for Whangārei Harbour. They do, however, assume iso-velocity sound channels and outputs are depth-averaged propagation losses unlike the PE model which accepts sound speed profiles.

For each node in the monopole source array, N_{PL} was calculated for 360 radials (1° bearings), with 2m range steps out to 10km. For each calculation point, the corresponding bathymetry value, seafloor reflectivity coefficients and sound speeds were also extracted from the underlying data layers/variables. This resulted in a calculated N_{PL} for each 2m along the radial, that together, formed a three-dimensional array for that frequency. The frequency-specific 3D array was then converted to a 2D map using linear interpolation and nearest neighbour extrapolation for each radial. The 2D map for that waypoint was then stored in structure arrays for later recall.

Table 38: Input parameters for the propagation loss modelling.

Model independent variables (global)	
Bathymetry	10m resolution ASCII raster.

[5] http://oalib.hlsresearch.com/AcousticsToolbox

Model independent variables (global)	
Model independent variables	360 radials; 10km per radial; 2m range steps.
3D array to 2D grid conversion	Natural neighbour interpolation with nearest neighbour extrapolation.
Model dependent variables	
Weston’s energy flux (airguns, boomer, sub-bottom profiler)	Fc = [1600 2000 2500 3200 4000 5000 6300 8000 10000 12500 16000 20000 25000 32000 40000]
RAMGeo (airguns, boomer, sub-bottom profiler)	Fc = [25 31.6 40 50 63 80 120 125 160 200 250 315 400 500 630 800 1000 1200] 5 Padé terms.
Sediments (global)	
Sediment types	Gravel/Shell: ρ 2000kg/m^3, c_p 1800m/s, α_p 0.6 dB/λ. Sand: ρ 1950kg/m^3, c_p 1725m/s, α_p 0.8 dB/λ. Silt: ρ 1700kg/m^3, c_p 1650m/s, α_p 1.0 dB/λ. Clay: ρ 1500kg/m^3, c_p 1500m/s, α_p 0.2 dB/λ.
Water column	
Sound speed	1500.93ms (depth average)
Water density	1025 kg/m^3
Salinity	35 psu.

Effects modelling for marine mammals

The overall objective of the acoustic modelling is to provide the acoustic footprint of the noisiest activities to inform an assessment of the potential impacts on marine animals. The physiological effects (AUD INJ/TTS) reported below are the two most serious effects that can directly impact an animal’s net fitness.

Auditory injury (including PTS) and Temporary Threshold Shifts

When a receiver is exposed to high noise levels over an extended period, the cells within the inner ear being to fatigue and become less sensitive. Therefore, a change in the animal receiver's hearing threshold occurs, and the degree at which those thresholds change is referred to as a threshold shift. If hearing returns to normal after a certain time post-exposure, the threshold shift is temporary (termed temporary threshold shift, TTS), but if not, then it is referred to as permanent threshold shift (PTS)[6]. The type and amount of threshold shift depends on the duration of noise, rise times, duty cycles, sound pressure levels within the listener's critical bandwidths (i.e., the spectral composition of the noise) and, of course, the overall energy.

The noise criteria used for the establishment of PTS and TTS radii was from NMFS (2024). Consequently, the various hearing groups are named HF, LF cetaceans and PCW, OCW for pinnipeds in water in this report. The 2024 update to the NMFS guidance also includes new M-weighting functions, revised TTS/PTS thresholds and refers to PTS as Auditory Injury (AUD INJ).

Because these updated functions, classes and thresholds are based on the latest science, we have adopted those functional hearing groups and thresholds in our assessment.

For percussive piling, NMFS (2024) prescribes criteria for the potential onset of either AUD INJ or TTS effects in both peak pressure (L_{pk}) or cumulative sound exposure level ($L_{E,p,24hr}$) (termed a duel-metric threshold), whichever is the highest (Table 39). The $L_{E,p,24hr}$ metric is commonly used for assessing impulsive signals as it can incorporate the energy from multiple pulses and the overall exposure required for an animal receiver to be at risk of TTS/AUD INJ onset. The number of pulses and delay between them, for each pile (in the case of percussive piling) can therefore be incorporated when calculating the $L_{E,p,24hr}$, unlike for the L_{pk}. In the case of multiple pulse sources, such as percussive piling, the dual metric is particularly relevant as often the $L_{E,p,24hr}$ values are be higher than L_{pk} levels for some marine mammal functional hearing groups, and therefore both must be considered.

For the percussive piling, the $L_{E,p,24hr}$ was calculated by adding $10\text{Log}_{10}(n)$ to the single-strike SEL, where n=2400 strikes, to the modelled single strike SEL.

[6] Classed as Auditory Injury (AUD INJ) in NMFS (2024).

Table 39: NMFS (2024) auditory threshold criteria for impulsive signals, for the functional hearing groups.

Functional Hearing Group	TTS Threshold		PTS Threshold	
	$L_{E,p,24hr}$ (weighted)	L_{pk} (unweighted)	$L_{E,p,24hr}$ (weighted)	L_{pk} (unweighted)
LF	168	216	183	222
HF	178	224	193	230
VHF	144	196	159	202
OCW	170	224	185	230
PCW	168	217	183	223

Behavioural responses

There is a substantial amount of literature on the behavioural effects of noise on marine mammals and several studies on fish. Those include direct evidence-based studies, opportunistic studies or observations that have been summarised in several reviews (for example Richardson et al. 1995; Hildebrand 2005; NRC 2005; MMC 2007; Nowacek et al. 2007; Weilgart 2007; NAS 2017). Behavioural effects are highly varied and may include changes in swimming behaviours (directions and speeds), diving behaviours (durations, depths, surface intervals), time spent on the surface, respiration rates, fleeing the noise source and changes to vocalisations. Predicting the zones within which behavioural effects may be seen is the most difficult noise effect to quantify due their dependency on the context, species and location (see Ellison et al. 2012; Gomez et al. 2016 for reviews on the issue of context dependency on marine mammal behaviour).

Consequently, there is no widely accepted regulatory guidance on behavioural effects currently in existence as it is still a research problem. The only interim guidance for behavioural responses is a single unweighted decibel value of 120 dB re 1 µPa for continuous noise sources (applicable to the CSD and BHDs) and 140 or 160 dB re 1 µPa for impulsive noise sources (applicable to the pile driving) from NOAA (the National Oceanic and Atmospheric Administration in the US). However, for many noise sources, such as continuous dredging noise, they have not had wide-spread uptake (Gomez et al. 2016). One of the issues of using a single noise threshold for behavioural responses is that the data currently available are not very comparable (Nowacek et al. 2007; Southall et al. 2007; Eillison et al 2012; Gomez et al 2016). There is a limited relationship between the severity of the behavioural response and the received level of underwater noise (Gomez et al 2016).

Some underwater noise assessments in New Zealand still consider the 120 dB re 1 µPa contour, stating the reason being it is the only threshold for the onset of some behavioural response. However, because of the uncertainty in assessing the risk of behavioural effects within and between species (based on the highly contextual nature of behavioural effects), the application of a simplistic noise threshold for behaviours should be avoided (Faulker et al. 2018).

Recent studies assess behavioural zones based on the probability of occurrence using dose-response curves specific for the species of interest (Joy et al. 2019). Dose-response curves show the relationship between the probability of a behavioural effect occurring at a given level of noise exposure (Joy et al. 2019). The dose-response formulas have been used by the U.S. Navy (US Navy 2008, 2012) and the scientific community for several years, primarily for sonar, among other transducers, and explosions or airgun pulses.

Species-specific dose-response curves for percussive piling driving, however, have not been explicitly calculated and the U.S. Navy continues to recommend the existing NMFS risk criteria for the onset of behavioural responses from impact pile driving (160 dB_{rms} re 1 µPa[7]). Therefore, in the absence of specific dose-response curves for percussive piling, the step function threshold of 160 dB_{rms} re 1 µPa continues to be used.

Extensive reviews show most marine mammals respond to impulsive noise of varying levels between 140 and 180 dB_{rms} re 1 µPa, including large whales (Malme et al. 1983, 1984; HESS 1999; Southall et al. 2007; Woods et al. 2012). Probabilistic metrics applied at 10%, 50% and 90% of exposed individuals having behavioural responses have been assumed above M-weighted levels of 140, 160 and 180 dB_{rms} re 1 µPa, respectively (Woods et al. 2012).

Considering no general consensus on behavioural threshold for percussive piling, the unweighted 140 and 160 dB_{rms} re 1 µPa step function thresholds have been used in this assessment. Being unweighted, they are more conservative.

For continuous noise sources, however, dose-response curves were used. Recent studies provide a specific dose-response function and thresholds for southern resident killer whales exposed to continuous noise sources (Joy et al. 2019). The thresholds make use of the most up-to-date data for killer whales and behavioural effects (specifically those effects classed as low[8] or moderate[9] (respectively, a Southall severity score of 2-3 and 4-6 (Southall et al. 2007)). Briefly explained, the researchers took empirical studies on killer whales and noise (42 studies in total) and correlated the estimated received sound pressure levels with the behavioural response type (i.e. the Southall severity scores (Southall et al. 2007)) to get a regression curve (linear relationship). From there, two received levels that corresponded to the 50% probability

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[7] Root mean square (rms) calculation for impact piling is based on the duration of the pulse defined by 90% of the cumulative energy in the impulse.

[8] Low behavioural responses are defined as minor changes in respiration rates, swimming speeds and direction (Joy et al. 2019).

[9] Moderate behavioural responses are defined as moderate to extensive changes in swimming speeds, direction and/or diving behaviours, moderate or prolonged cessation of vocalisations, and/or avoidance (Joy et al. 2019).

of either a low or moderate behavioural response occurring was calculated. Dose-response curves for killer whales were then generated from those received levels.

The dose-response curve used in this assessment was calculated using:

$$R = \frac{1-\left(\frac{L-B}{K}\right)^{-A}}{1-\left(\frac{L-B}{K}\right)^{-2A}} \qquad \text{eq. 8}$$

where *R* was the risk from 0 to 1 (i.e. the probability of an effect occurring) at the noise level *L*, *B* was the basement received level (*RL*) at which the risk of an effect occurring is so low it does not warrant calculating, *K* was the *RL* increment above *B* at which there is 50% risk and *A* was a transition sharpness parameter (Joy et al. 2019). The *RL* at which there was a 50% risk of an effect was set at 129.5 (for a low response (Southall severity 2.5)) and 137.2 dB re 1 μPa (for a moderate response (Southall severity 5)) (Joy et al. 2019).

Since this method is based on more accurate data (and on killer whales, which is a species that occurs within Whangārei Harbour and its entrance, with hearing biology similar to other delphinids), we applied the same method and assumptions to our data. However, for this assessment, we altered the basement received level, *B*, to be the averaged 1-min *SPL* of ambient noise over our monitoring period (between June and December 2020). This provided a conservative baseline level specifically related to the Whangarei harbour entrance that is more useful than the unweighted threshold level for continuous noises of 120 dB_{rms} re 1 μPa for all marine mammals.

For larger mystecete species, such as humpback whales (which have been seen inside the harbour on occasion) and Bryde's whales, the *RL* at which 50% risk of behavioural response occurring was set at 120 dB_{rms} re 1 μPa. This was because that level is the lowest level at which bowhead whales, another mystecete species and one of the only whales with estimated levels of exposure (from continuous noise), has been linked to a certain behavioural response (Southall et al. 2007). This is conservative. No assessment for moderate behavioural effects for mystecetes was done because we do not know what such a threshold would look like and is therefore too speculative to be meaningful. The same basement levels and transition sharpness values were applied.

Dose-responses functions were not used for pinnipeds. Data for leopard seals and fur seals (the two seal species considered in this assessment) are not available and therefore the step function approach was used and applied to both species. Southall et al. (2007) review studies showing pinnipeds responding to continuous noise, with individuals shown to react above 120 dB_{rms} μPa (Southall severity score 3[10]). Above 130 dB_{rms} re 1 μPa, the behavioural responses reviewed by Southall et al. (2007) are more moderate[11]. These unweighted thresholds were

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[10] Such as alert behaviours, minor changes to swimming speeds, dive profiles or directions, changes to respiration rates, or minor cessation or modification of vocalisations (Southall et al. 2017, Table 4).

[11] Such as prolonged changes to swimming speeds, dive profiles, or directions, moderate shifts in distributions, prolonged cessation or modification of vocalisations (Southall et al. 2017, Table 4).

used to determine the potential onset for low and moderate severity behavioural responses in this assessment.

Auditory masking (including kororā/little penguins)

Several species of marine mammals and fish are known to have hearing ranges that overlap with low-frequency anthropogenic noise – such as vessels or machinery such as renewable energy devices. For example, bottlenose dolphins (*Tursiops truncates*) and common dolphins (*Delphinus delphis*) have shown hearing sensitivities to signals as low as 100 Hz, while killer whales (*Orcinus orca*) show sensitivity down to 500 Hz (Hall & Johnson 1972; Popov & Klishin 1998; Szymanski et al. 1999). Therefore, auditory masking - the interference of a biologically important signal (such as vocalisations from conspecifics or predator/prey etc) by an unimportant noise that prevents the listener from properly perceiving the signal (Erbe 2008) – is expected to occur (Pine et al. 2019). Piling has the potential to interfere with an animal's ability to perceive their natural acoustic environment (Erbe et al. 2016; Popov & Klishin 1998). The inclusion of auditory masking in underwater noise effects assessments is best practice because behavioural effects generally occur at moderate levels of masking and thus understanding the spatial limits of masking is important (Pine et al. 2019).

We assessed auditory masking for marine mammals by quantifying the reduction in an animal's listening space. An animal's listening space is the immediate area (volume of ocean) surrounding it within which it can detect and perceive a biologically important signal. The listening space method was used instead of sonar equations in this case because the call structures of all the species of interest at the source are not well understood, while the listening space method is more sensitive to changes in the existing sound environment (Pine et al. 2018).

As an animal receiver moves through the area while the pile-driving is underway, the animal's listening space will decrease to a new, smaller listening space. The difference between the original and the smaller listening space under masking conditions is termed the listening space reduction (**LSR**).

The method for calculating the LSR is fully described by Pine et al. (2018) who define the LSR as:

$$LSR = 100\left(1 - 10^{-2\frac{\Delta}{N}}\right) \qquad \text{eq. 9}$$

where N is the frequency-dependent N_{PL} slope coefficient (set at $15 + \alpha_f$) and Δ is the difference between the perceived base ambient noise level NL_1 and anthropogenic noise level NL_2 at a given distance (NL_2 was the modelled sound pressure levels/SELs of the percussive piling). The ambient noise levels were taken from the passive acoustic monitoring (as described in Appendix B). It is important to note that NL_1, being the perceived base ambient noise level, is the maximum of the listener's hearing threshold (audiogram value) and the ambient level inside a critical band, approximated herein by 1/3 octave bands (Erbe et al. 2016; Pine et al. 2018). Audiogram values for little penguins were taken from Wei & Erbe (2024), while the various marine mammal species in Whangārei Harbour were based on composite audiograms (see NMFS (2024) for details). Composite audiograms for each 1 Hz over the complete modelled bandwidth were calculated using:

$$T(f) = T_0 + A\,Log_{10}\left(1 + \frac{F_1}{f}\right) + \left(\frac{f}{F_2}\right)^B \qquad \text{eq. 10}$$

where $T(f)$ is the auditory threshold at frequency f, and T_0, F_1, F_2, A, and B are fitting parameters provided by NMFS (2024).

The N_{PL} slope coefficient was calculated by curve fitting the empirical N_{PL} of each 1/3 octave band between 32 Hz and 32 kHz over a distance that represented the listener's maximum listening range under natural sound conditions. This was done using a simplified sonar equation without signal gain (to increase conservativeness):

$$\Delta L_{SE} = SL - PL - NL_1 - \Delta L_{DT} \qquad \text{eq. 11}$$

where signal excess (ΔL_{SE}) is set to zero to indicate detection onset, NL_1 was the 5th percentile ambient noise level and ΔL_{DT} was the detection threshold (conservatively set at 10 dB for (Clark et al. 2009; Kastelein et al. 2013; Putland et al. 2017; Pine et al. 2018; Pine et al 2019)). This was done because the N_{PL} slope can have some range-dependence.

The empirical source levels, ambient levels and audiograms are provided in Figure 19.

The LSR was then calculated for each decidecade band at each depth step – resulting in an LSR map for each band. Those maps were then overlaid on top of each other (forming a 3D matrix) and averaged through layers to provide an overall 2D LSR map for the project area (Pine et al. 2018).

It is important to note the three important assumptions applied to the auditory masking model: (1) the listener exhibits omnidirectional hearing; (2) the sound propagation field is omnidirectional; and (3) no masking release mechanisms occurred. The exclusion of masking release is an important assumption as it means the results are likely to be conservative (i.e., has the potential to overstate true masking).

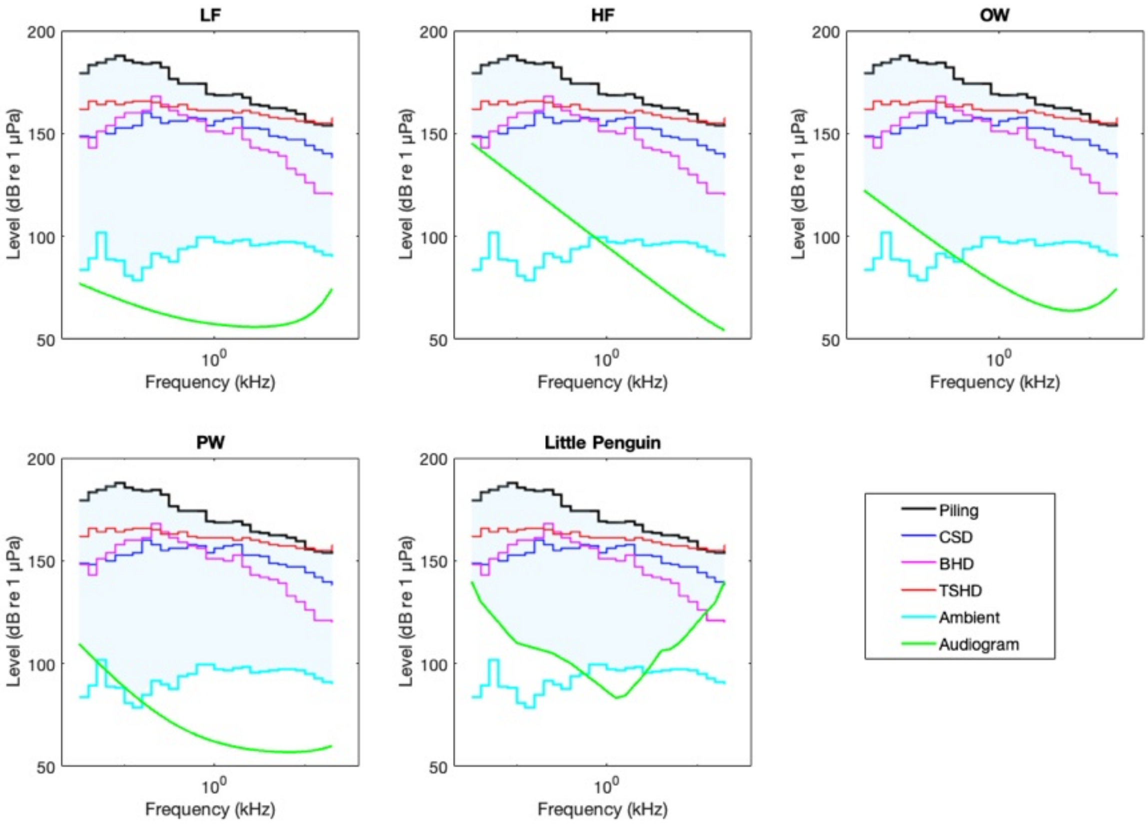

Figure 19 Decidecade band source levels, 5th percentile ambient sound levels within Whangārei Harbour and NMFS (2024) composite audiograms for different species (each of the NMFS functional hearing groups). The blue shading represents the area used as NL1 in the LSR equation and the larger the area, the more sensitive a listener is to masking effects.

Marine fauna has evolved in a naturally noisy environment, with many natural sources (such as waves and conspecific or heterospecific vocalisations etc) acting as effective maskers (Radford et al. 2014). Taxa have therefore evolved to counteract naturally occurring maskers, ensuring their vocalisations can be detected by a listener in a range of environments. Anti-masking strategies by the sender are predominately altering the call's characteristics, such as increasing call amplitude (Lombard effects), changing the spectral characteristics of the call (such as lowering or raising the fundamental or peak frequencies) to reduce spectral overlap, or altering the temporal dynamics of the call, such as increasing call rates or repetition (Radford et al. 2014; Erbe et al. 2016). There may also be repeating information at multiple frequencies within a call's harmonics (such as in some fish calls, graded structures in dolphin vocalisations and whale calls). In addition, masking release at the listener may occur when the call and masking noise are coming from different direction (termed spatial release from masking) or when the masking noise is amplitude modulated over a bandwidth much wider than the critical band of the listener (termed comodulation masking release) (Erbe et al. 2016). All these masking release mechanisms have been documented in marine mammals and fish, and thus the importance of this assumption.

Audibility ranges (including kororā/little penguins)

In order for any noise effect to occur, the noise has to first be audible to a receiver. It is important to note, however, that simply detecting a noise source does not equate to an effect occurring. Notwithstanding, the limits of audibility do provide us a maximum area within which the risk of any effect occurring is theoretically greater than 1 %. By calculating the limits of audibility for each of the species of concern, it allows regulatory bodies to better understand the acoustic footprint of the proposed dredging for particular species or groups.

A conservative approach was taken – detection thresholds, auditory gain functions and directivity of hearing sensitivities have been left out of the calculations because they are unknown for the species of concern. Masking release mechanisms have also been left out for the same reason. The key assumption, therefore, is that detectability of the anthropogenic noise is omnidirectional[12] and directly relates to the difference between the ambient sound level, the anthropogenic noise and hearing thresholds at each critical band.

Effects modelling for fishes

Fish and invertebrates can be negatively impacted by anthropogenic noise, just as marine mammals. However, unlike marine mammals who have statutory protections in several countries, noise exposure criteria for fish are far more varied in their usefulness (Hawkins & Popper 2017). Data that establishes the expected severity of a certain effect following the exposure to some pressure levels are scarce. Some of the only regulatory guidance for the potential onset of physical injury from pile-driving on fishes that has experienced some uptake internationally is the NMFS (2025) summary thresholds and the ANSI-accredited guidance from Popper et al. (2014). These provide useful guidelines (within the limitations and constraints) in gauging the spatial extent of potential impact. For percussive pile-driving, the criteria for various fish-groups are provided as decibel ranges. No guidance on vessel or dredging noise exists and have therefore fallen outside this assessments scope.

While thresholds are a good starting point, noise criteria for fishes should consider the biological significance of sound exposure (Hawkins et al. 2020). The biological significance of the sound exposure relates to whether the animal experiences an adverse effect in its life, i.e., is the invasive noise likely to cause significant physical, chemical or biological responses that have real consequences for the net fitness of the individual or population (Hawkins et al. 2020). The only effect that can currently be directly linked to such an impact is mortality or severe injury that eventually may be fatal. Other biologically significant effects include PTS, TTS, sub-lethal injuries, behavioural and auditory masking but the relationship between the severity of those effects and exposure to noise is data deficient and still a research question (Hawkins et al. 2020). Notwithstanding, hearing loss (either permanent or temporary) is an impact that can

[12] Also assumed in peer reviewed scientific publications, such as Pine et al. 2016; Pine et al. 2018; Pine et al. 2019; Putland et al. 2017; Stanley et al. 2018.

impact an individual's net fitness because their perception of predators can be inhibited. We have therefore considered physical injury in fishes from the percussive piling. Thresholds for the potential onset injury in fishes from piling are provided by NMFS (2025). Being based on percussive piling instead of airguns, it was selected over the ANSI-accredited guidance.

Multiple studies have been published that present noise exposure data and effects on fishes, but they suffer from a wide range of laboratory conditions, experimental methods, species and conclusions. NMFS[13] recommend the following thresholds (Table 40) for the onset of physical injury as for impact piling.

Table 40: NMFS thresholds for physical injury in fishes

Fish size	Onset of physical injury (received level)
>/= 2g	$L_{p,0\text{-}pk,flat}$ 206 dB; $L_{E,p,12h}$: 187 dB
</= 2g	$L_{p,0\text{-}pk,flat}$ 206 dB; $L_{E,p,12h}$: 183 dB

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Appendix E Unmitigated (no CBC) piling noise effects plots

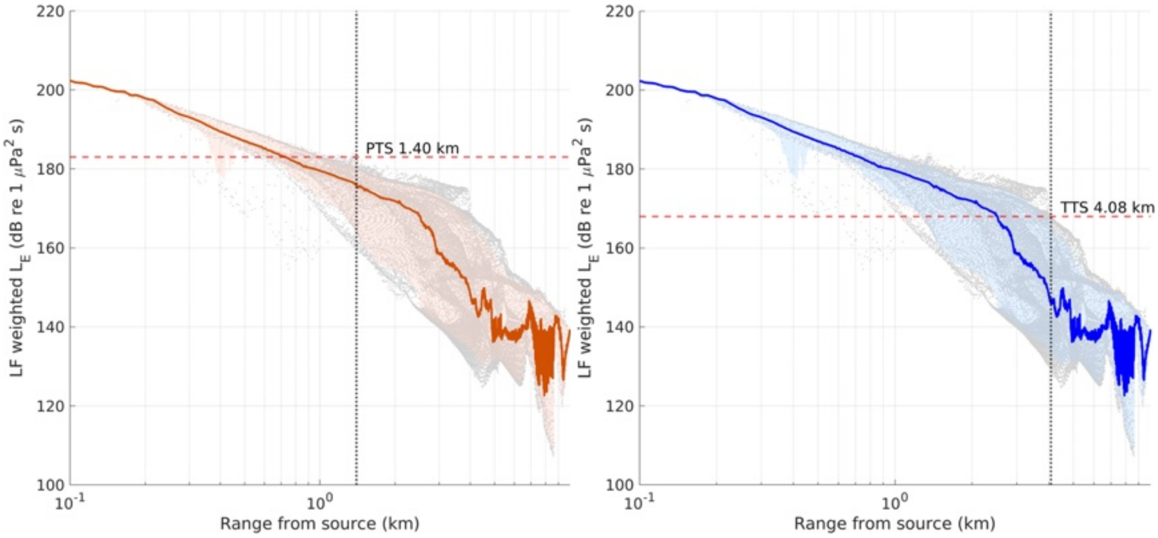


Figure 20 Modelled noise ($L_{E,p,24hr}$) for LF cetaceans from the percussive piling along the combi wall. The red dotted line represents the AUD INJ (Incl. PTS) (left plot), or the TTS threshold (right plot). Solid lines are the average $L_{E,p,24hr}$ with range across all calculation steps in the model's grid.

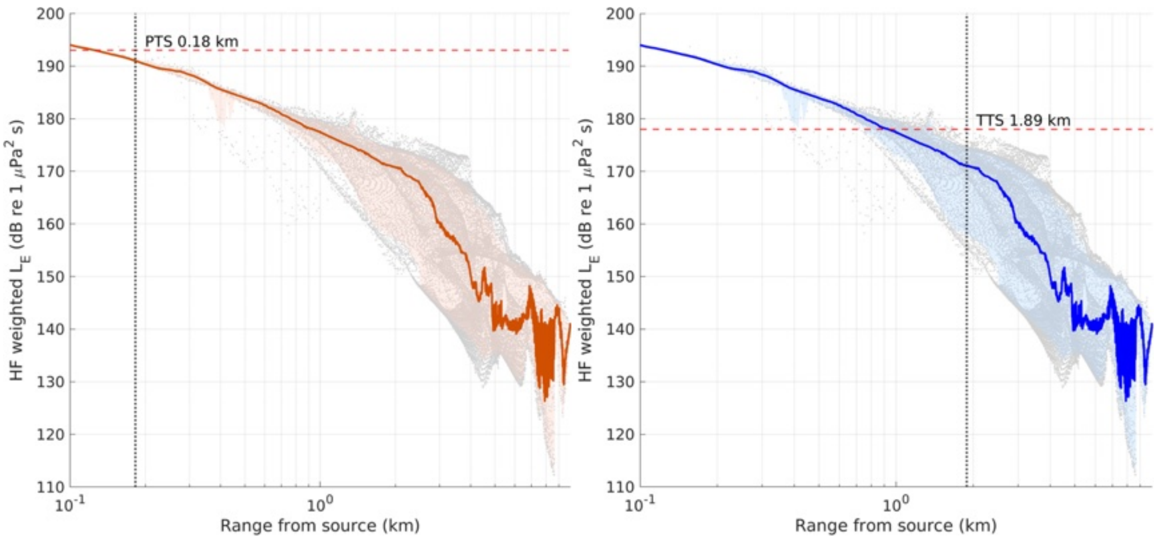


Figure 21 Modelled noise ($L_{E,p,24hr}$) for HF cetaceans from the percussive piling along the combi wall. The red dotted line represents the AUD INJ (Incl. PTS) (left plot), or the TTS threshold (right plot). Solid lines are the average $L_{E,p,24hr}$ with range across all calculation steps in the model's grid.

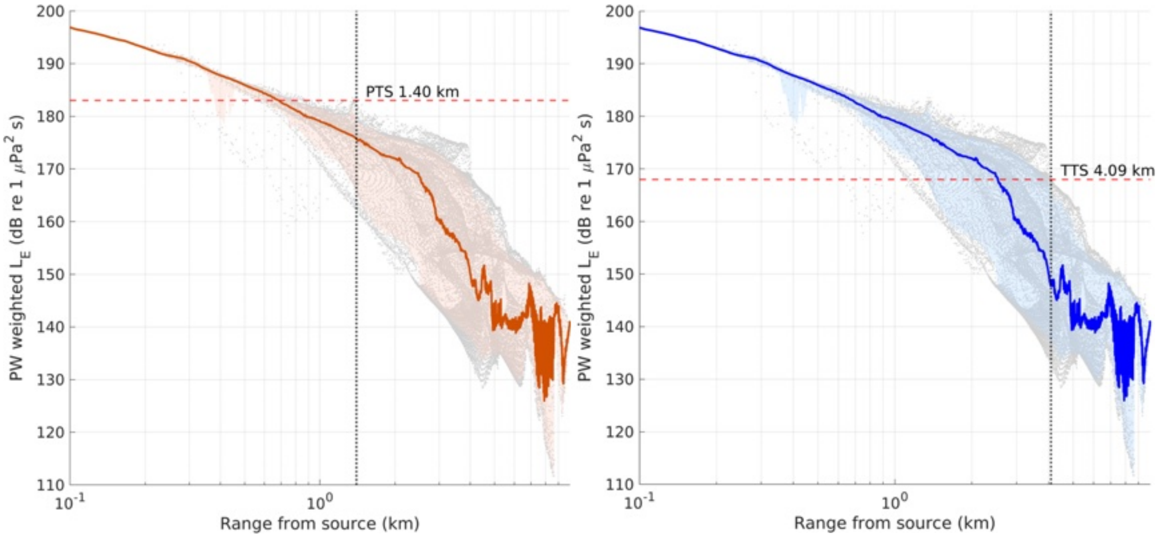


Figure 22 Modelled noise ($L_{E,p,24hr}$) for PW pinnipeds from the percussive piling along the combi wall. The red dotted line represents the AUD INJ (Incl. PTS) (left plot), or the TTS threshold (right plot). Solid lines are the average $L_{E,p,24hr}$ with range across all calculation steps in the model's grid.

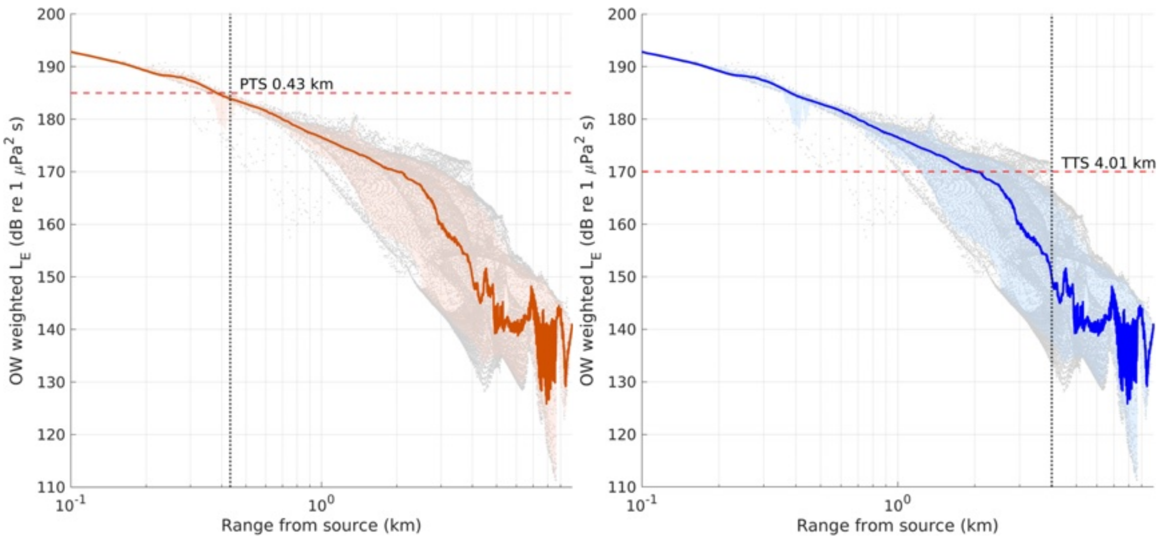


Figure 23 Modelled noise ($L_{E,p,24hr}$) for OW pinnipeds from the percussive piling along the combi wall. The red dotted line represents the AUD INJ (Incl. PTS) (left plot), or the TTS threshold (right plot). Solid lines are the average $L_{E,p,24hr}$ with range across all calculation steps in the model's grid.

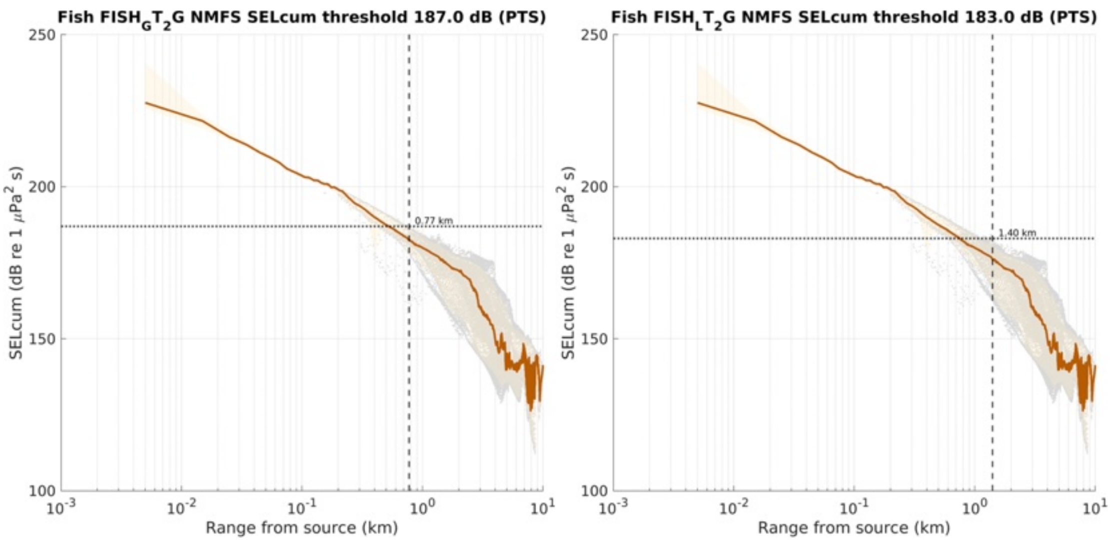


Figure 24 Modelled noise ($L_{E,p,24hr}$) for fishes from the percussive piling along the combi wall. The horizontal dotted line represents the threshold for the onset of physical injury in fishes >/= 2g in size (left plot), or </= 2g in size (right plot). Solid lines are the average $L_{E,p,12hr}$ with range across all calculation steps in the model's grid.

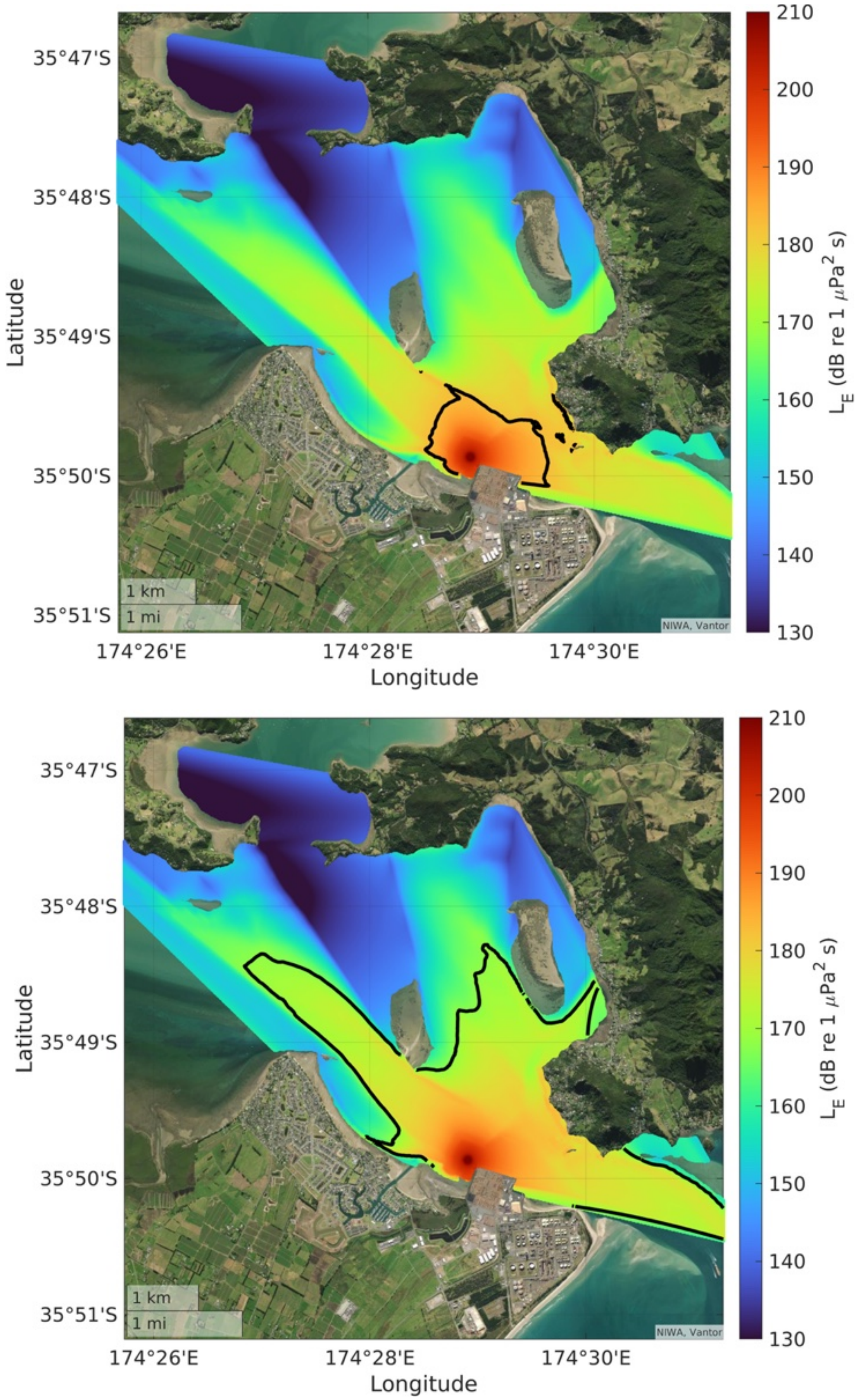


Figure 25 Modelled noise ($L_{E,p,24hr}$) for LF cetaceans from the percussive piling along the combi wall. The top panel shows the AUD INJ (Incl. PTS) contour, while the bottom panel shows the TTS contour.

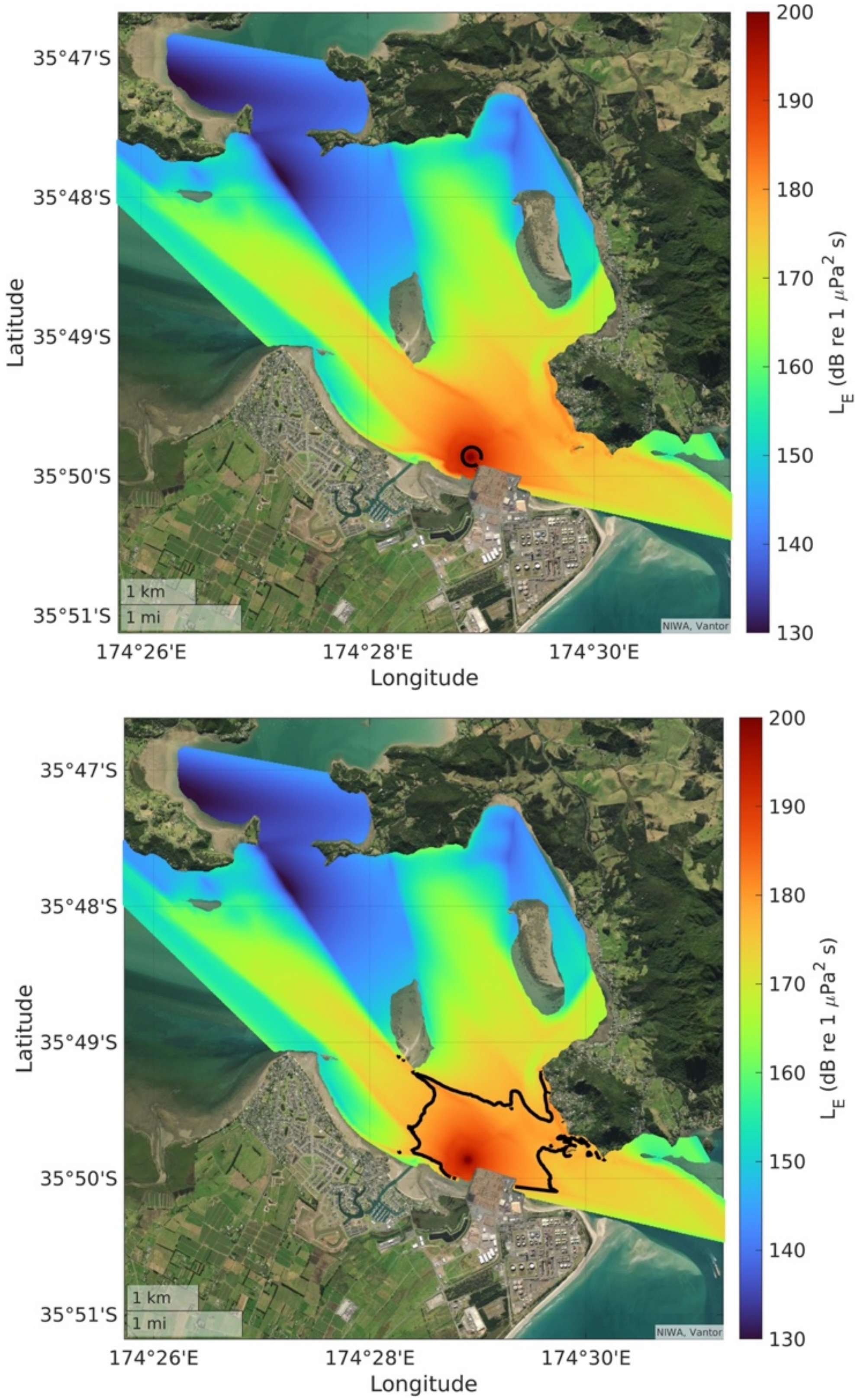


Figure 26 Modelled noise ($L_{E,p,24hr}$) for HF cetaceans from the percussive piling along the combi wall. The top panel shows the AUD INJ (Incl. PTS) contour, while the bottom panel shows the TTS contour.

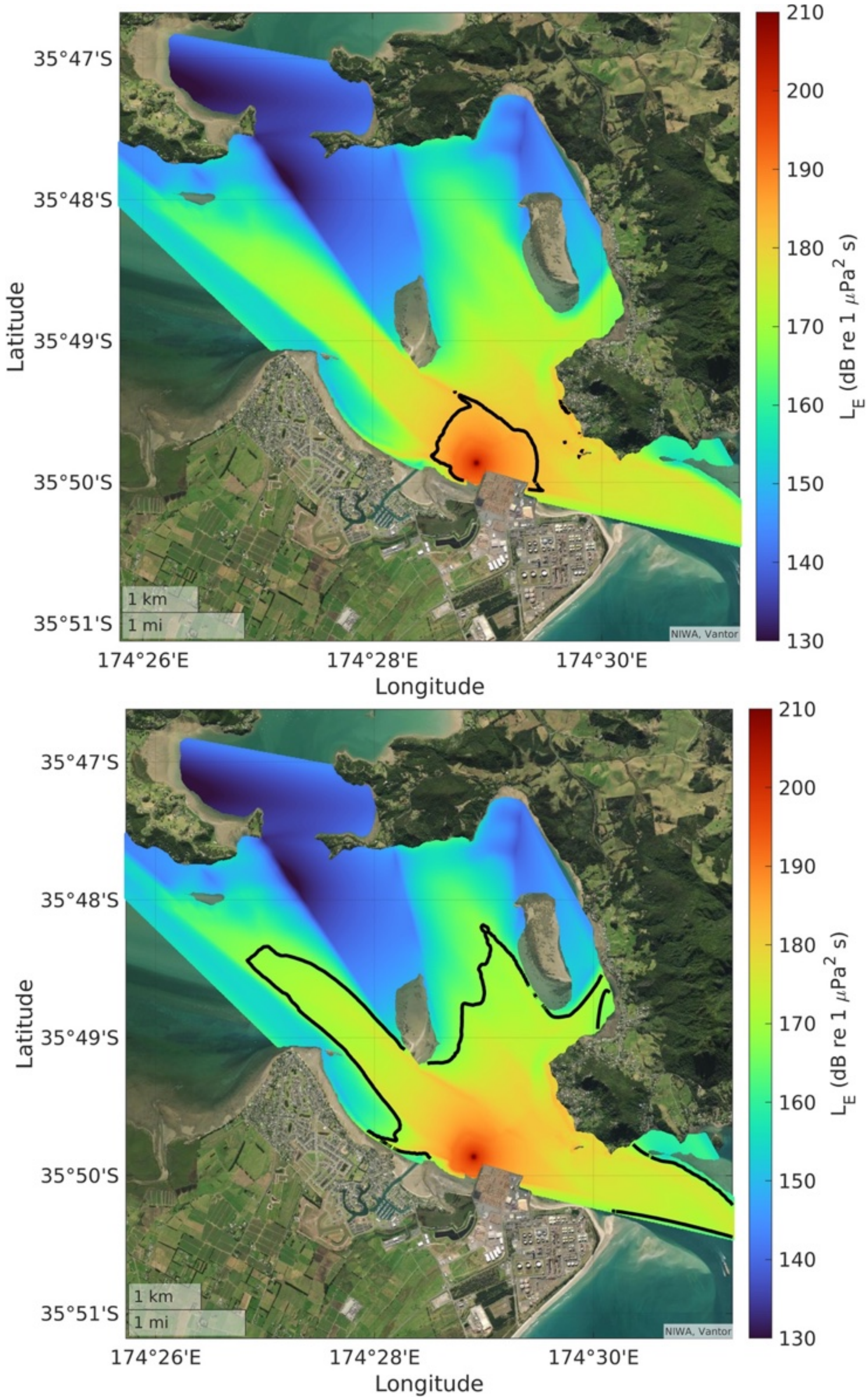


Figure 27 Modelled noise ($L_{E,p,24hr}$) for PW cetaceans from the percussive piling along the combi wall. The top panel shows the AUD INJ (Incl. PTS) contour, while the bottom panel shows the TTS contour.

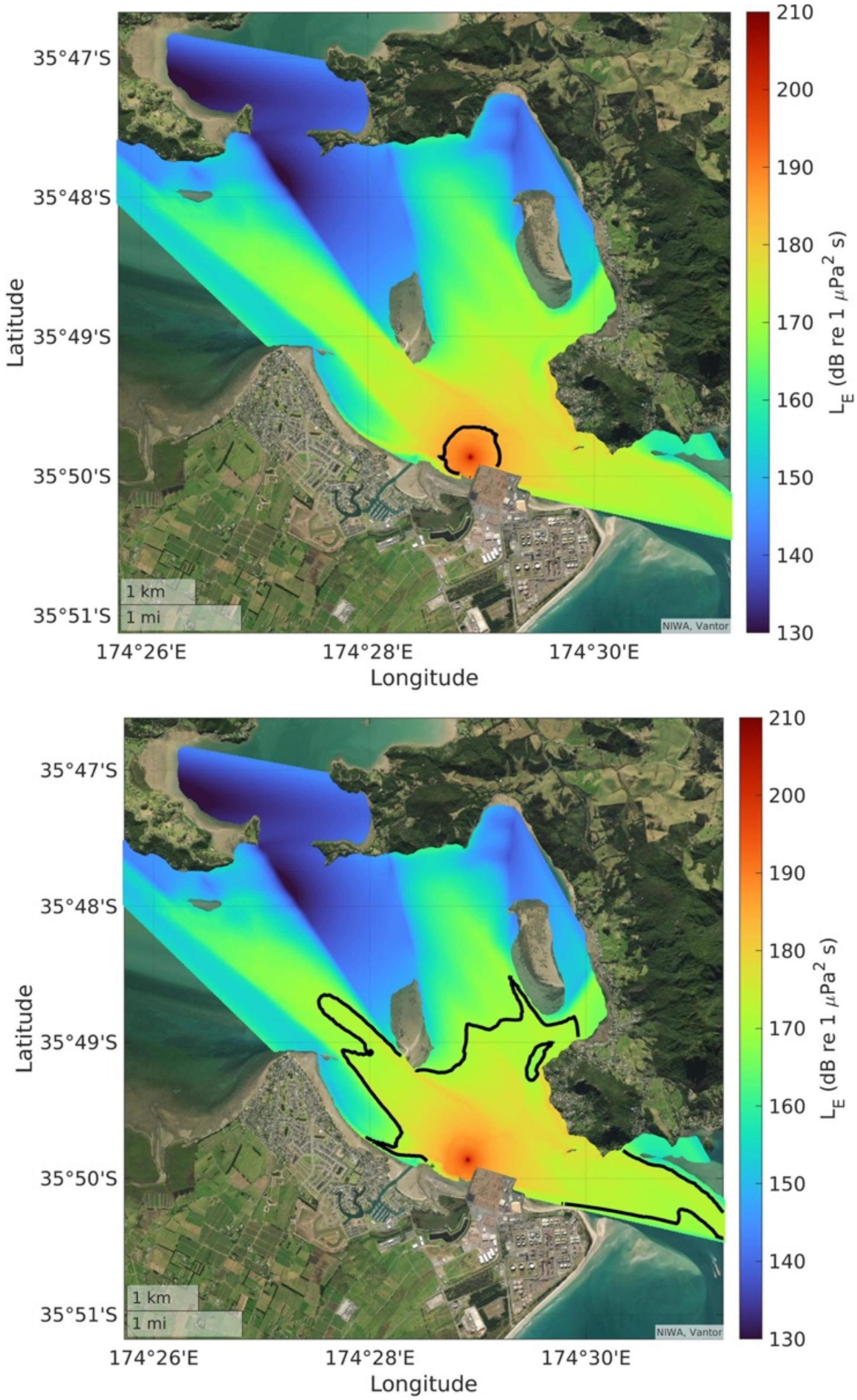


Figure 28 Modelled noise ($L_{E,p,24hr}$) for OW cetaceans from the percussive piling along the combi wall. The top panel shows the AUD INJ (Incl. PTS) contour, while the bottom panel shows the TTS contour.

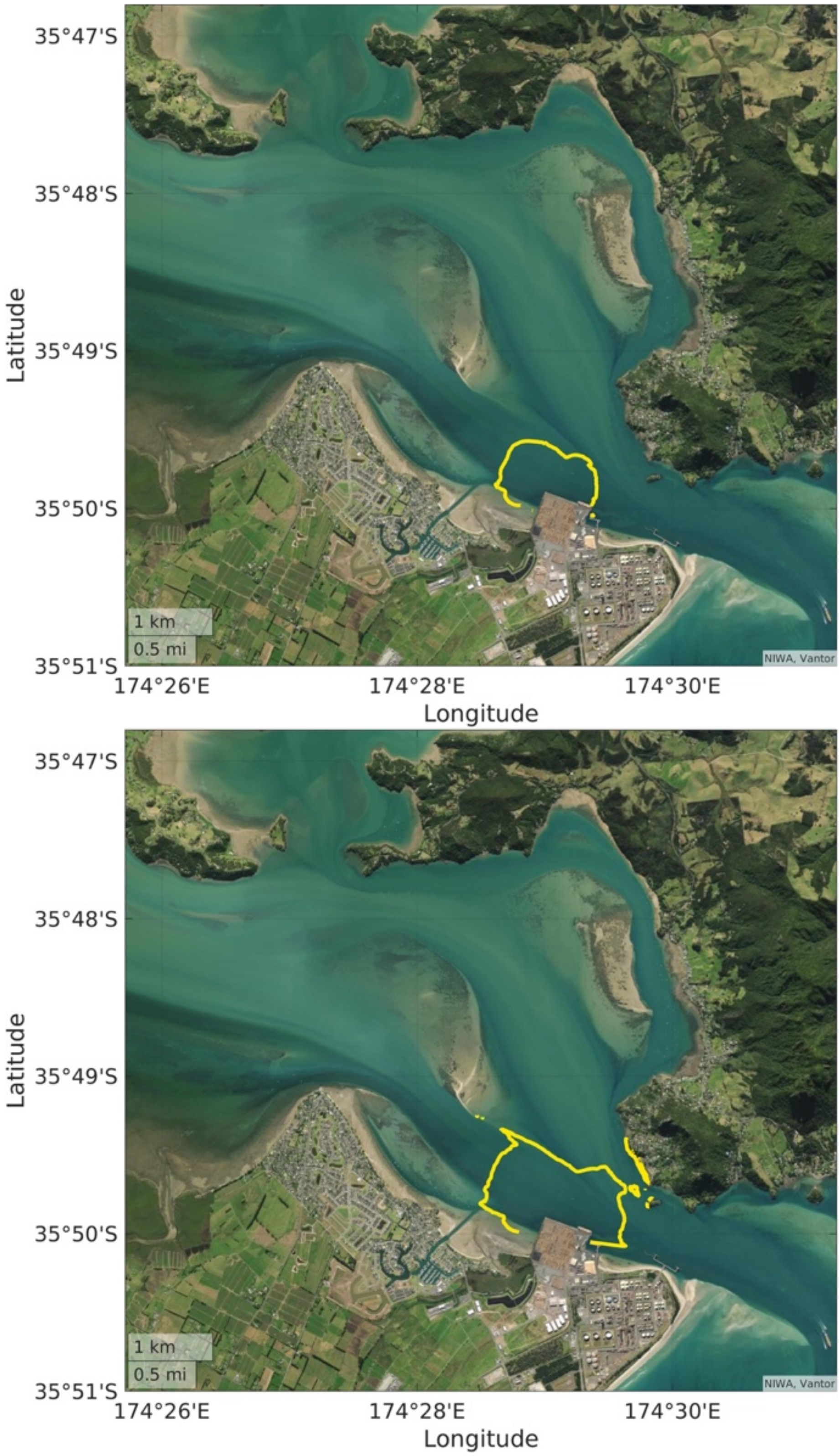


Figure 29 Contours showing the ranges within which the potential onset of physical injury for fishes >= 2g in size (top panel) and <= 2g may occur.

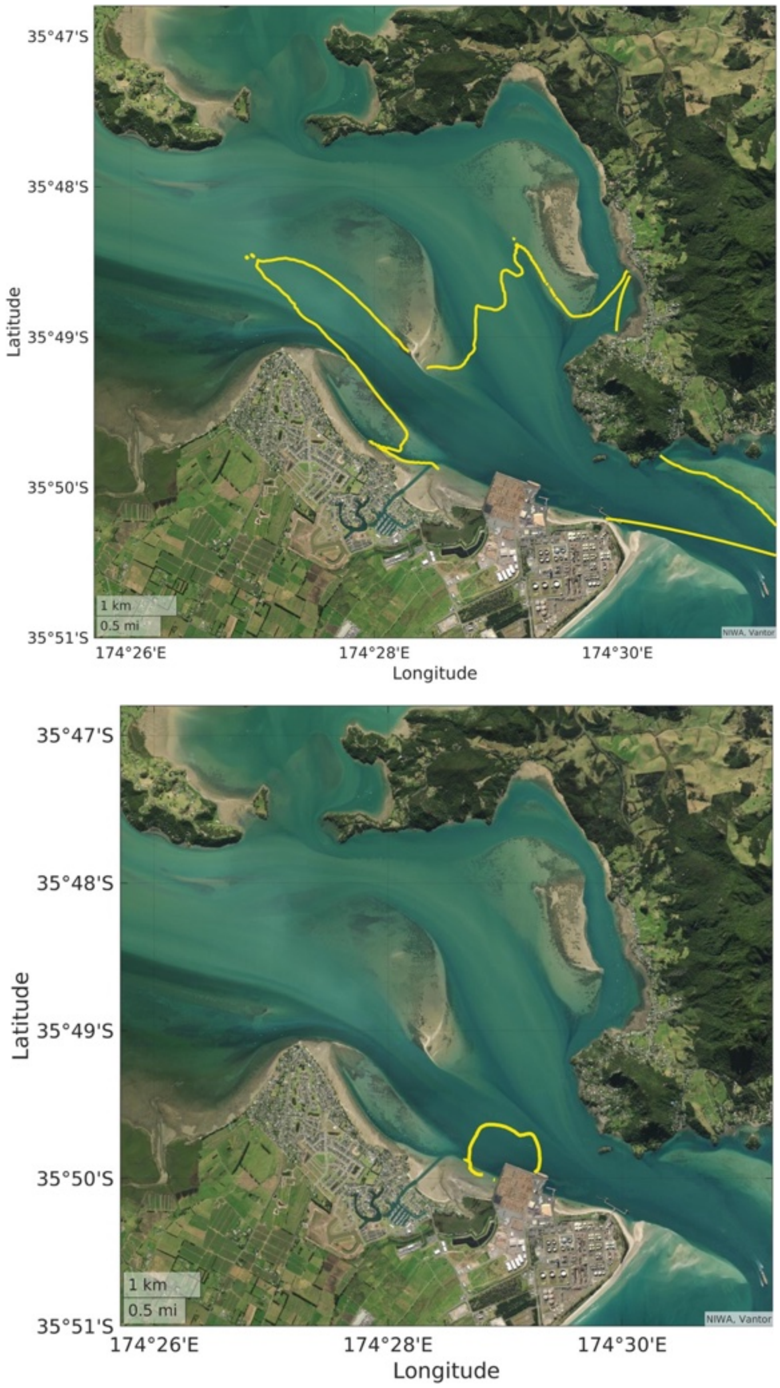


Figure 30 Contours showing the ranges within which the potential onset of behavioural responses may occur in cetaceans: the top panel shows the 140 dB contour, while the bottom panel shows the 160 dB contour.

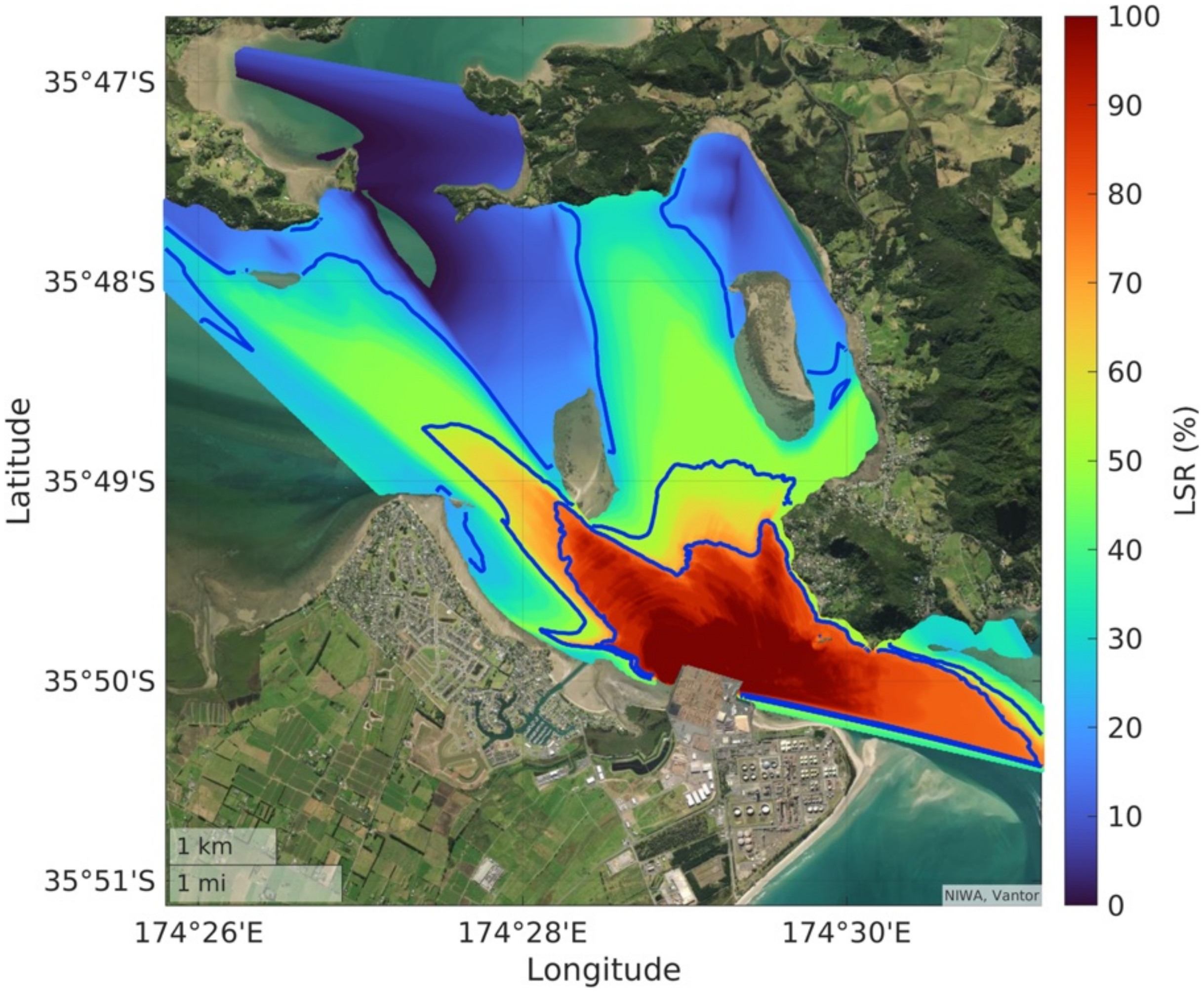


Figure 31 Map showing the listening space reductions (%) for LF cetaceans during the percussive piling along the combi wall. The contours represent LSRs of 75%, 50% and 25% LSRs.

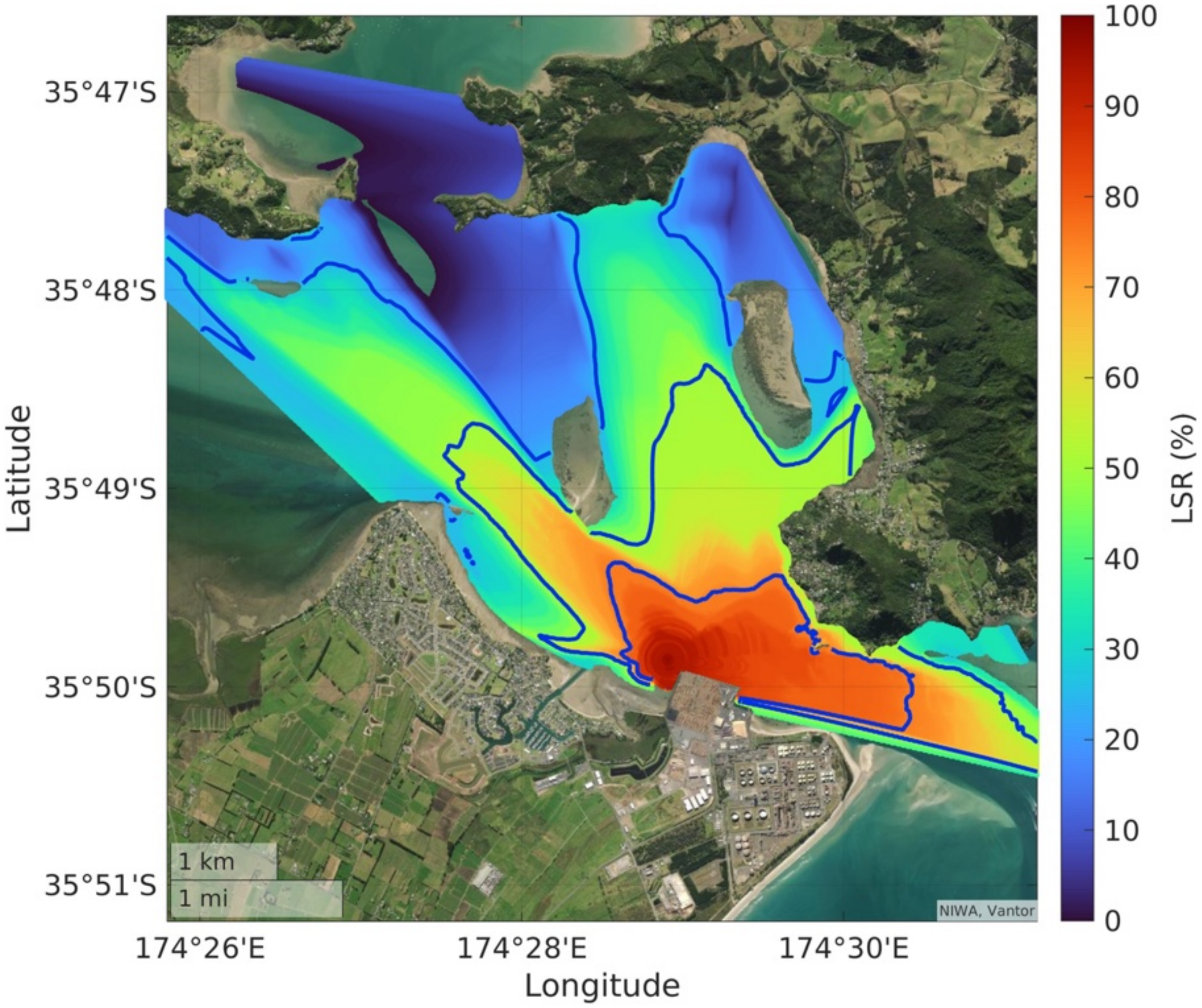


Figure 32 Map showing the listening space reductions (%) for HF cetaceans during the percussive piling along the combi wall. The contours represent LSRs of 75%, 50% and 25% LSRs.

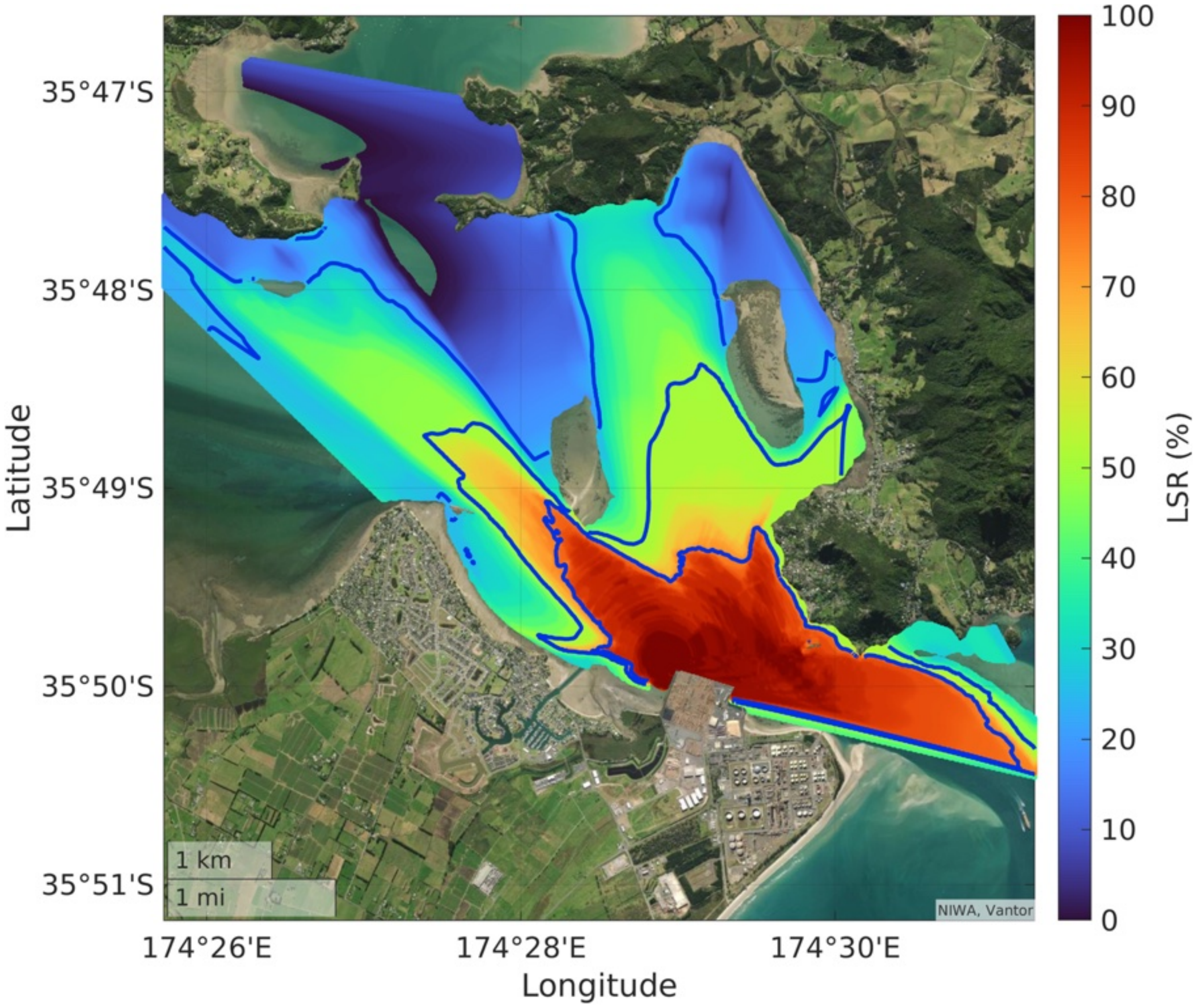


Figure 33 Map showing the listening space reductions (%) for PW pinnipeds during the percussive piling along the combi wall. The contours represent LSRs of 75%, 50% and 25% LSRs.

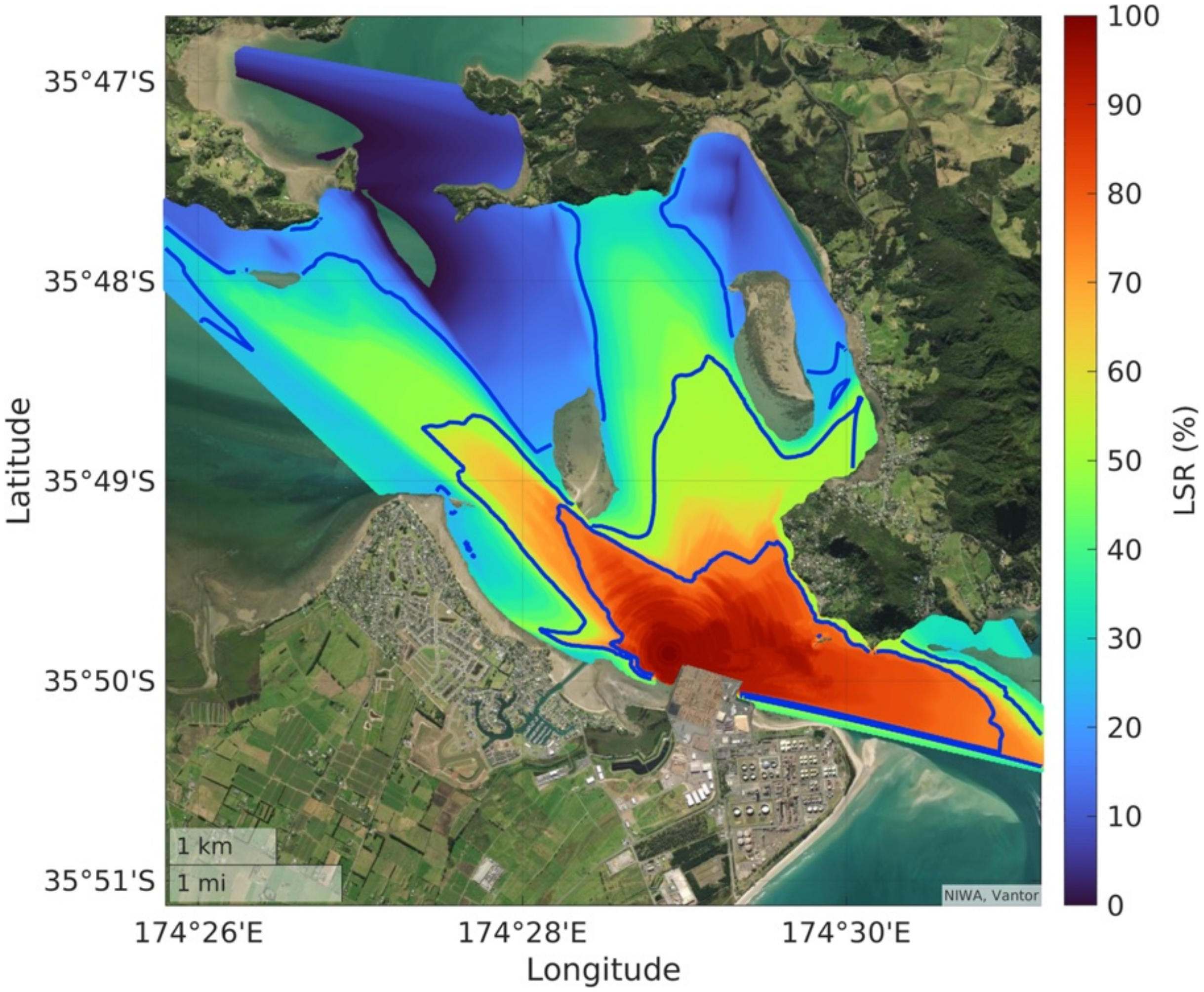


Figure 34 Map showing the listening space reductions (%) for OW pinnipeds during the percussive piling along the combi wall. The contours represent LSRs of 75%, 50% and 25% LSRs .

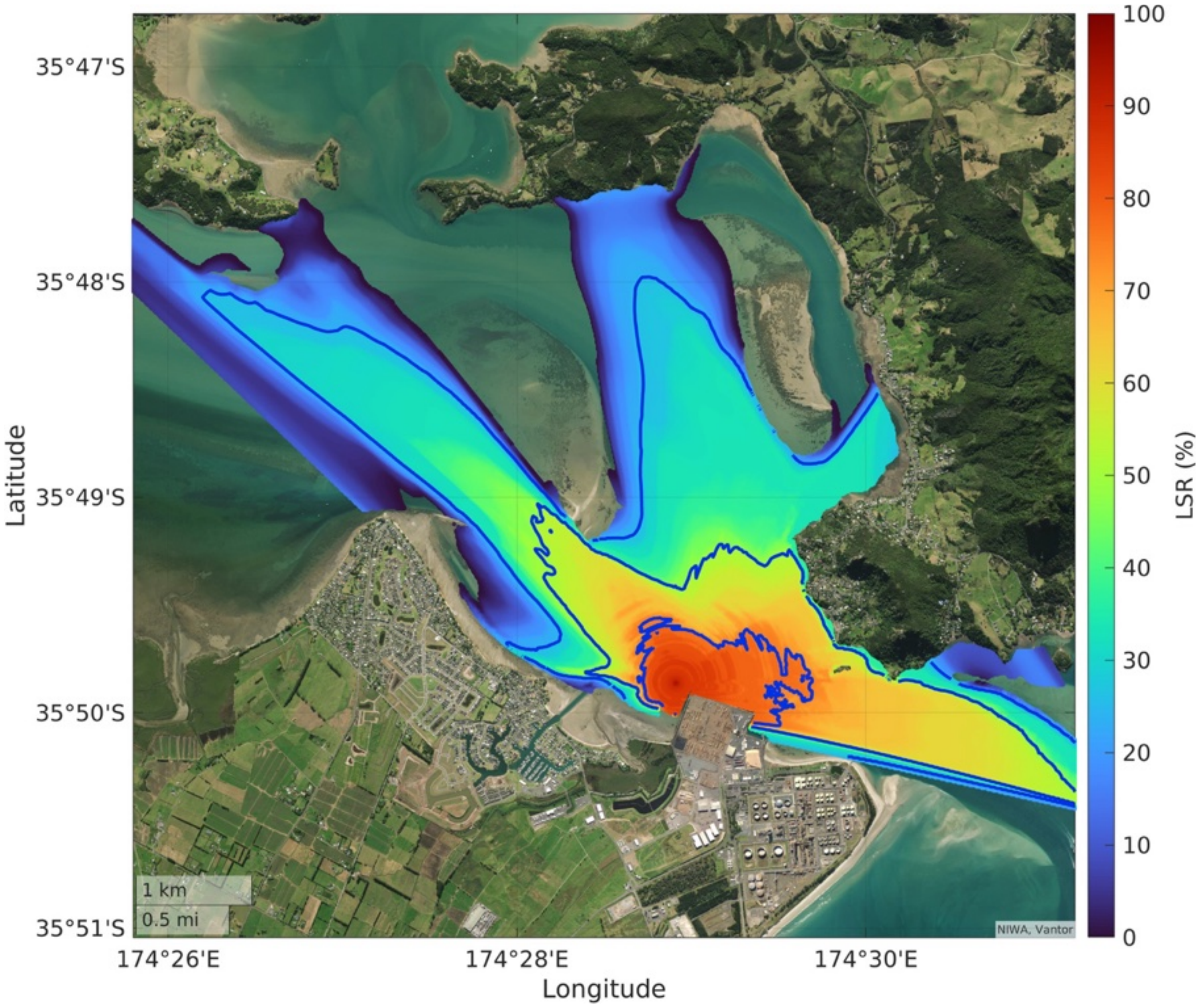


Figure 35 Map showing the listening space reductions (%) for kororā/little penguins during the percussive piling along the combi wall. The contours represent LSRs of 75%, 50% and 25% LSRs .

Appendix F Mitigated (with CBC) piling noise effects plots

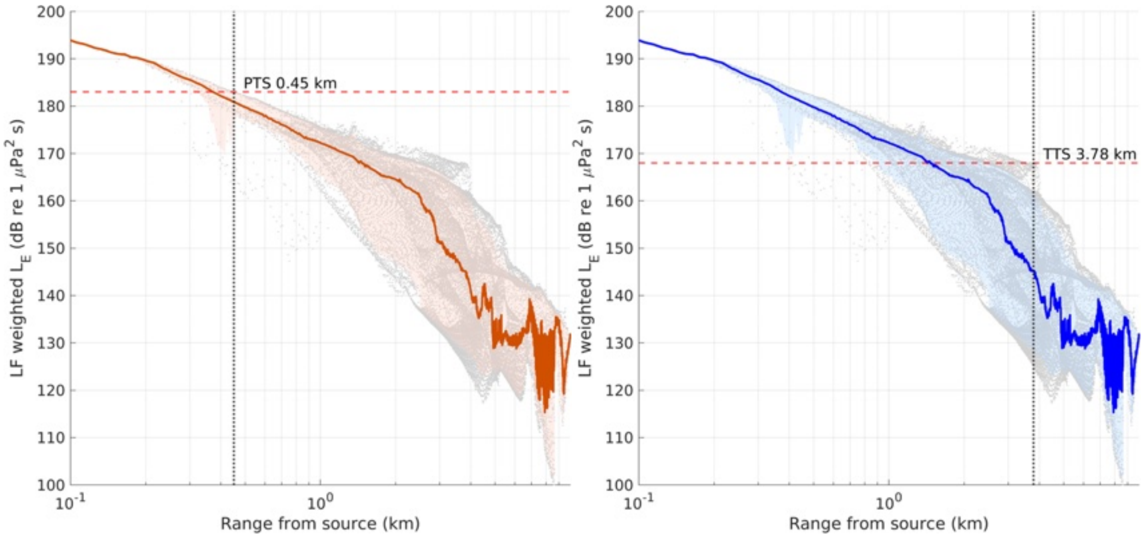


Figure 36 Modelled percussive piling noise ($L_{E,p,24hr}$) for LF cetaceans with a confined bubble curtain along the combi wall. The red dotted line represents the AUD INJ (Incl. PTS) (left plot), or the TTS threshold (right plot). Solid lines are the average $L_{E,p,24hr}$ with range across all calculation steps in the model's grid.

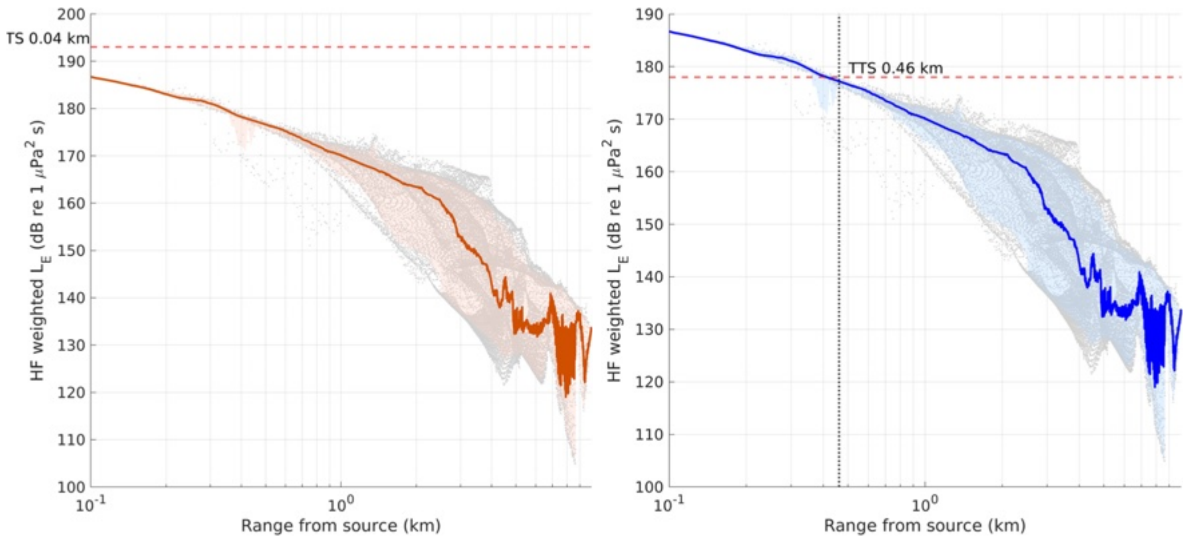


Figure 37 Modelled percussive piling noise ($L_{E,p,24hr}$) for HF cetaceans with a confined bubble curtain along the combi wall. The red dotted line represents the AUD INJ (Incl. PTS) (left plot), or the TTS threshold (right plot). Solid lines are the average $L_{E,p,24hr}$ with range across all calculation steps in the model's grid.

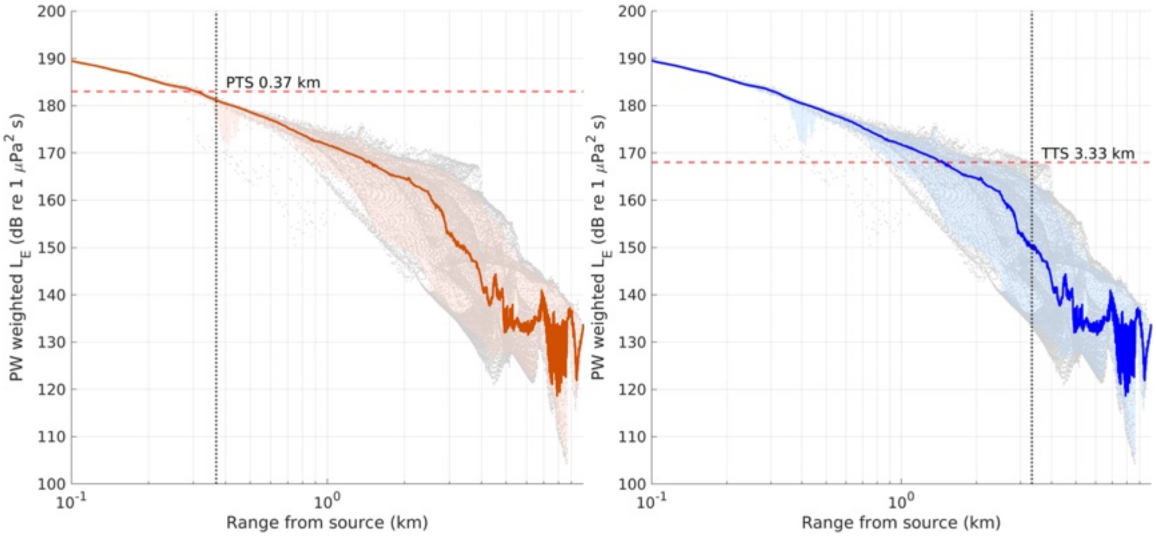


Figure 38 Modelled percussive piling noise ($L_{E,p,24hr}$) for PW pinnipeds with a confined bubble curtain along the combi wall. The red dotted line represents the AUD INJ (Incl. PTS) (left plot), or the TTS threshold (right plot). Solid lines are the average $L_{E,p,24hr}$ with range across all calculation steps in the model's grid.

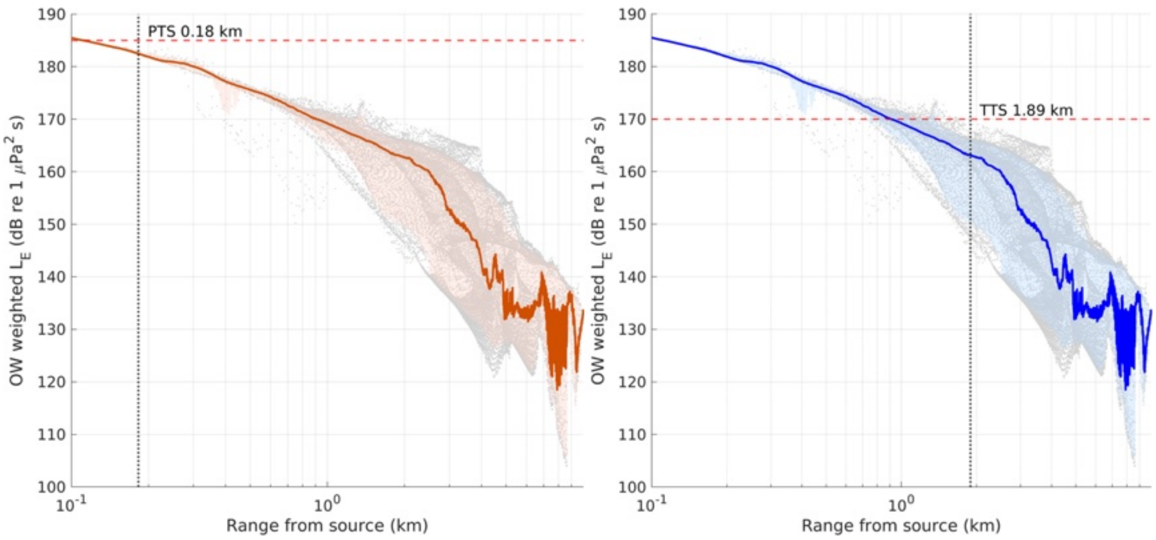


Figure 39 Modelled percussive piling noise ($L_{E,p,24hr}$) for OW pinnipeds with a confined bubble curtain along the combi wall. The red dotted line represents the AUD INJ (Incl. PTS) (left plot), or the TTS threshold (right plot). Solid lines are the average $L_{E,p,24hr}$ with range across all calculation steps in the model's grid.

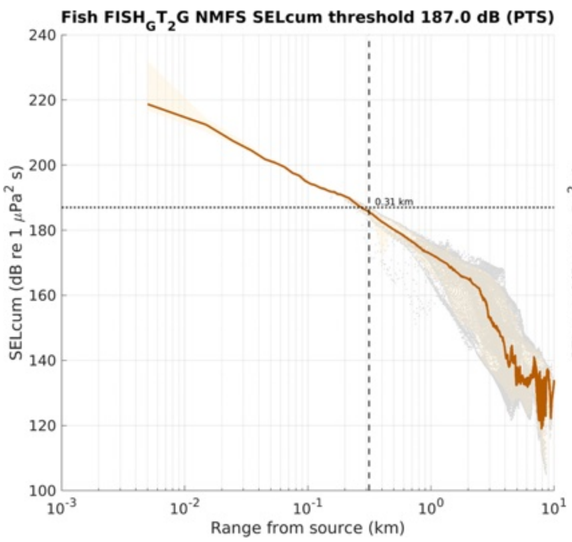


Figure 40 Modelled percussive piling noise ($L_{E,p,24hr}$) for fishes with a confined bubble curtain along the combi wall. The horizontal dotted line represents the threshold for the onset of physical injury in fishes >/= 2g in size (left plot), or </= 2g in size (right plot). Solid lines are the average $L_{E,p,12hr}$ with range across all calculation steps in the model's grid

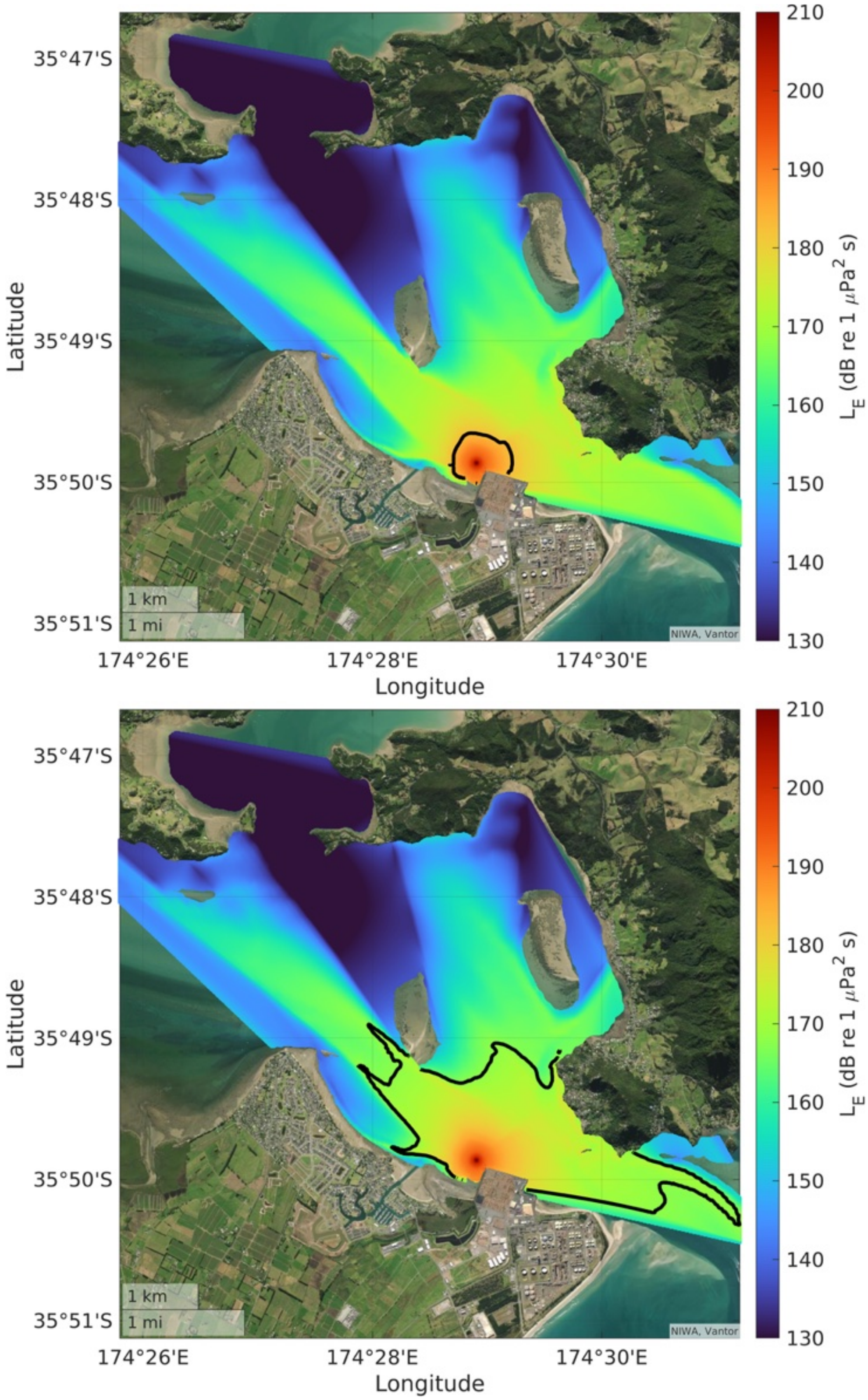


Figure 41 Modelled percussive piling noise ($L_{E,p,24hr}$) for LF cetaceans with a confined bubble curtain. The top panel shows the AUD INJ (Incl. PTS) contour, while the bottom panel shows the TTS contour.

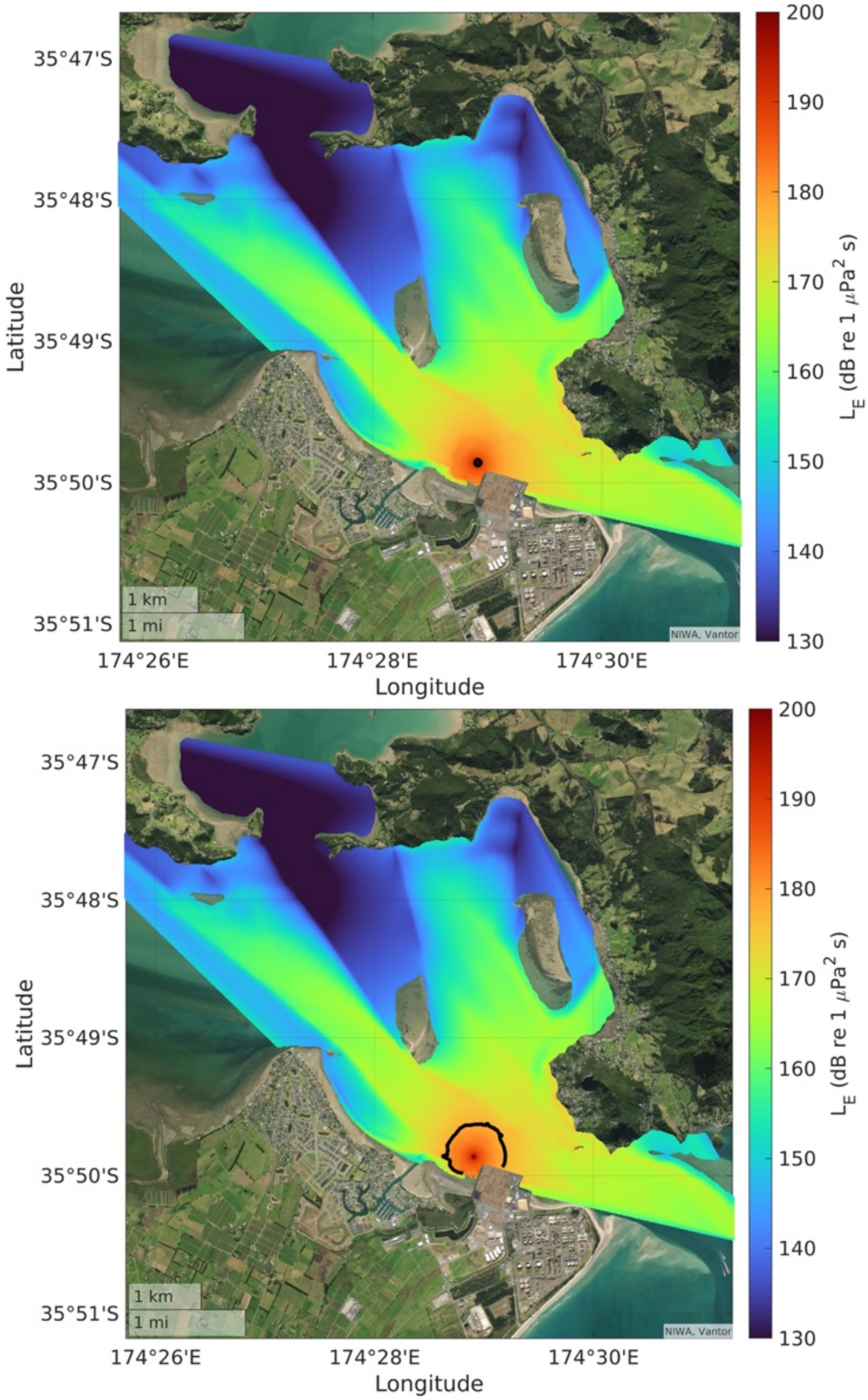


Figure 42 Modelled percussive piling noise ($L_{E,p,24hr}$) for HF cetaceans with a confined bubble curtain. The top panel shows the AUD INJ (Incl. PTS) contour, while the bottom panel shows the TTS contour.

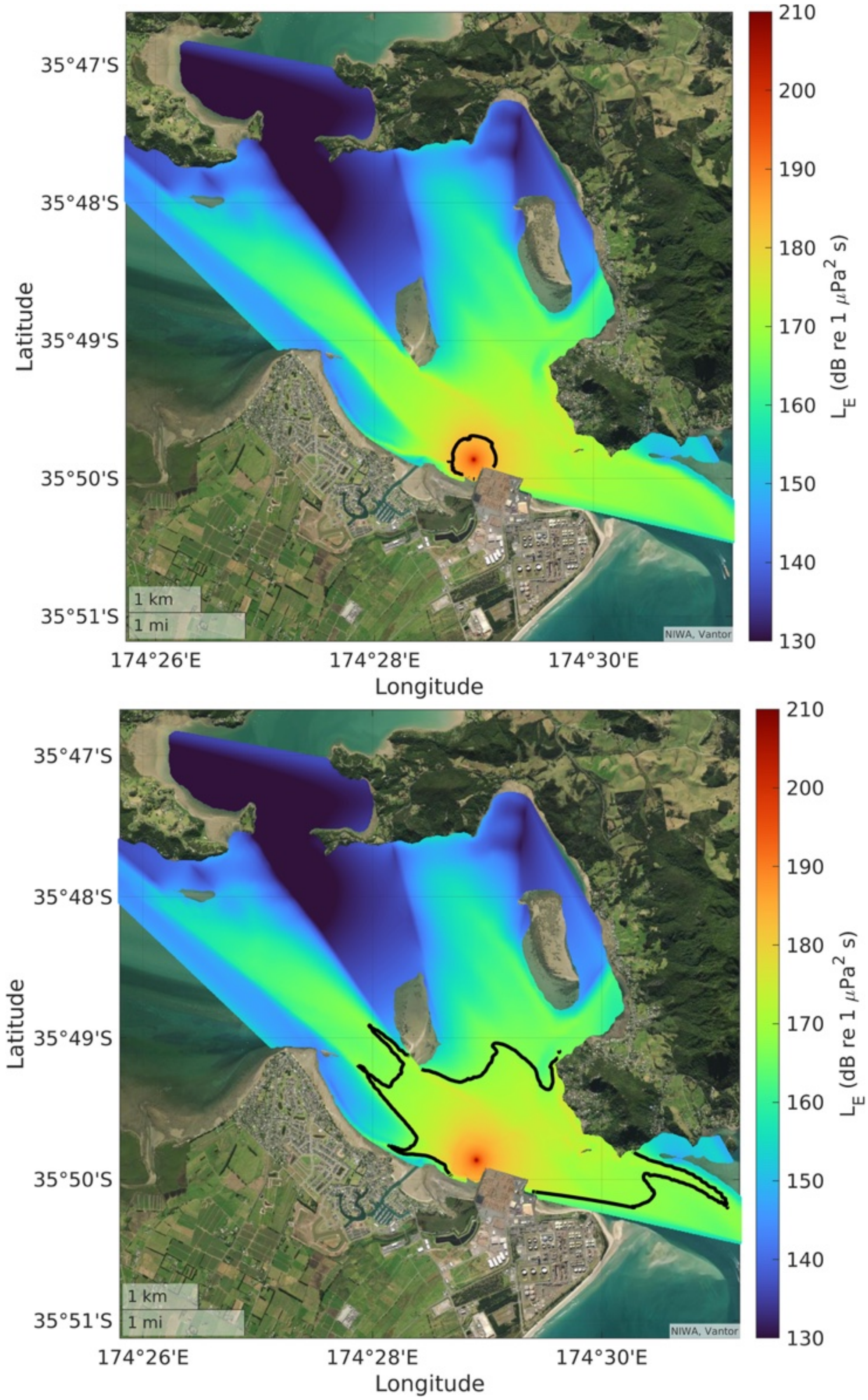


Figure 43 Modelled percussive piling noise ($L_{E,p,24hr}$) for PW pinnipeds with a confined bubble curtain. The top panel shows the AUD INJ (Incl. PTS) contour, while the bottom panel shows the TTS contour.

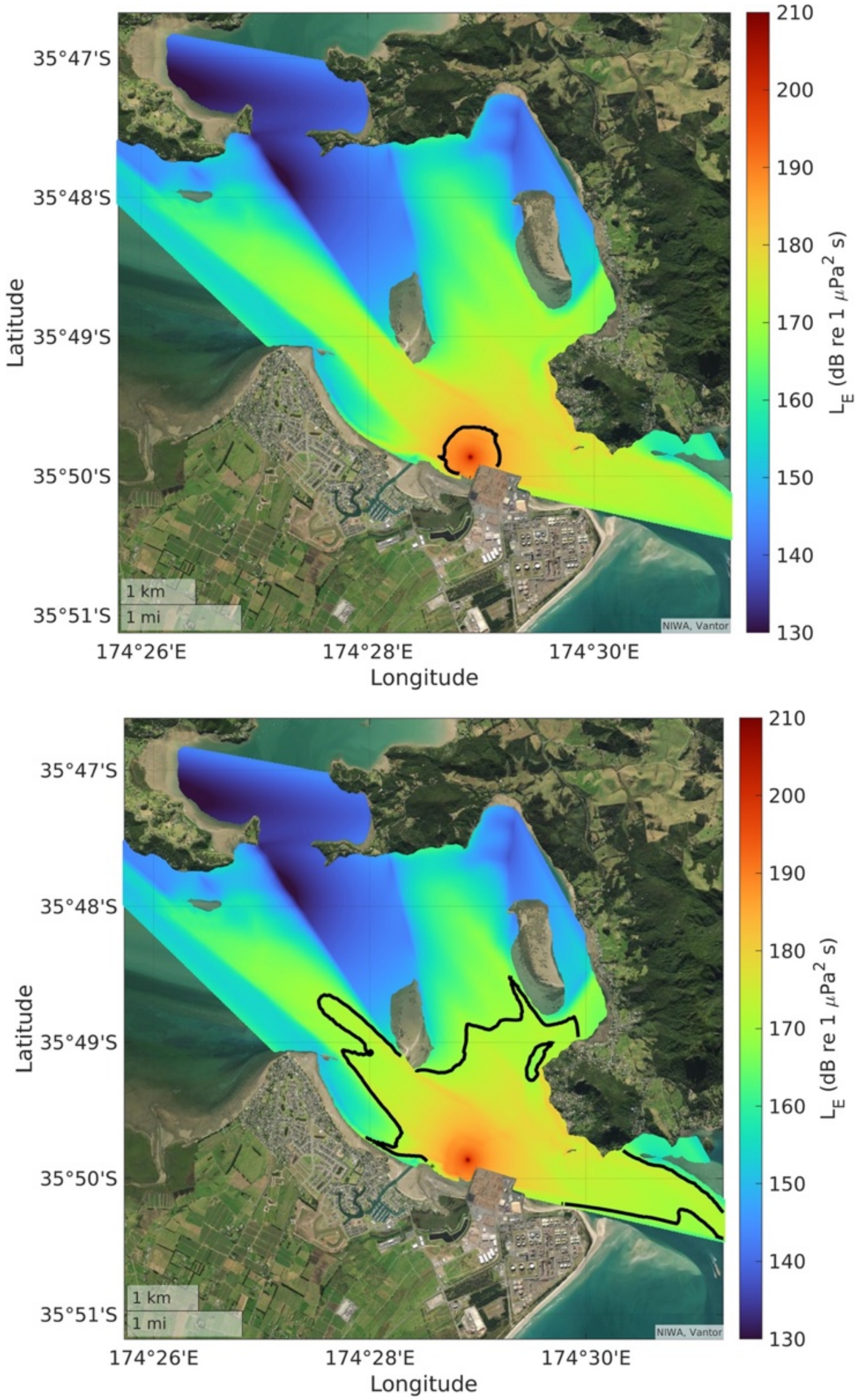


Figure 44 Modelled percussive piling noise ($L_{E,p,24hr}$) for OW pinnipeds with a confined bubble curtain. The top panel shows the AUD INJ (Incl. PTS) contour, while the bottom panel shows the TTS contour.

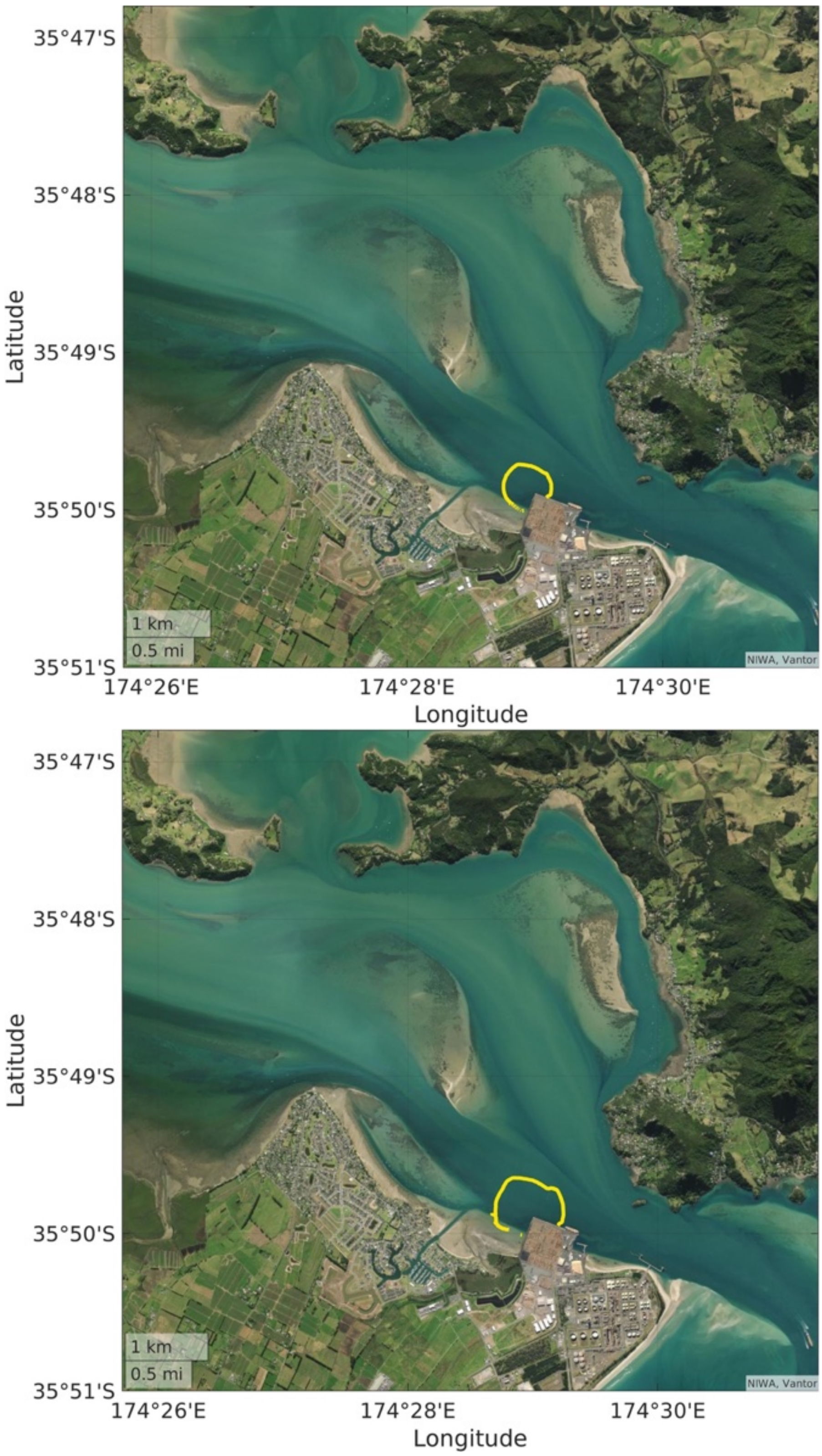


Figure 45 Contours showing the ranges within which the potential onset of physical injury for fishes >= 2g in size (top panel) and <= 2g may occur when using a confined bubble curtain.

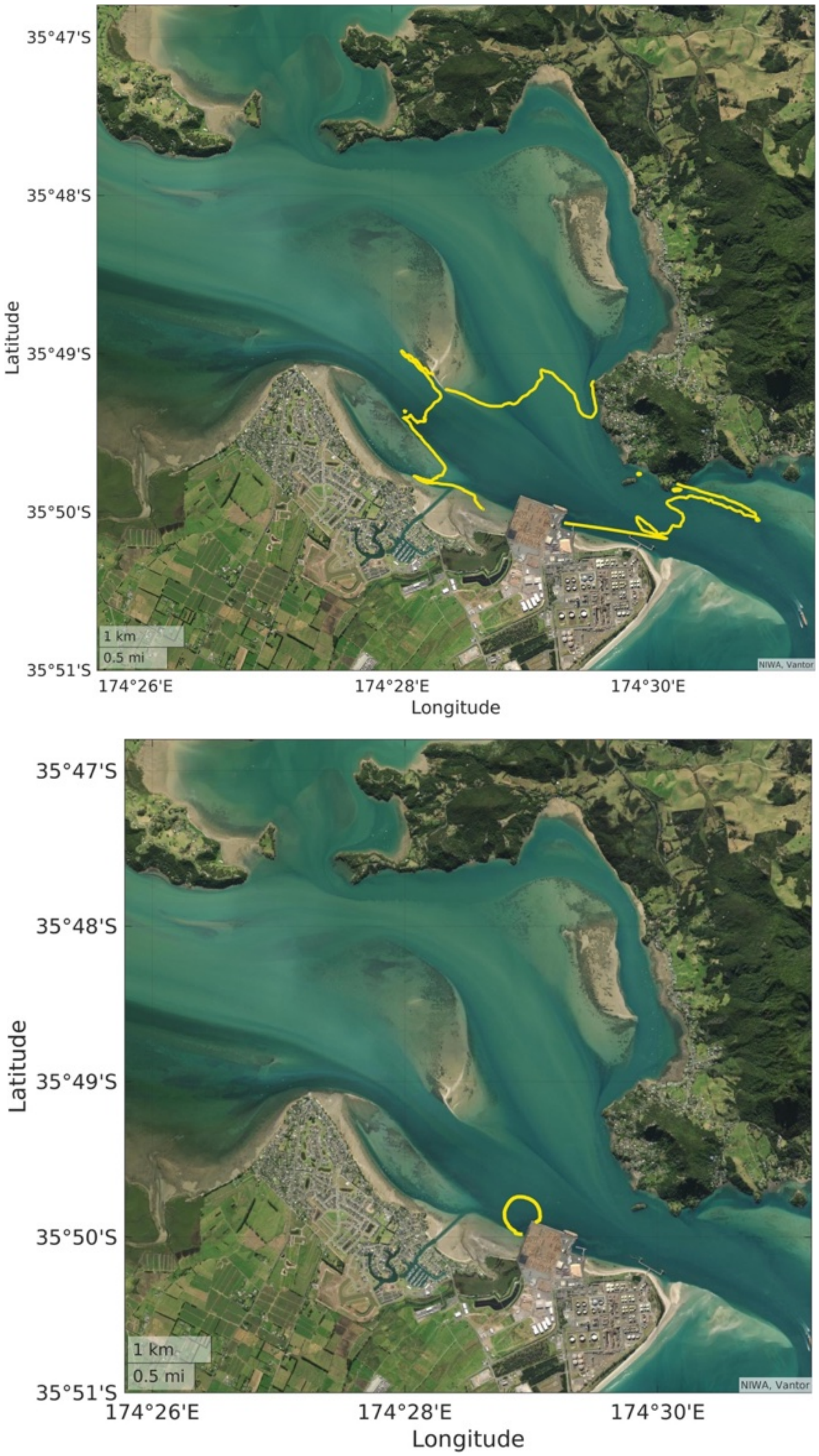


Figure 46 Mitigated (with confined bubble curtain) contours showing the ranges within which the potential onset of behavioural responses may occur in cetaceans: the top panel shows the 140 dB contour, while the bottom panel shows the 160 dB contour.

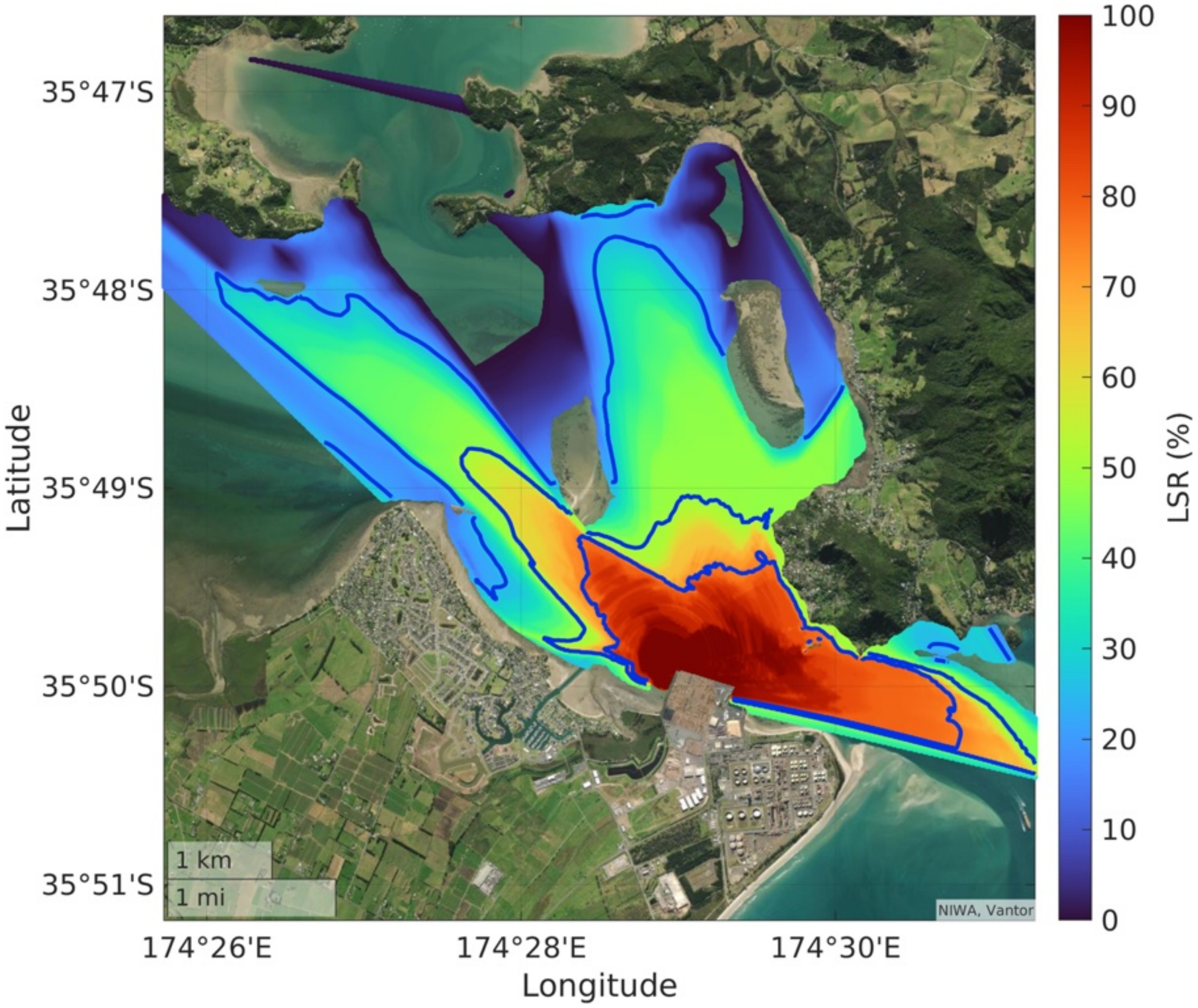


Figure 47 Map showing the listening space reductions (%) for LF cetaceans during the mitigated (with a confined bubble curtain) percussive piling along the combi wall. The contours represent LSRs of 75%, 50% and 25% LSRs.

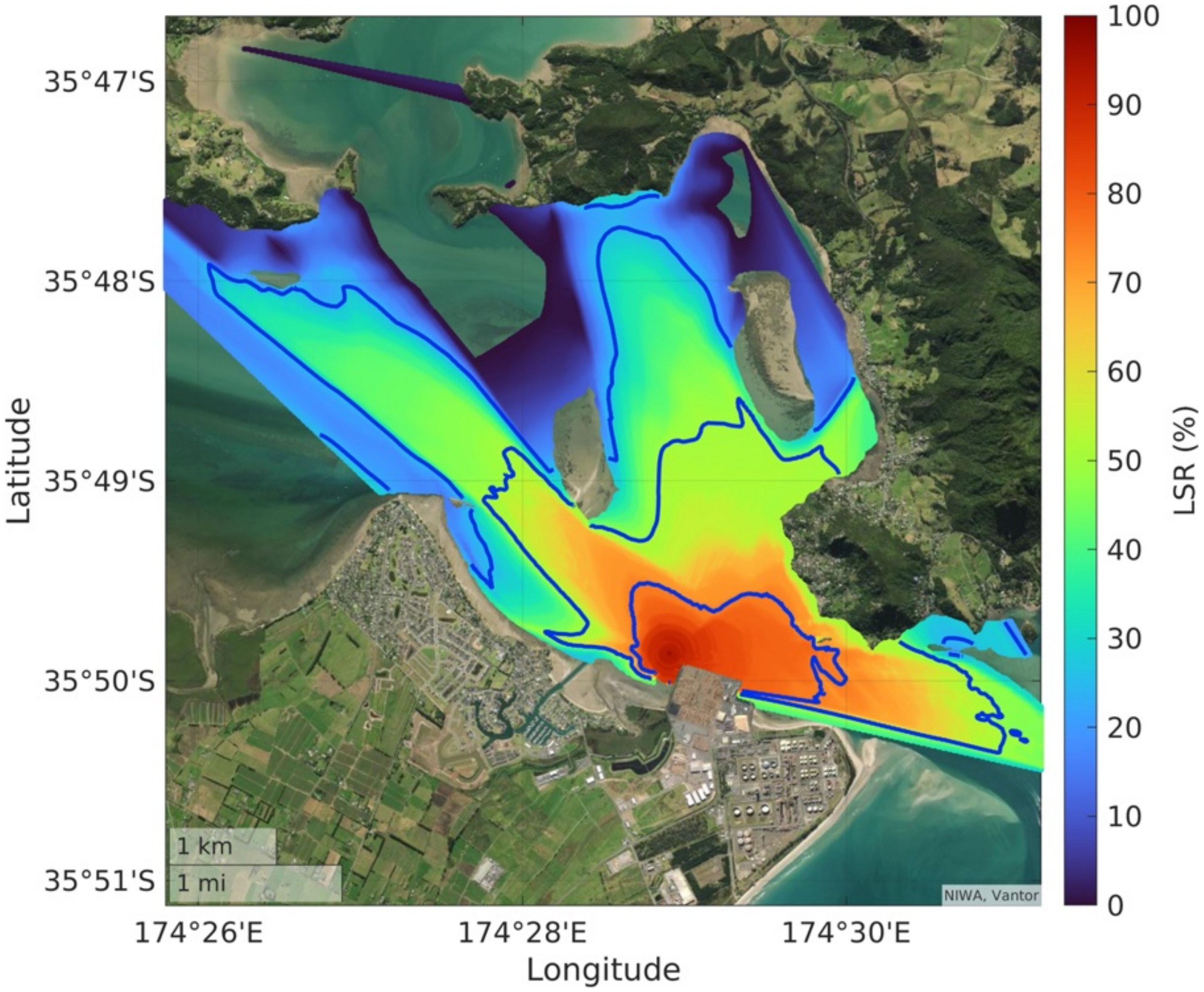


Figure 48 Map showing the listening space reductions (%) for HF cetaceans during the mitigated (with a confined bubble curtain) percussive piling along the combi wall. The contours represent LSRs of 75%, 50% and 25% LSRs..

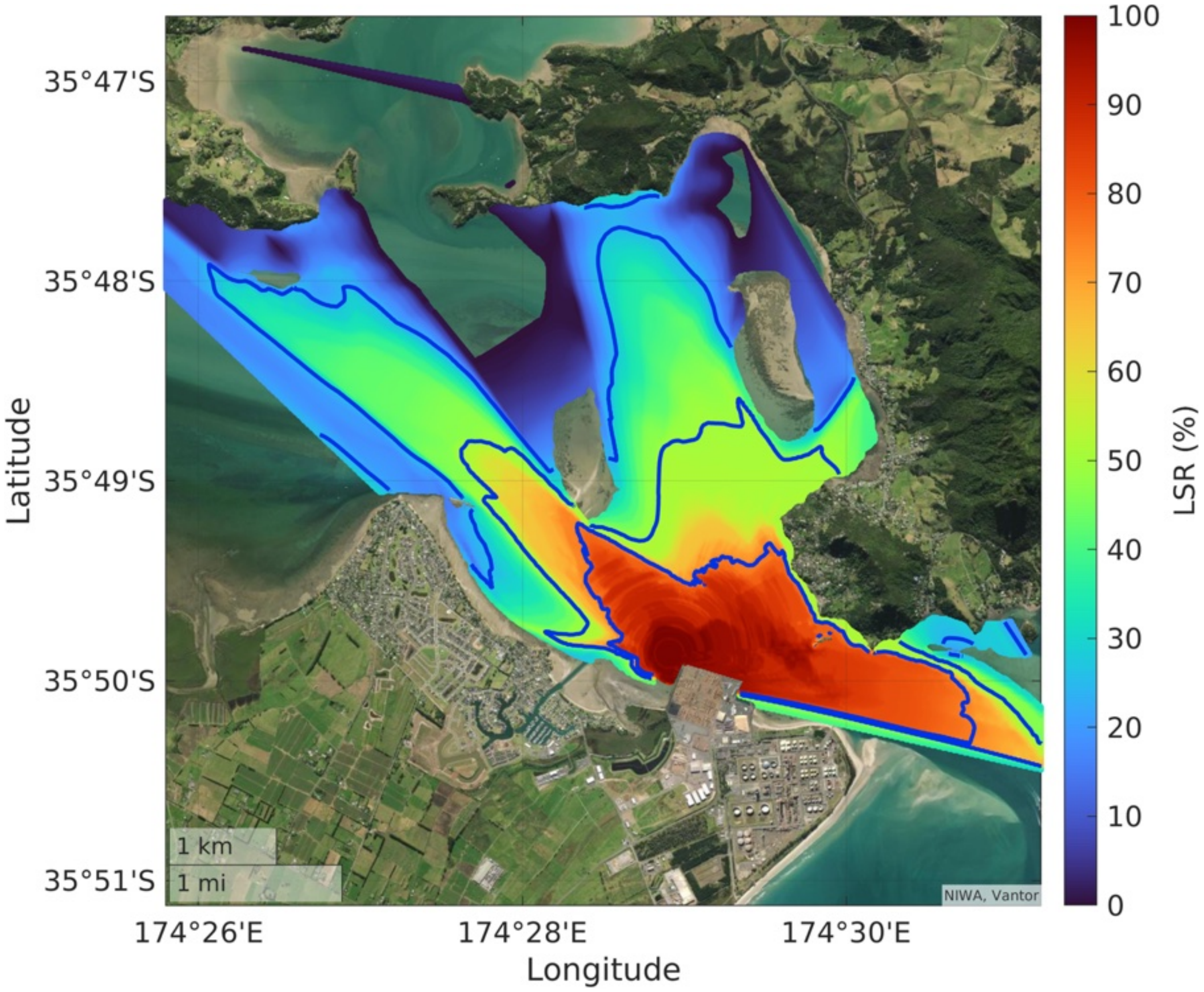


Figure 49 Map showing the listening space reductions (%) for PW pinnipeds during the mitigated (with a confined bubble curtain) percussive piling along the combi wall. The contours represent LSRs of 75%, 50% and 25% LSRs..

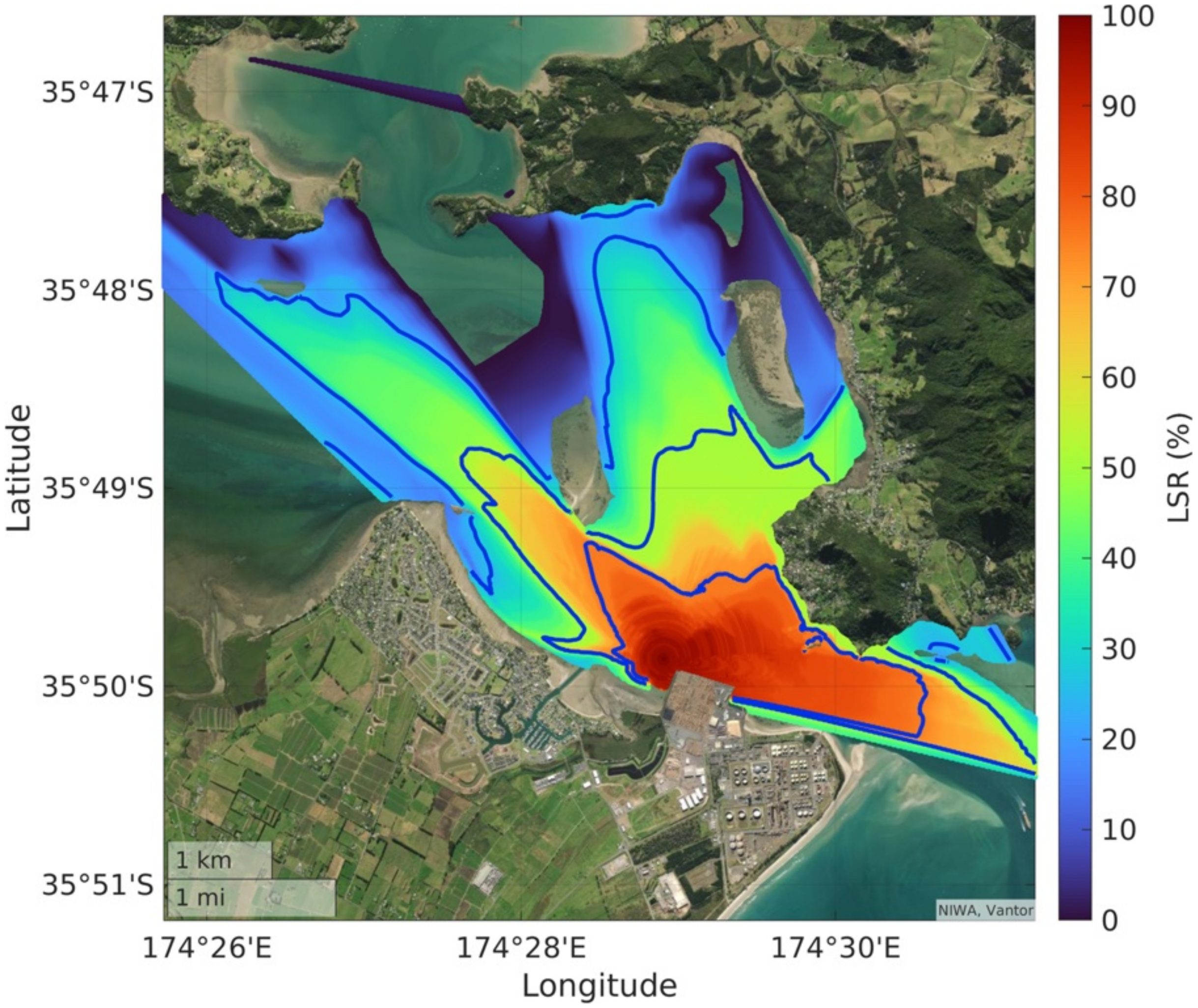


Figure 50 Map showing the listening space reductions (%) for OW pinnipeds during the mitigated (with a confined bubble curtain) percussive piling along the combi wall. The contours represent LSRs of 75%, 50% and 25% LSRs..

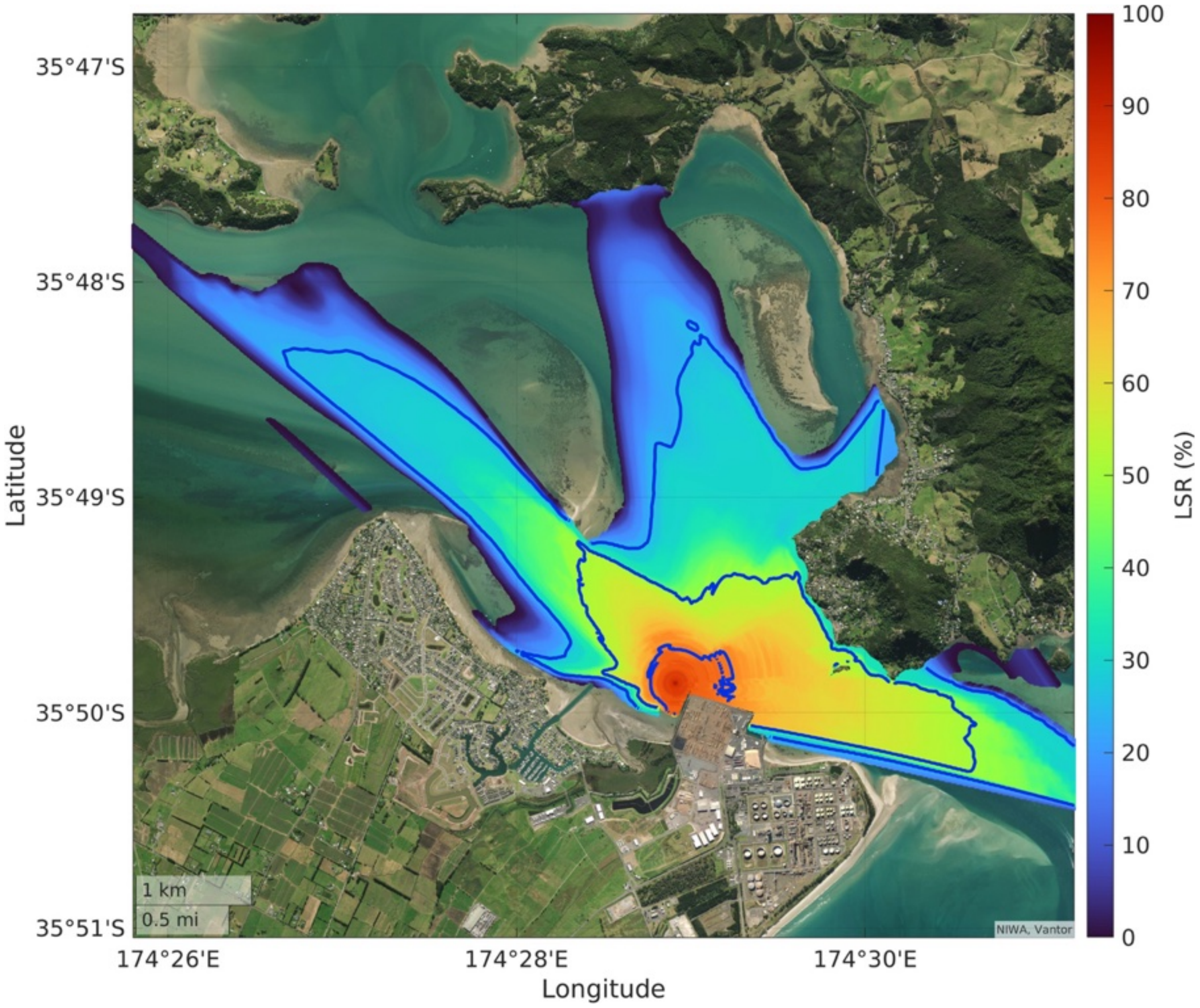


Figure 51 Map showing the listening space reductions (%) for kororā/little penguins during the mitigated (with a confined bubble curtain) percussive piling along the combi wall. The contours represent LSRs of 75%, 50% and 25% LSRs..

Appendix G Dredging noise effects plots: TSHD

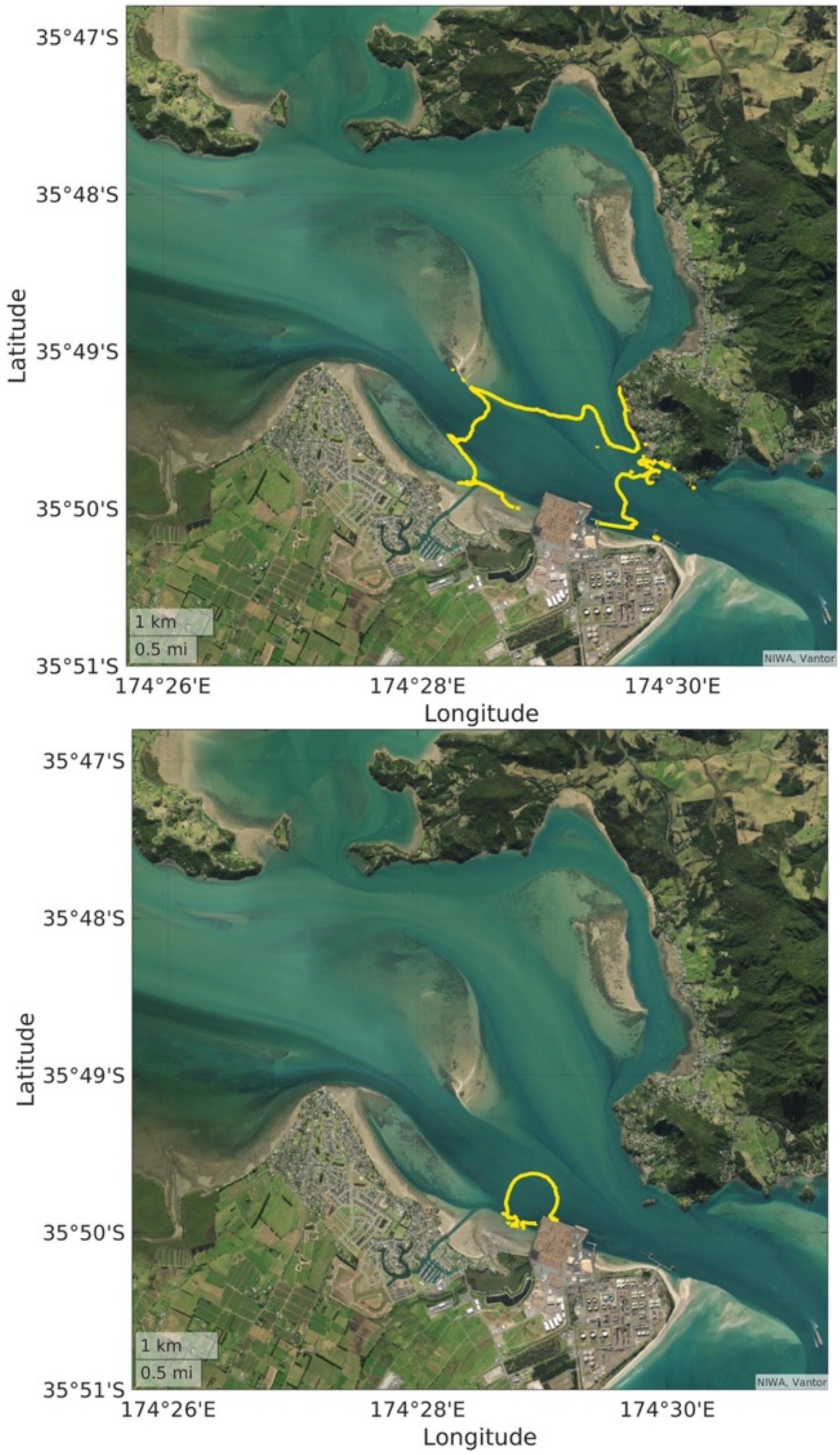


Figure 52 Contours showing the ranges within which the potential onset of behavioural responses may occur in cetaceans: the top panel shows the 120 dB contour, while the bottom panel shows the 130 dB contour.

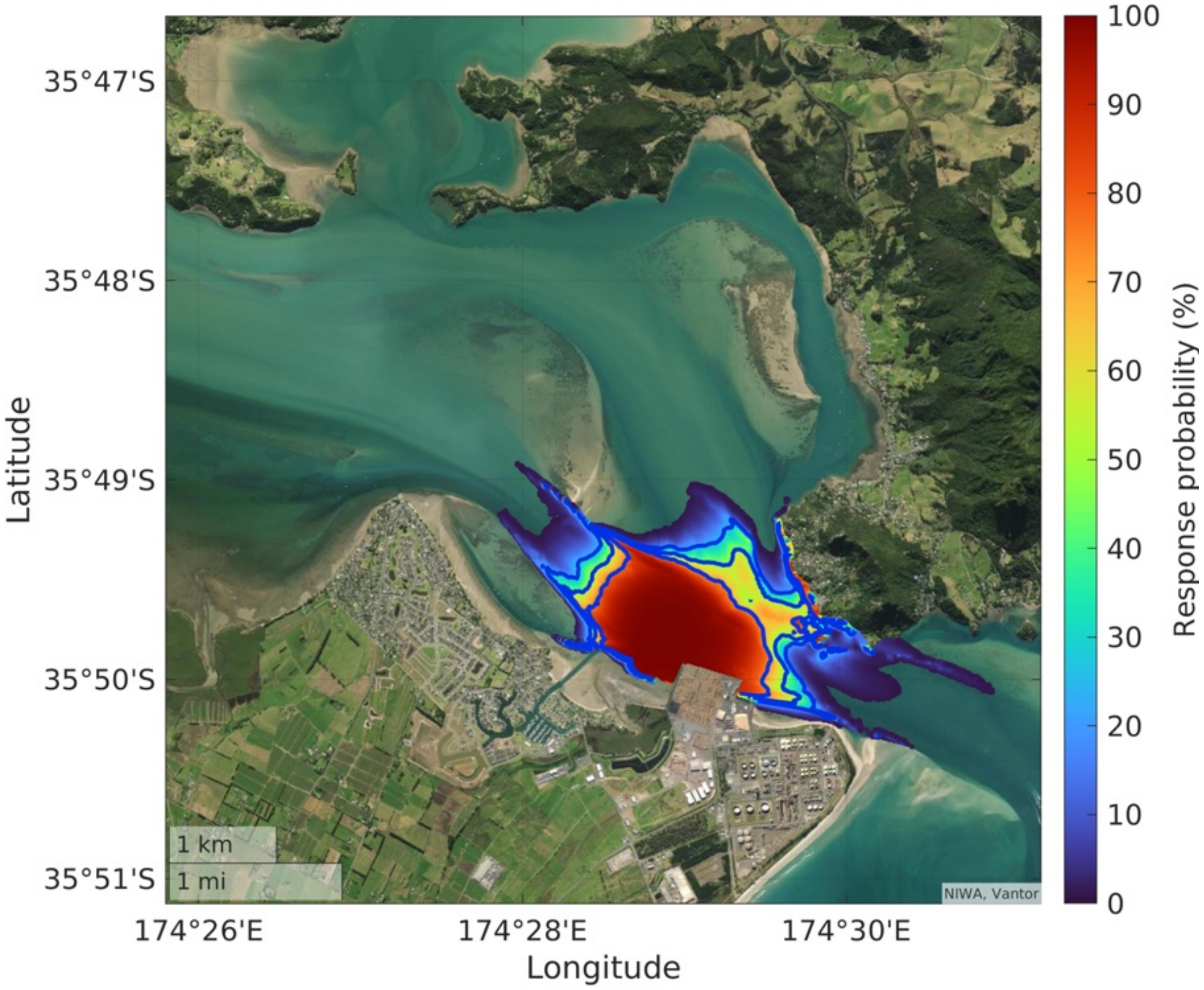


Figure 53 Low behavioural response risk for large whales (mysticetes) within Whangārei Harbour entrance from a medium sized trail-suction hopper dredger (TSHD).

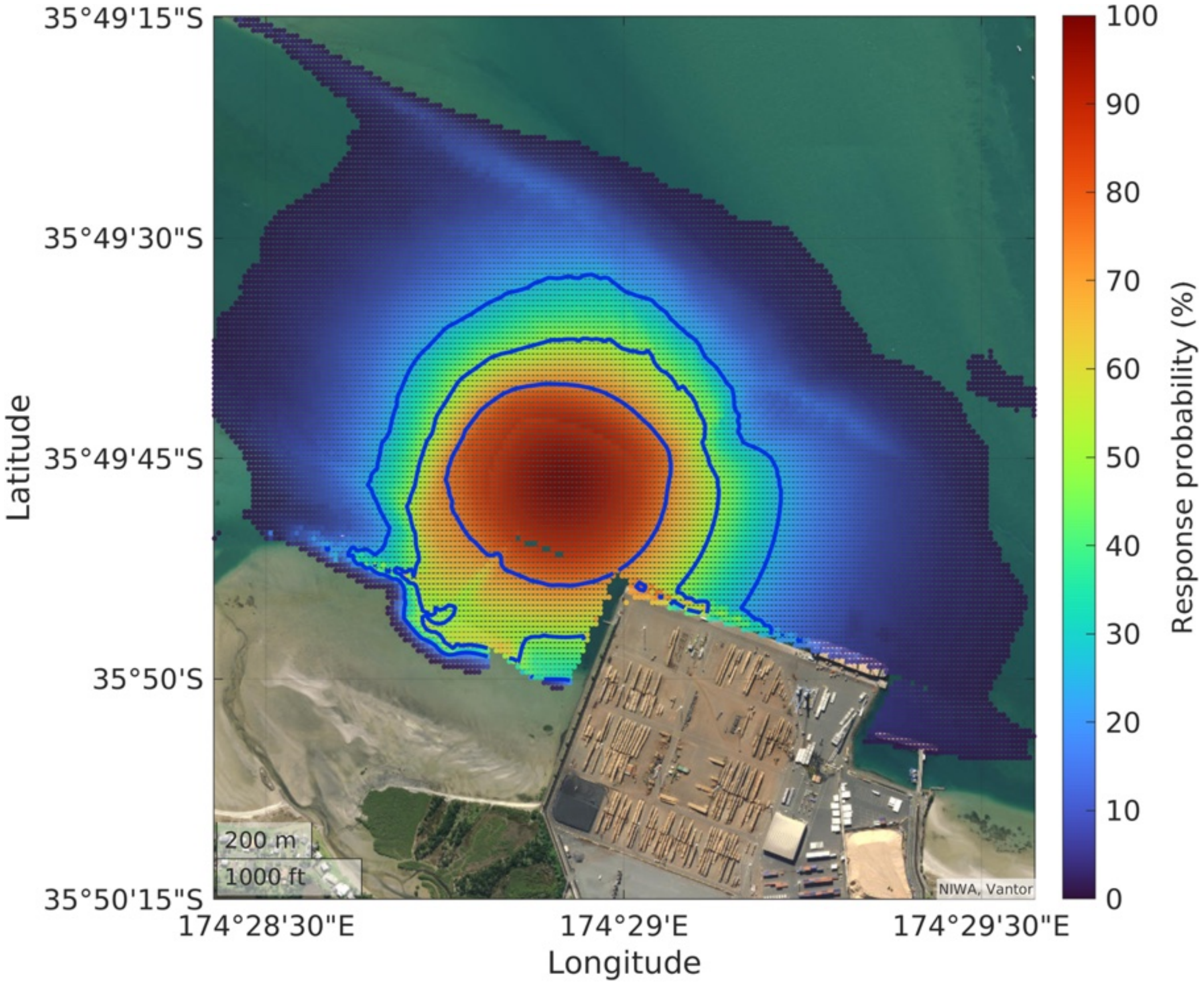


Figure 54 Low behavioural response risk for dolphin species (delphinids) within Whangārei Harbour entrance from a medium sized trail-suction hopper dredger (TSHD).

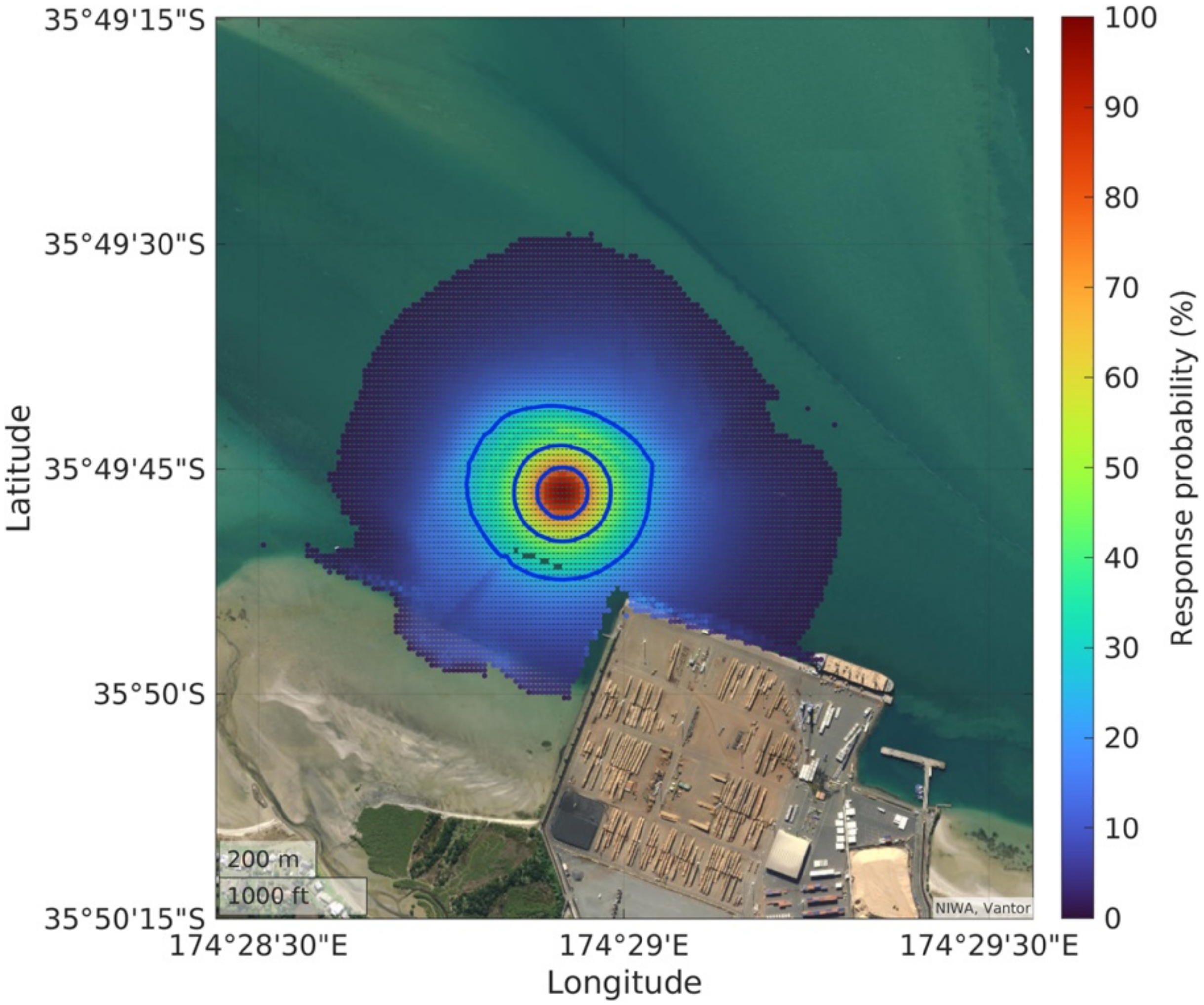


Figure 55 Moderate behavioural response risk for dolphin species (delphinids) within Whangārei Harbour entrance from a medium sized TSHD.

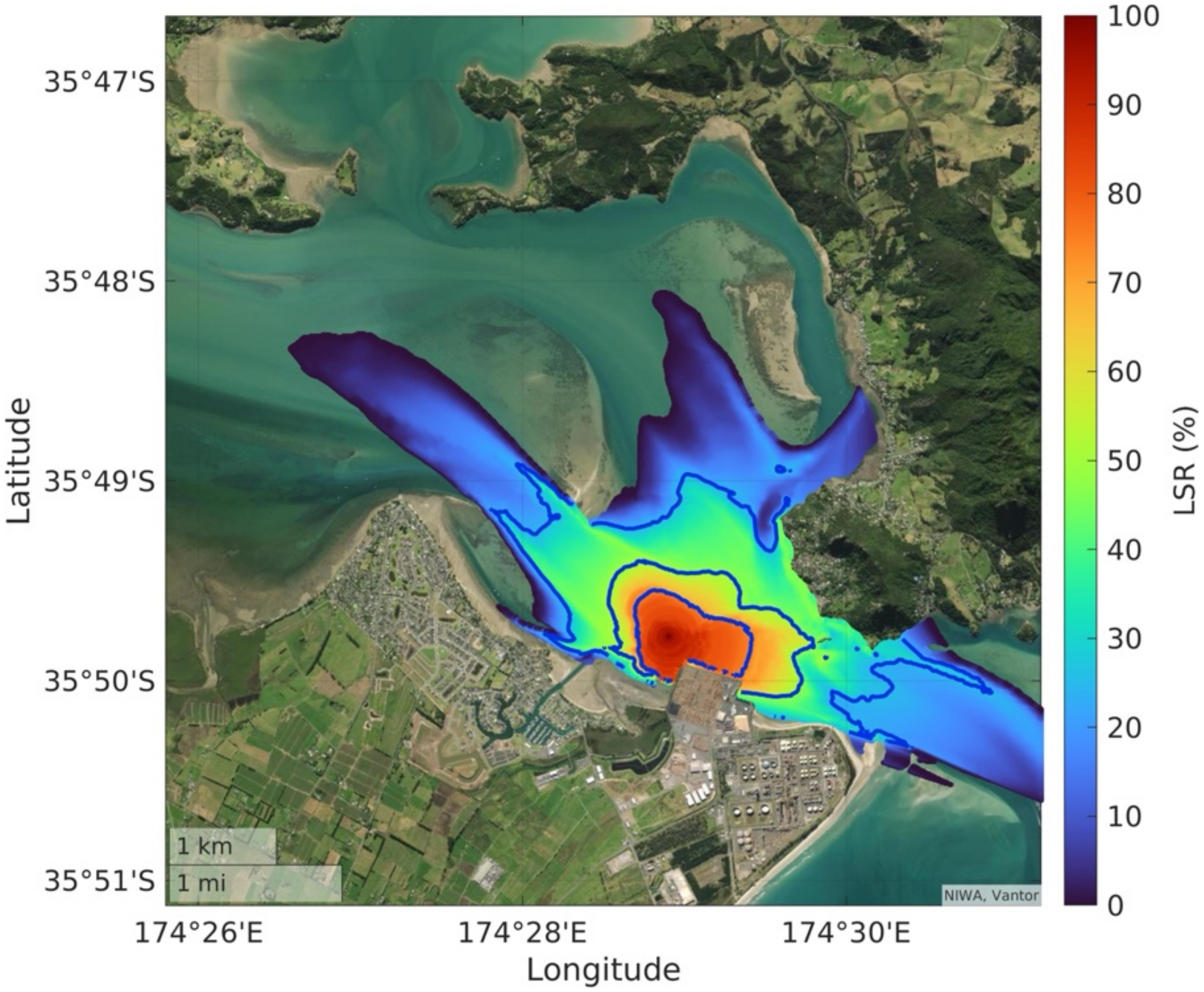


Figure 56 Map showing the listening space reductions (%) for LF cetaceans from a medium sized TSHD in extraction mode (draghead down, pumps on and under power). The contours represent LSRs of 75%, 50% and 25% LSRs.

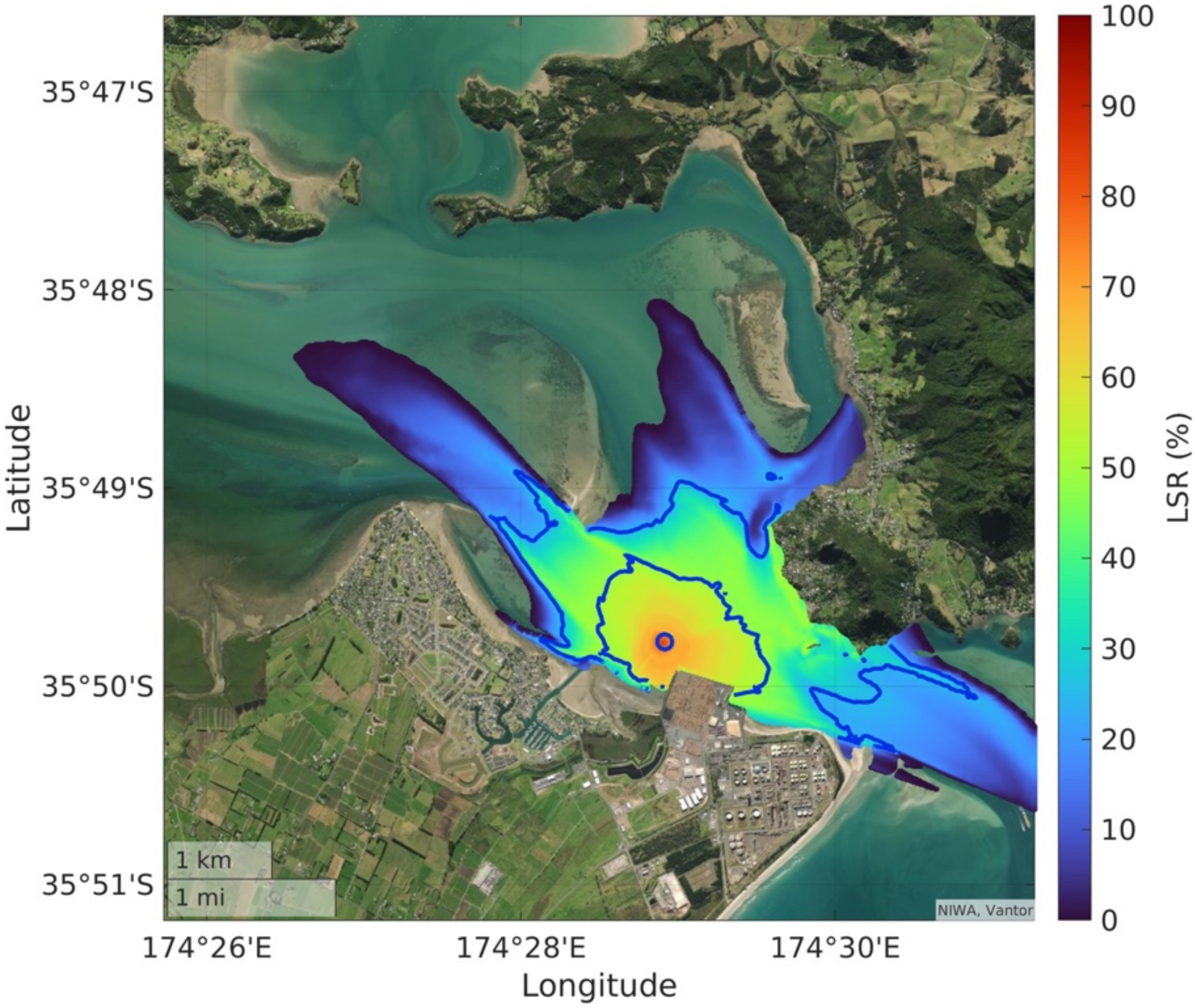


Figure 57 Map showing the listening space reductions (%) for HF cetaceans from a medium sized TSHD in extraction mode (draghead down, pumps on and under power). The contours represent LSRs of 75%, 50% and 25% LSRs.

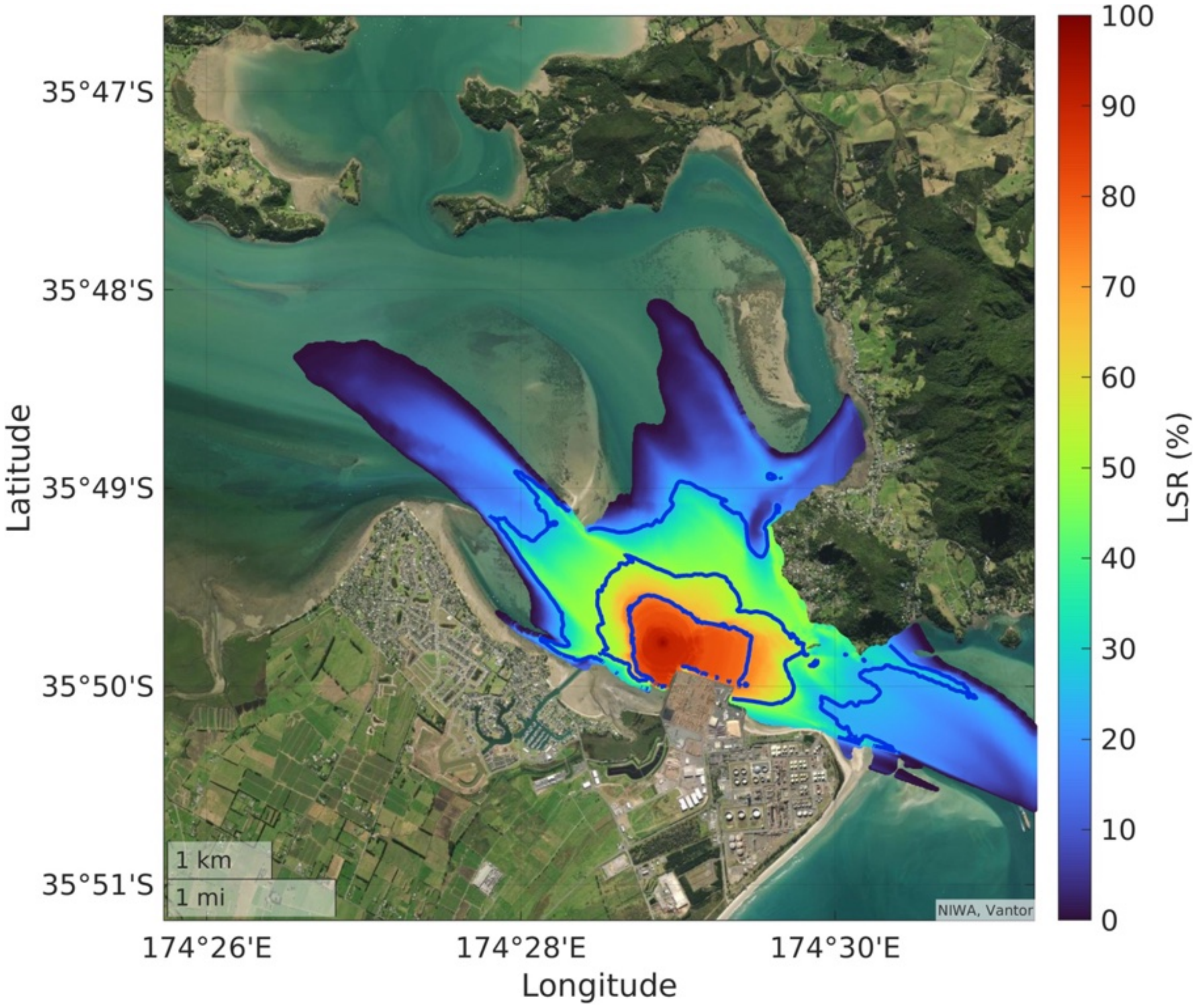


Figure 58 Map showing the listening space reductions (%) for PW pinnipeds from a medium sized TSHD in extraction mode (draghead down, pumps on and under power). The contours represent LSRs of 75%, 50% and 25% LSRs.

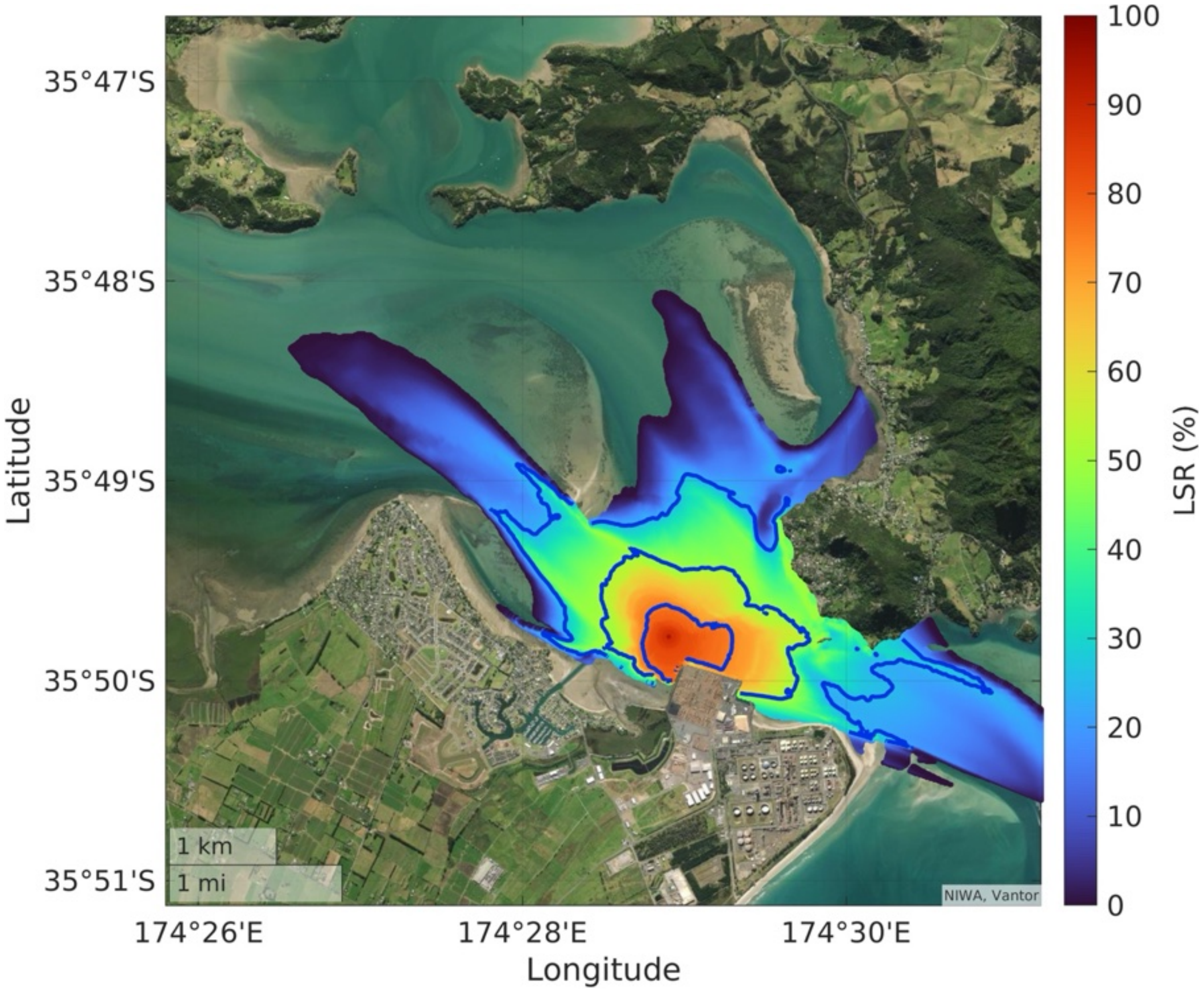


Figure 59 Map showing the listening space reductions (%) for OW pinnipeds from a medium sized TSHD in extraction mode (draghead down, pumps on and under power). The contours represent LSRs of 75%, 50% and 25% LSRs.

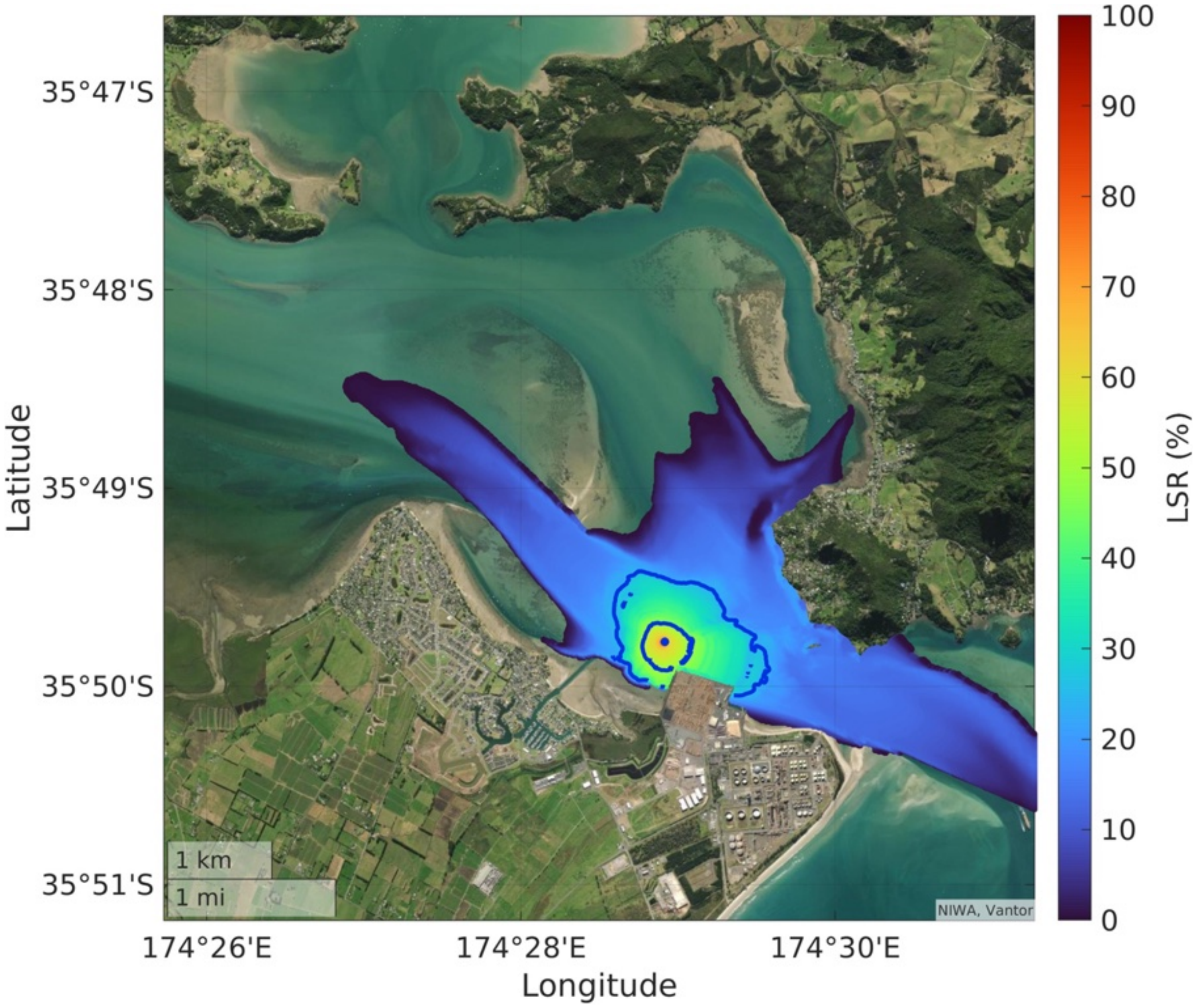


Figure 60 Map showing the listening space reductions (%) for kororā/little penguins from a medium sized TSHD in extraction mode (draghead down, pumps on and under power). The contours represent LSRs of 75%, 50% and 25% LSRs.

Appendix H Dredging noise effects plots: CSD

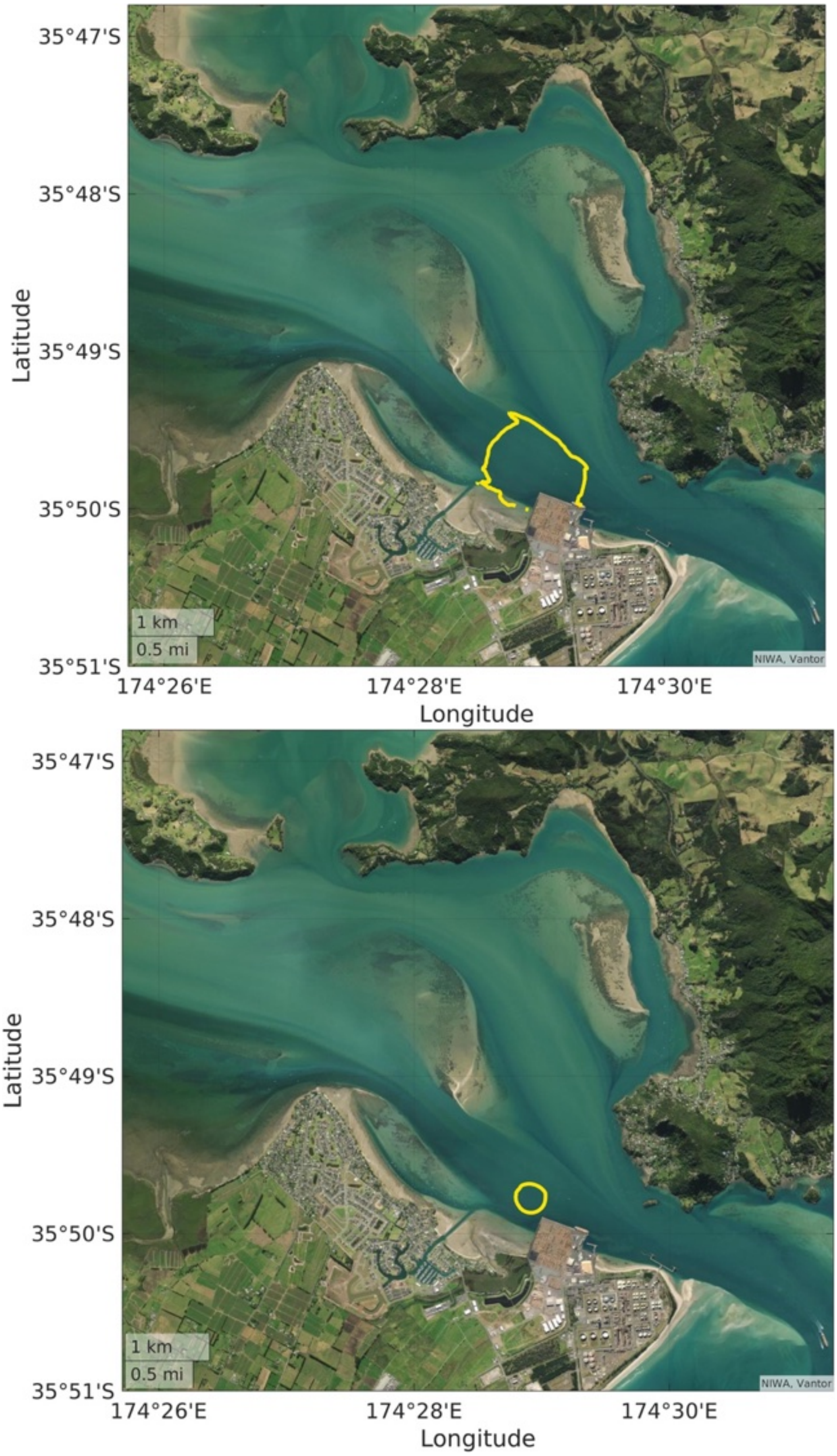


Figure 61 Contours showing the ranges within which the potential onset of behavioural responses may occur in cetaceans: the top panel shows the 120 dB contour, while the bottom panel shows the 130 dB contour.

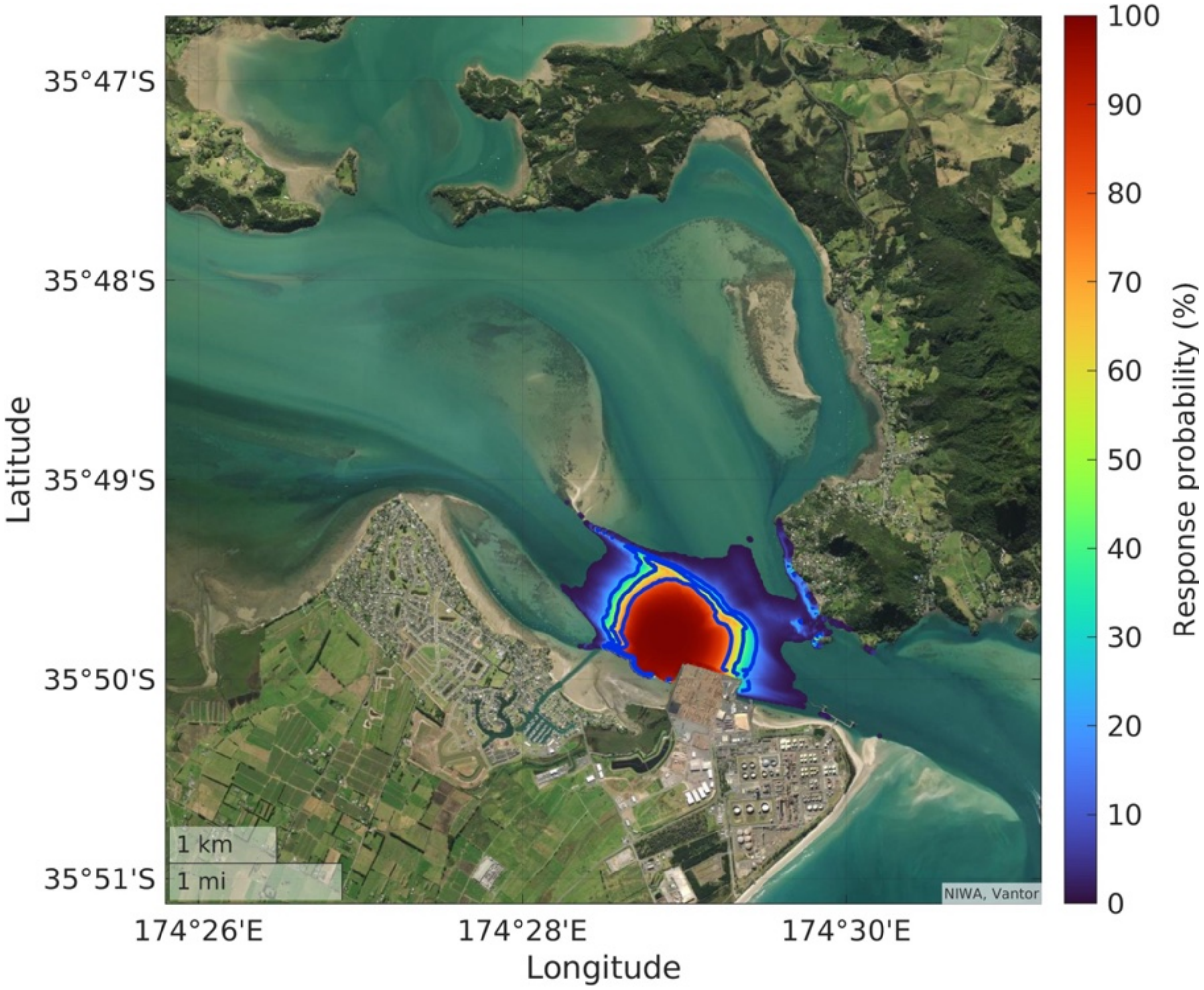


Figure 62 Low behavioural response risk for large whales (mysticetes) within Whangārei Harbour entrance from a large cutter-suction dredger (CSD).

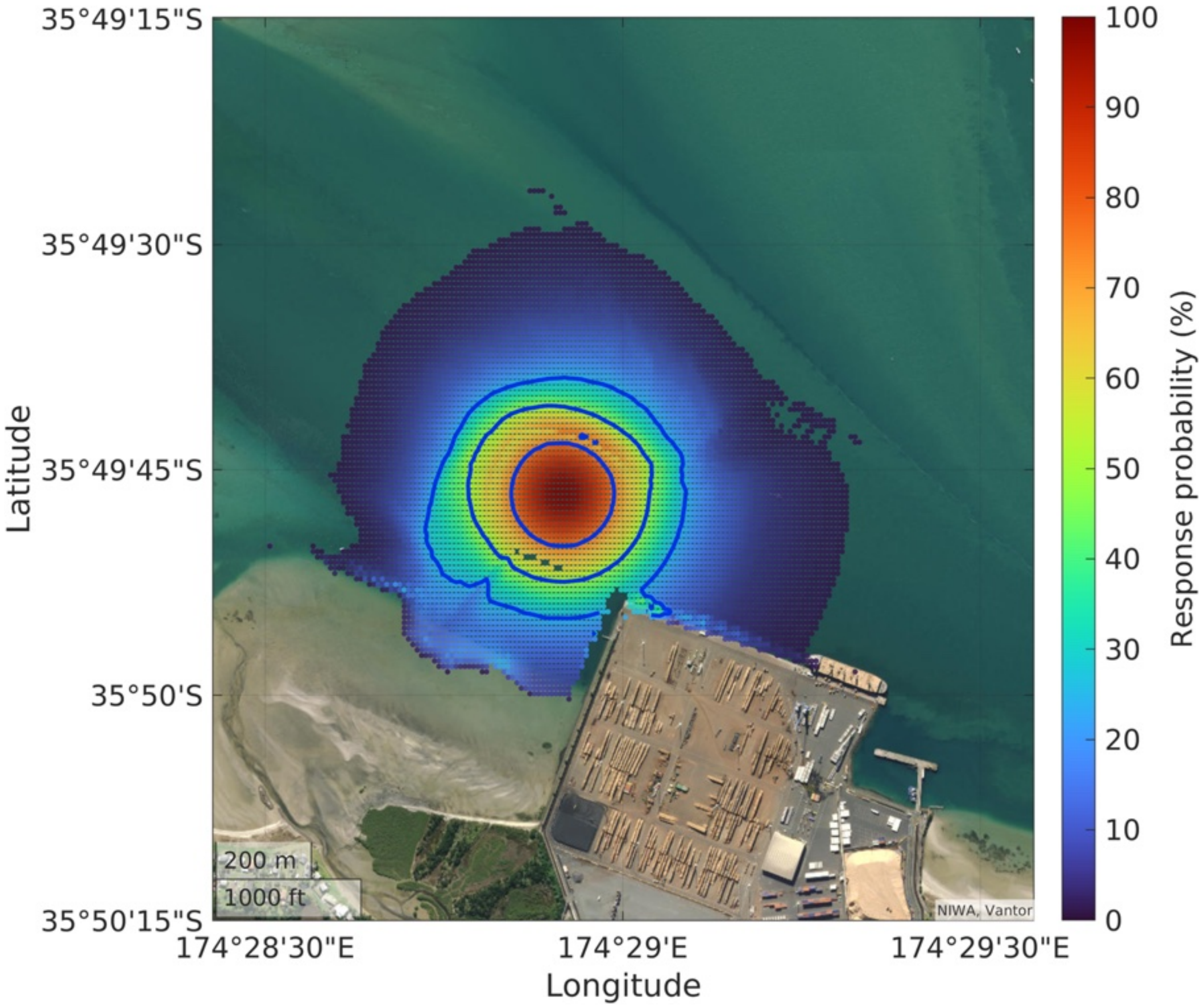


Figure 63 Low behavioural response risk for dolphin species (delphinids) within Whangārei Harbour entrance from a large cutter-suction dredger (CSD).

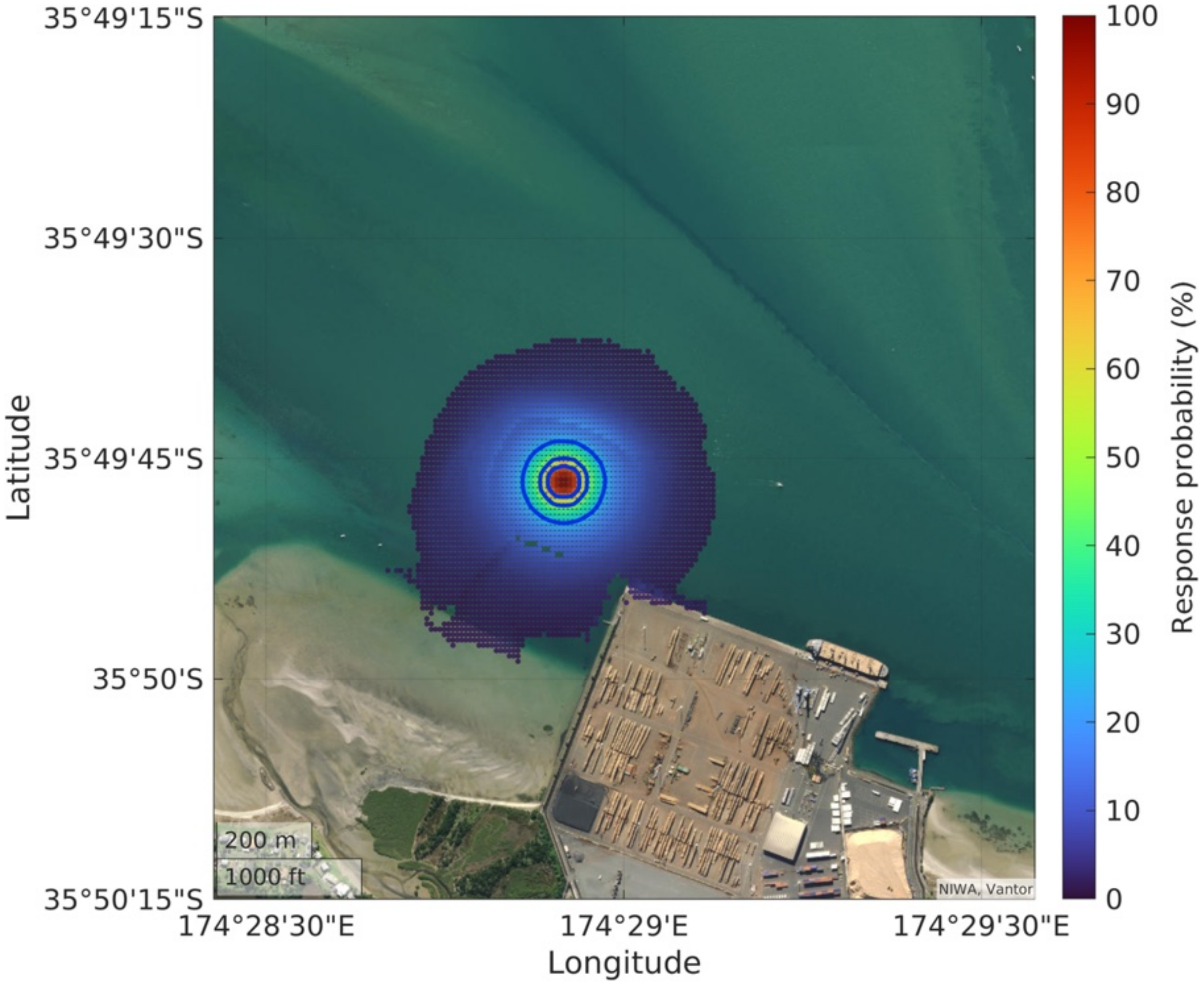


Figure 64 Moderate behavioural response risk for dolphin species (delphinids) within Whangārei Harbour entrance from a large cutter-suction dredger (CSD).

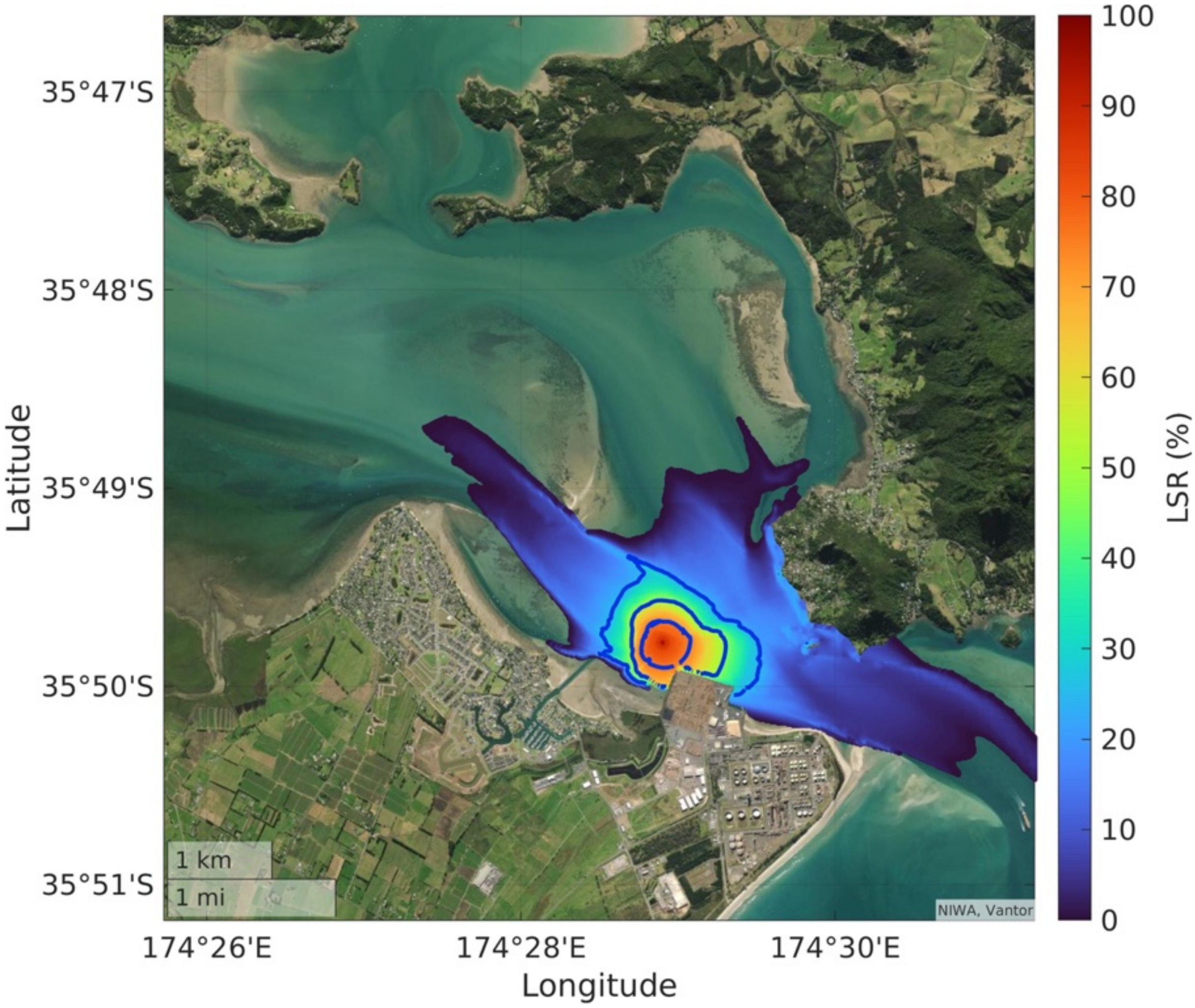


Figure 65 Map showing the listening space reductions (%) for LF cetaceans from a large CSD. The contours represent LSRs of 75%, 50% and 25% LSRs.

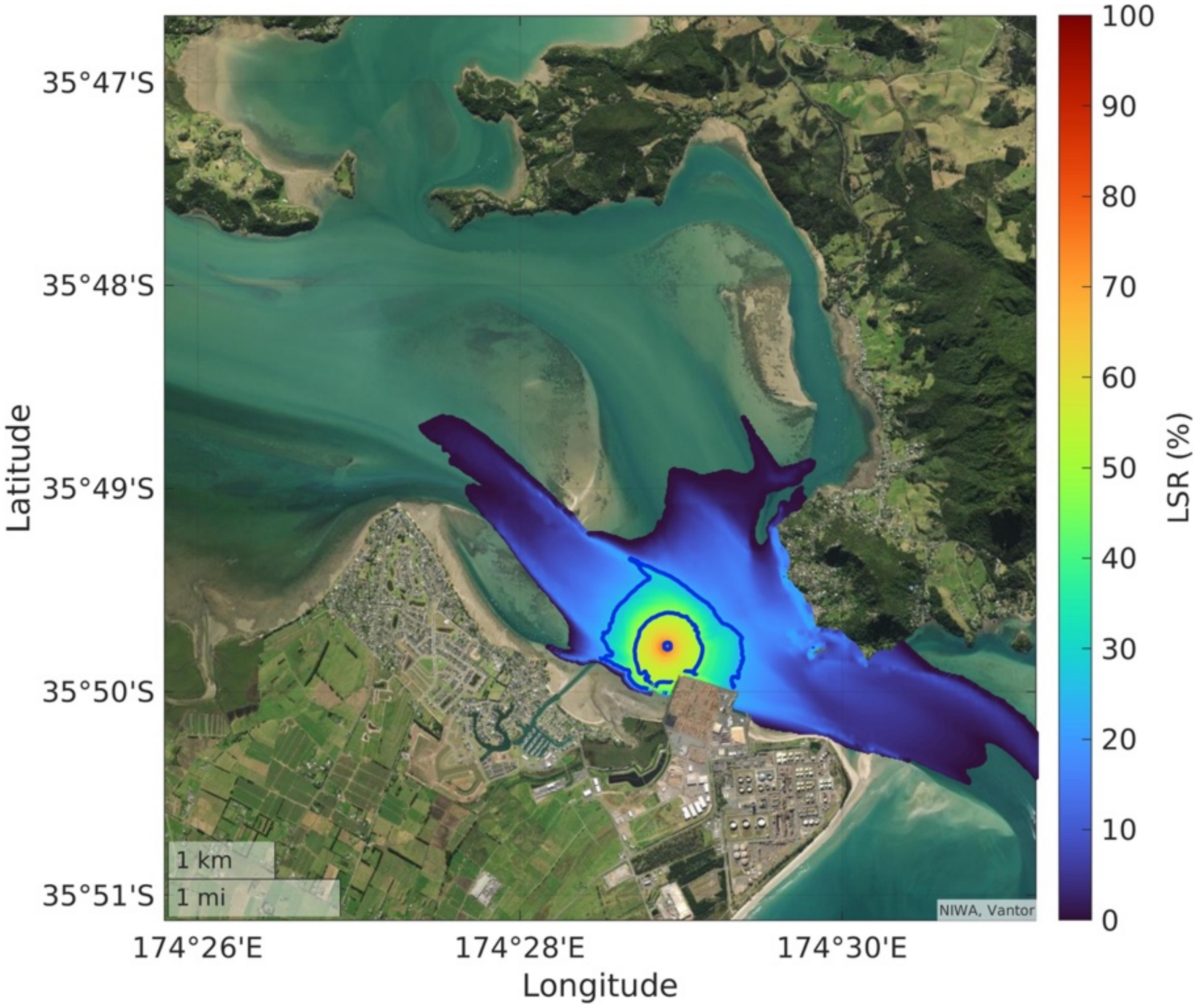


Figure 66 Map showing the listening space reductions (%) for HF cetaceans from a large CSD. The contours represent LSRs of 75%, 50% and 25% LSRs.

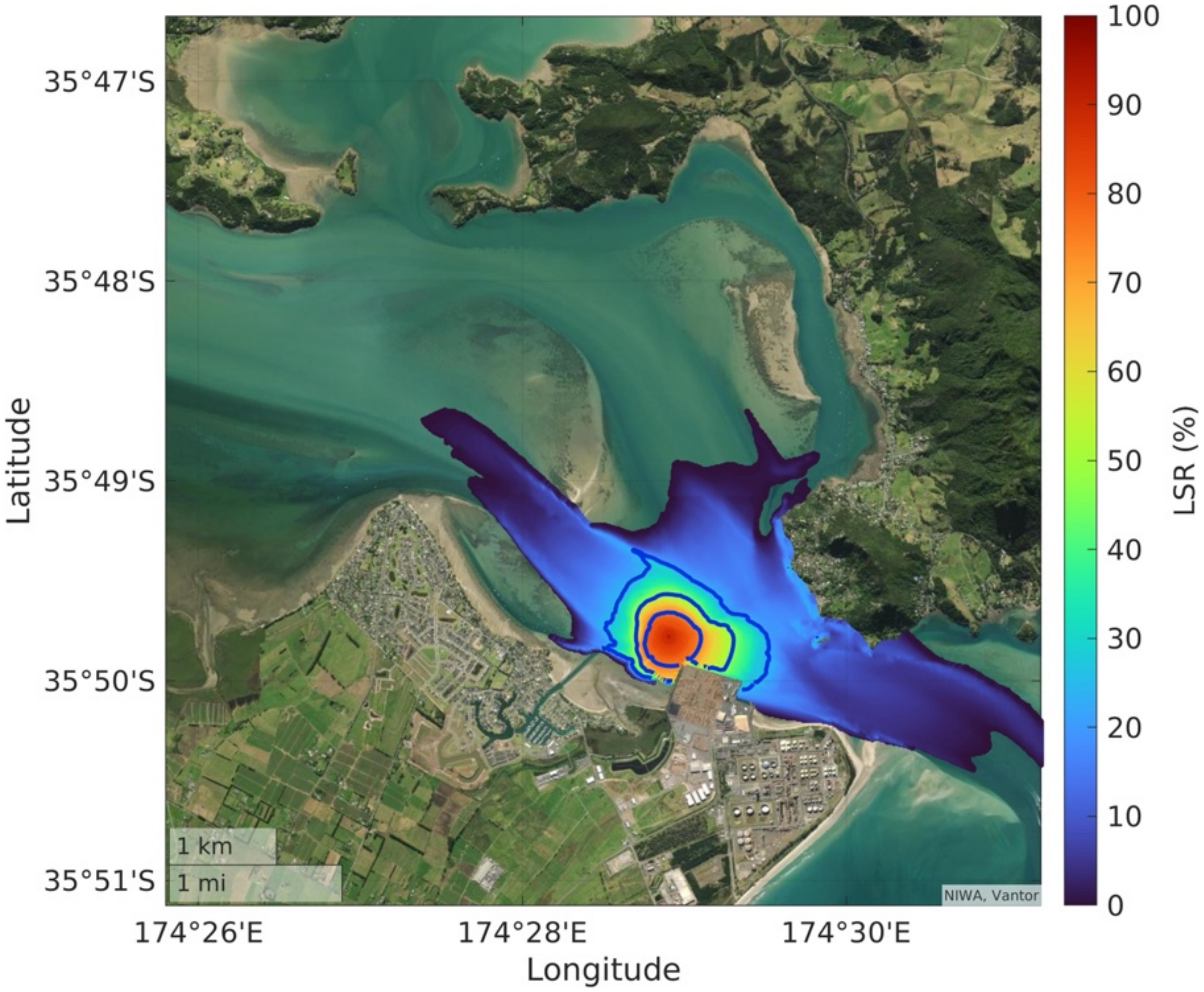


Figure 67 Map showing the listening space reductions (%) for PW pinnipeds from a large CSD. The contours represent LSRs of 75%, 50% and 25% LSRs.

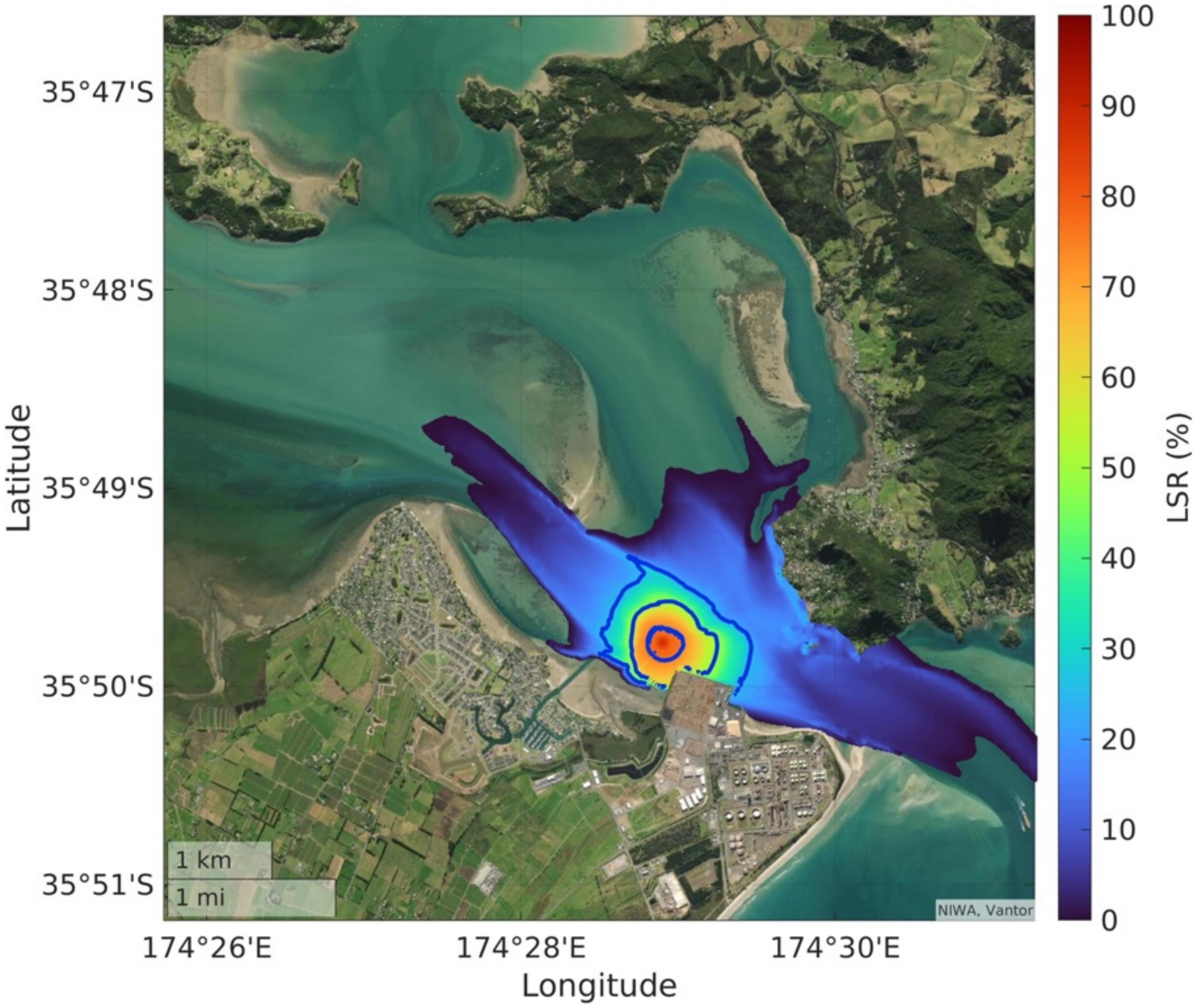


Figure 68 Map showing the listening space reductions (%) for OW pinnipeds from a large CSD. The contours represent LSRs of 75%, 50% and 25% LSRs.

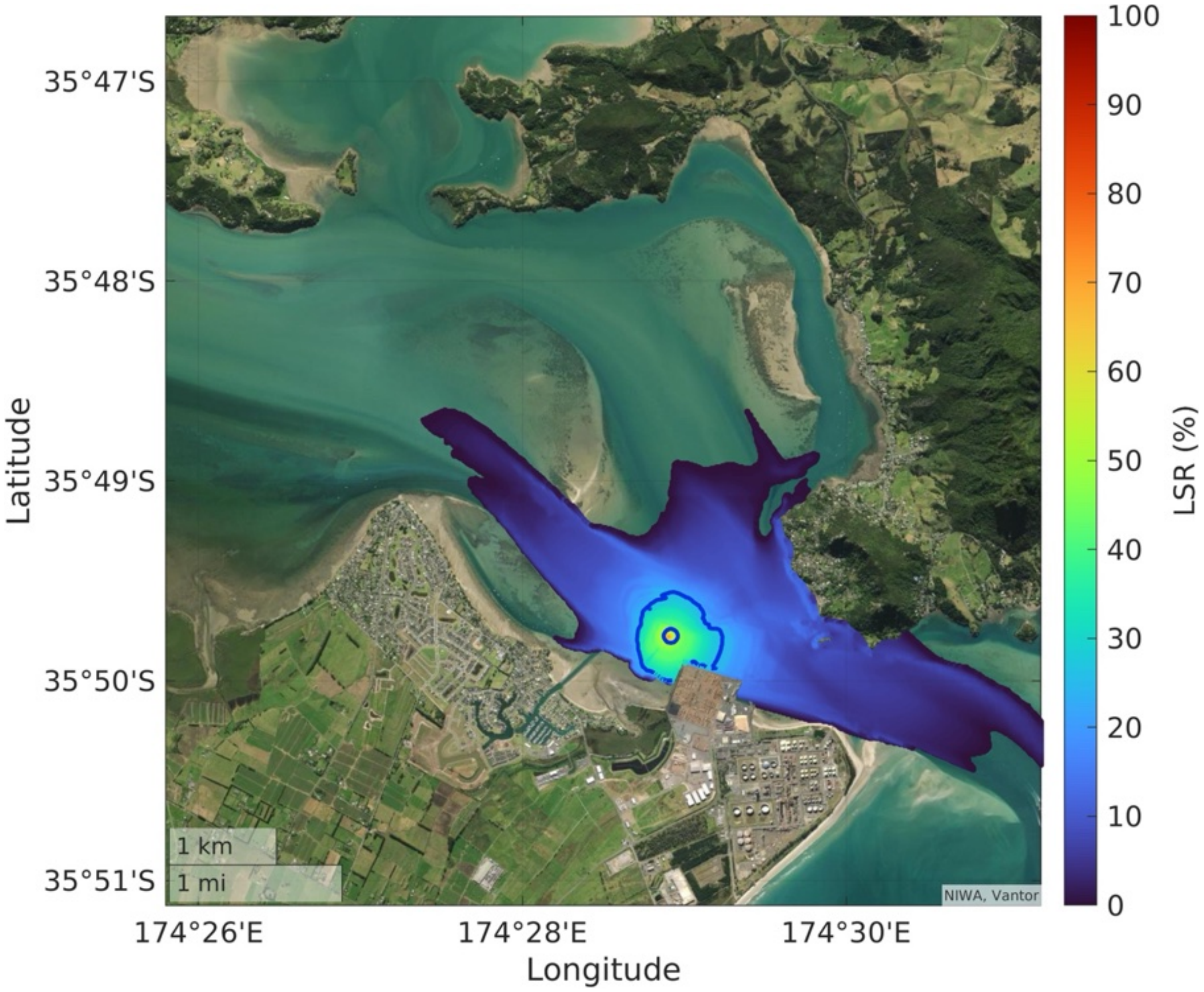


Figure 69 Map showing the listening space reductions (%) for kororā/little penguins from a large CSD. The contours represent LSRs of 75%, 50% and 25% LSRs.

Appendix I Dredging noise effects plots: BHD

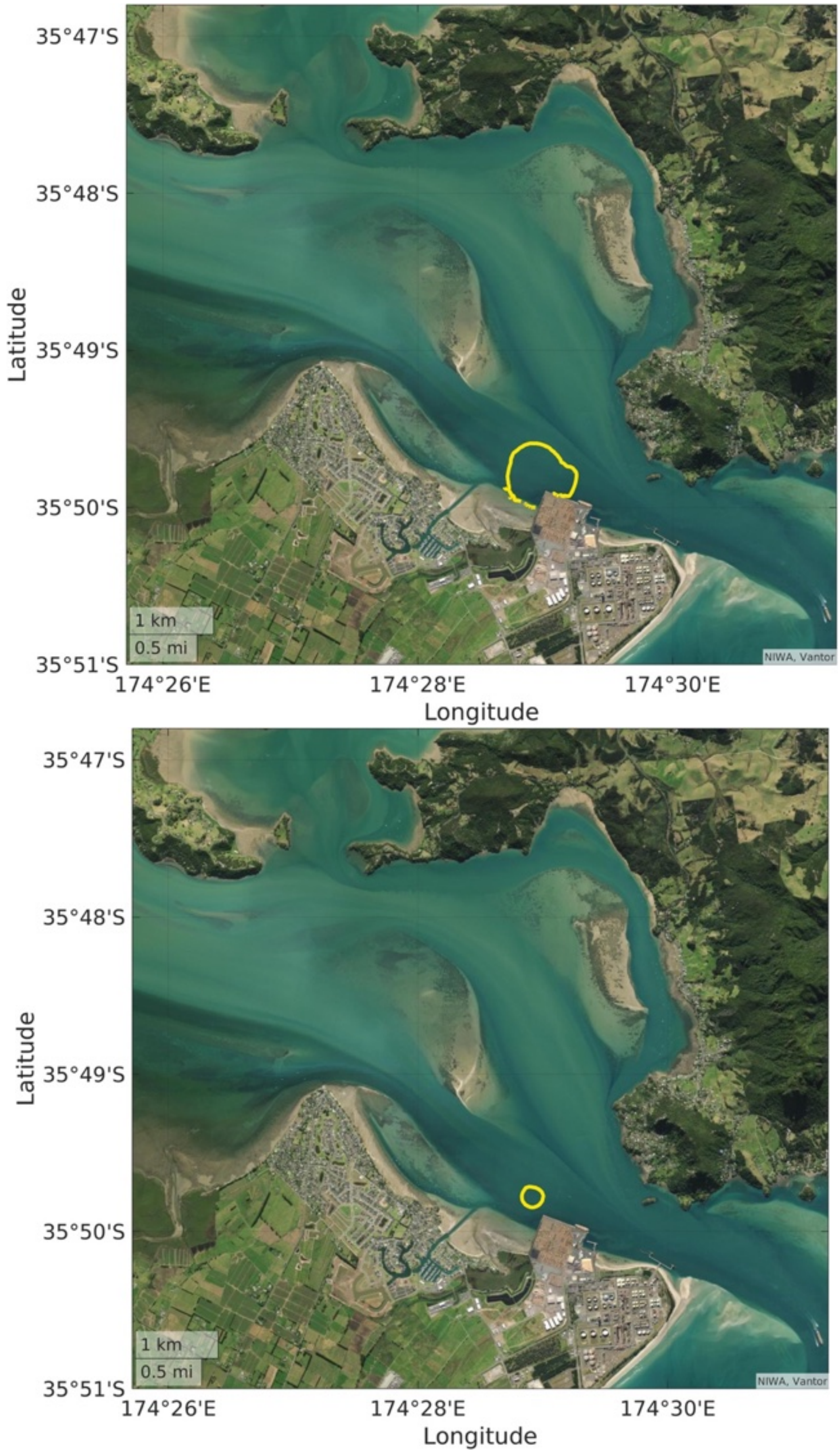


Figure 70 Contours showing the ranges within which the potential onset of behavioural responses may occur in cetaceans: the top panel shows the 120 dB contour, while the bottom panel shows the 130 dB contour.

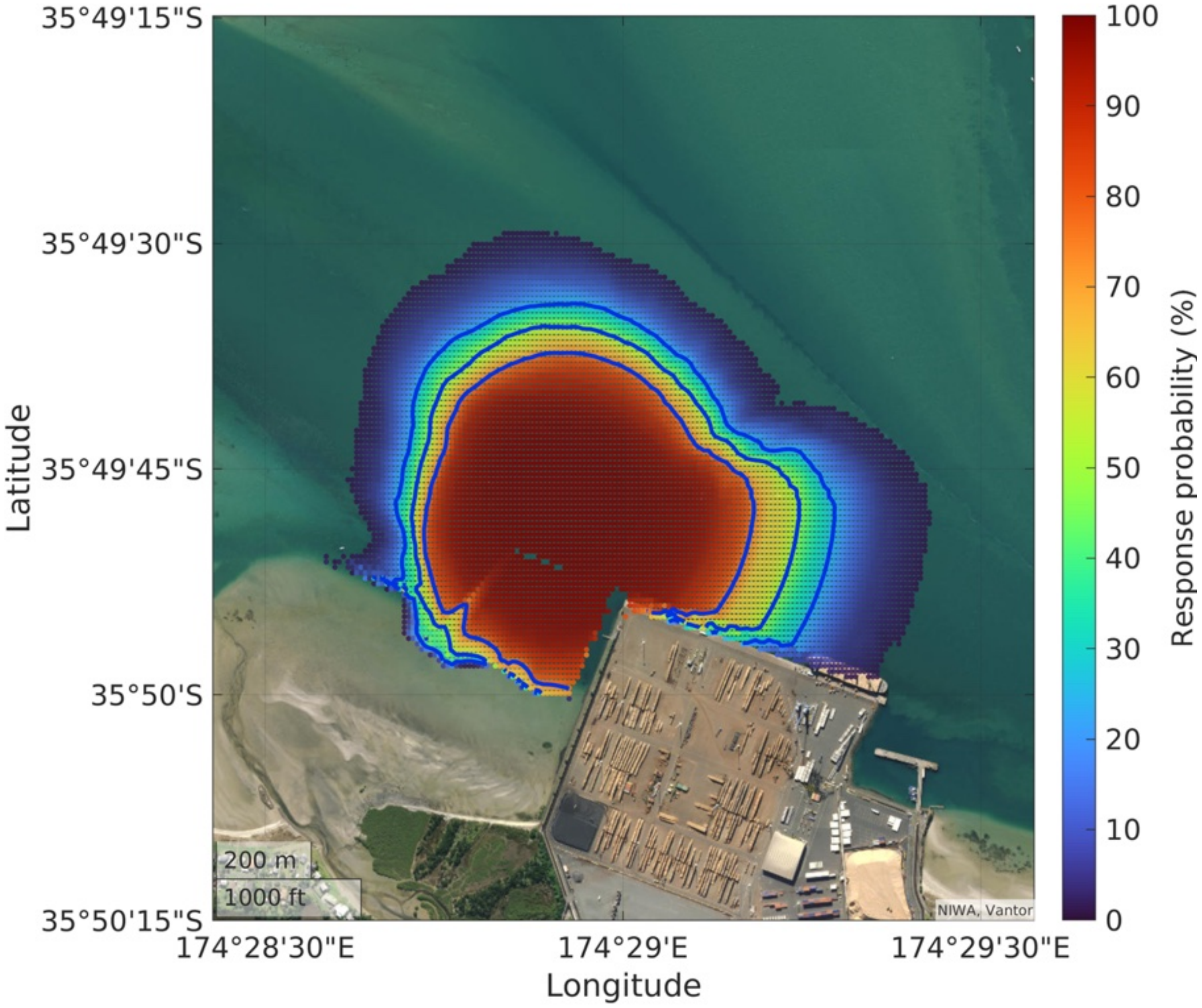


Figure 71 Low behavioural response risk for large whales (mysticetes) within Whangārei Harbour entrance from a large backhoe dredger (BHD).

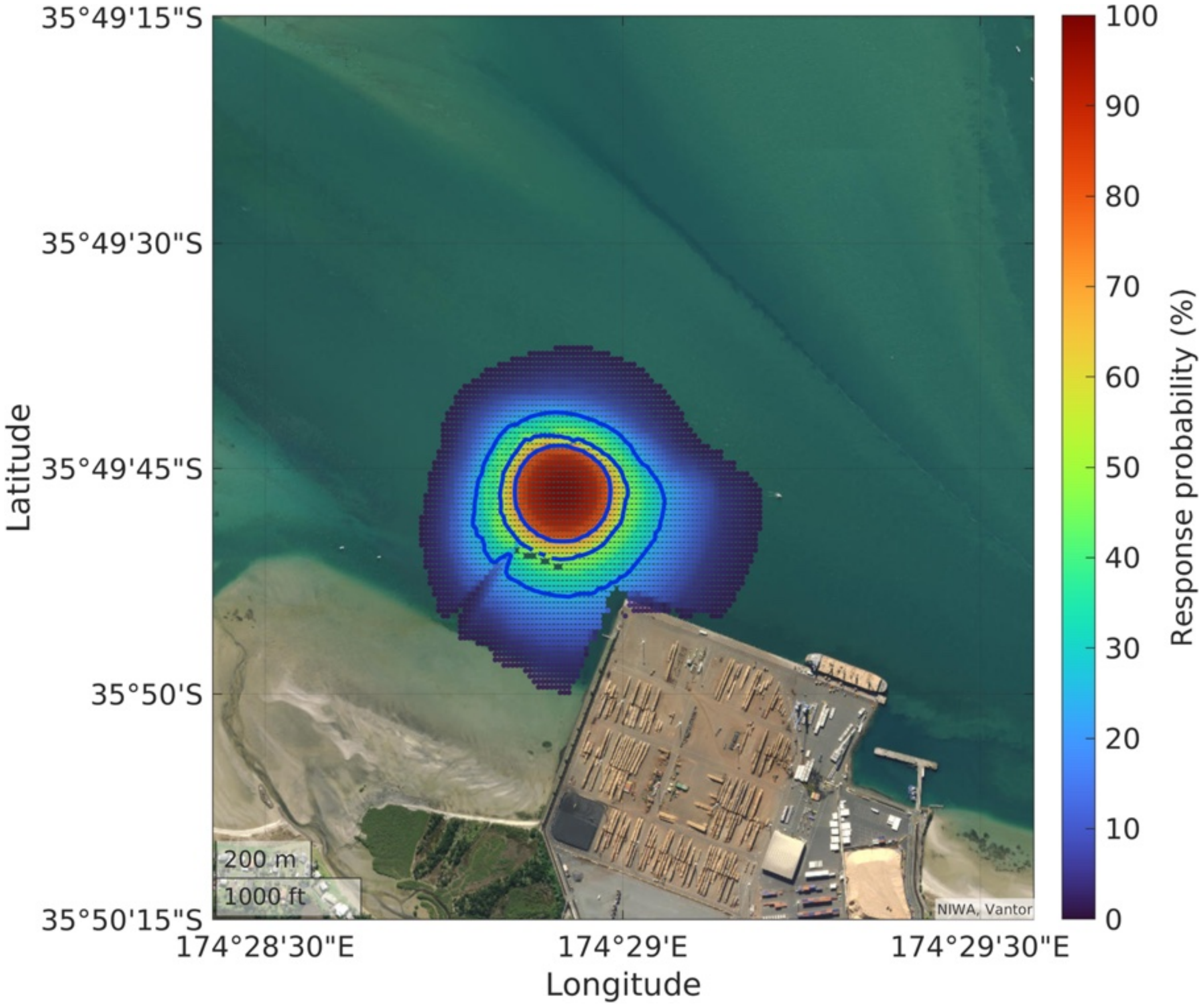


Figure 72 Low behavioural response risk for dolphin species (delphinds) within Whangārei Harbour entrance from a large backhoe dredger (BHD).

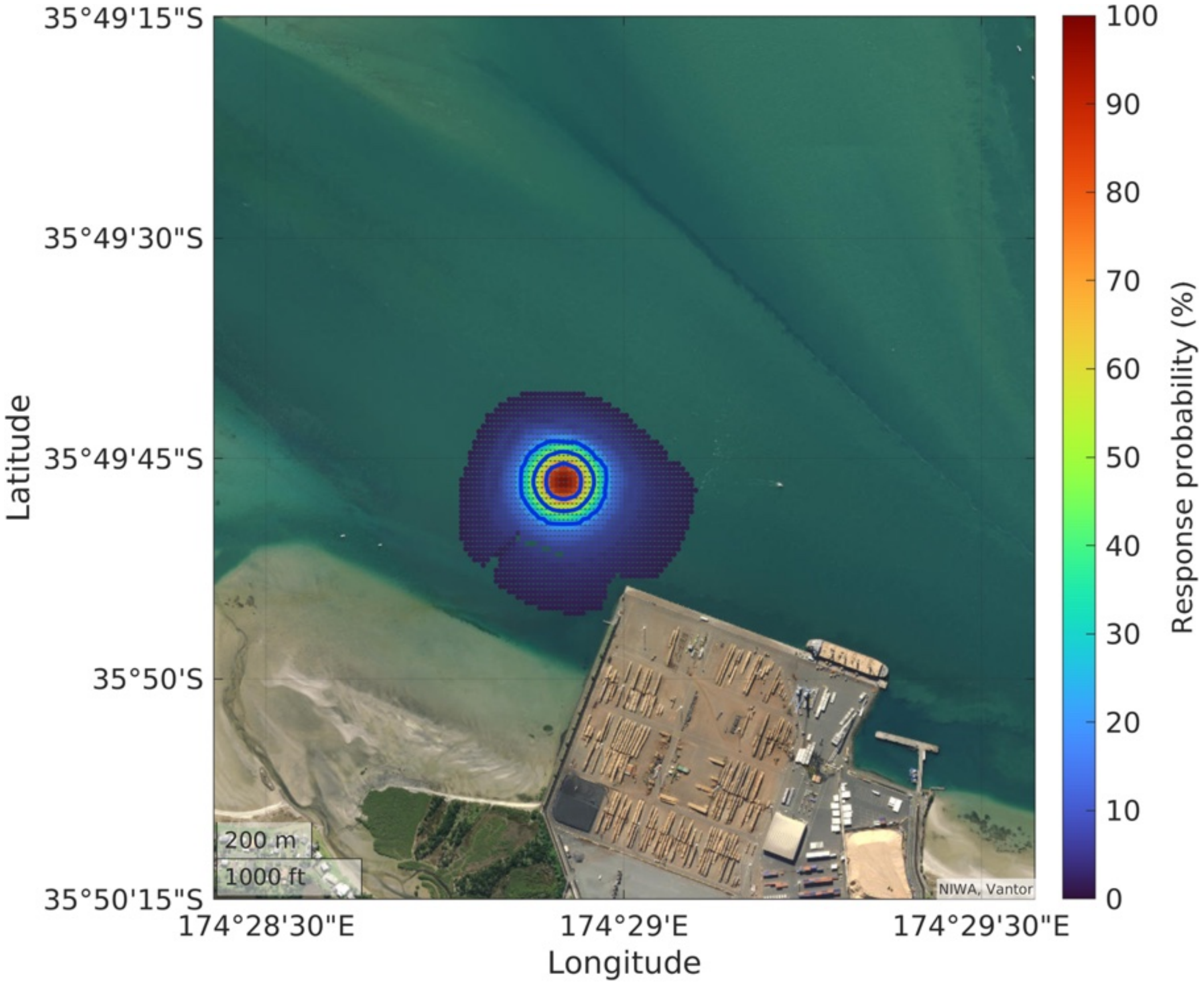


Figure 73 Moderate behavioural response risk for dolphin species (delphinds) within Whangārei Harbour entrance from a large backhoe dredger (BHD).

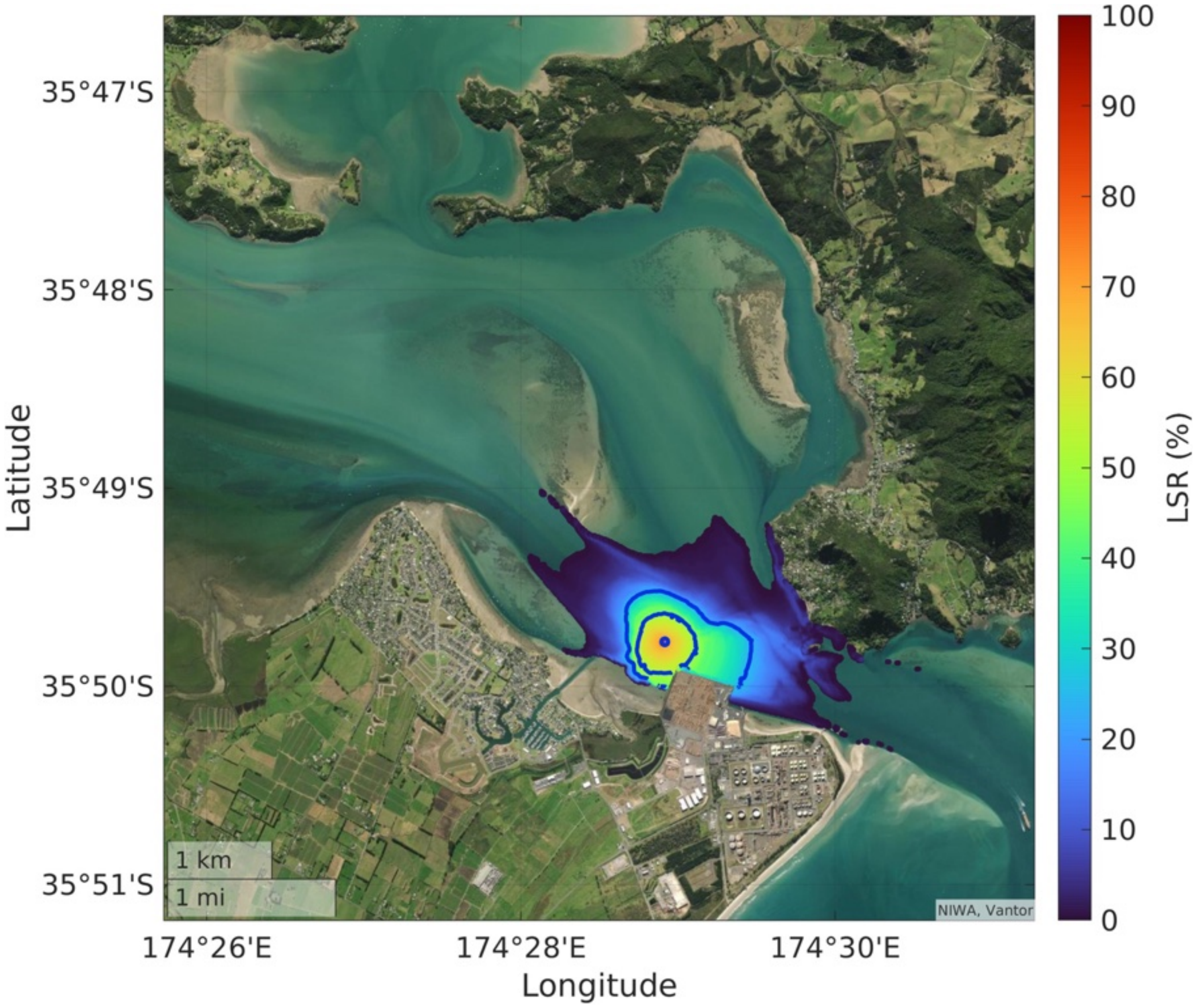


Figure 74 Map showing the listening space reductions (%) for LF cetaceans from a large BHD. The contours represent LSRs of 75%, 50% and 25% LSRs.

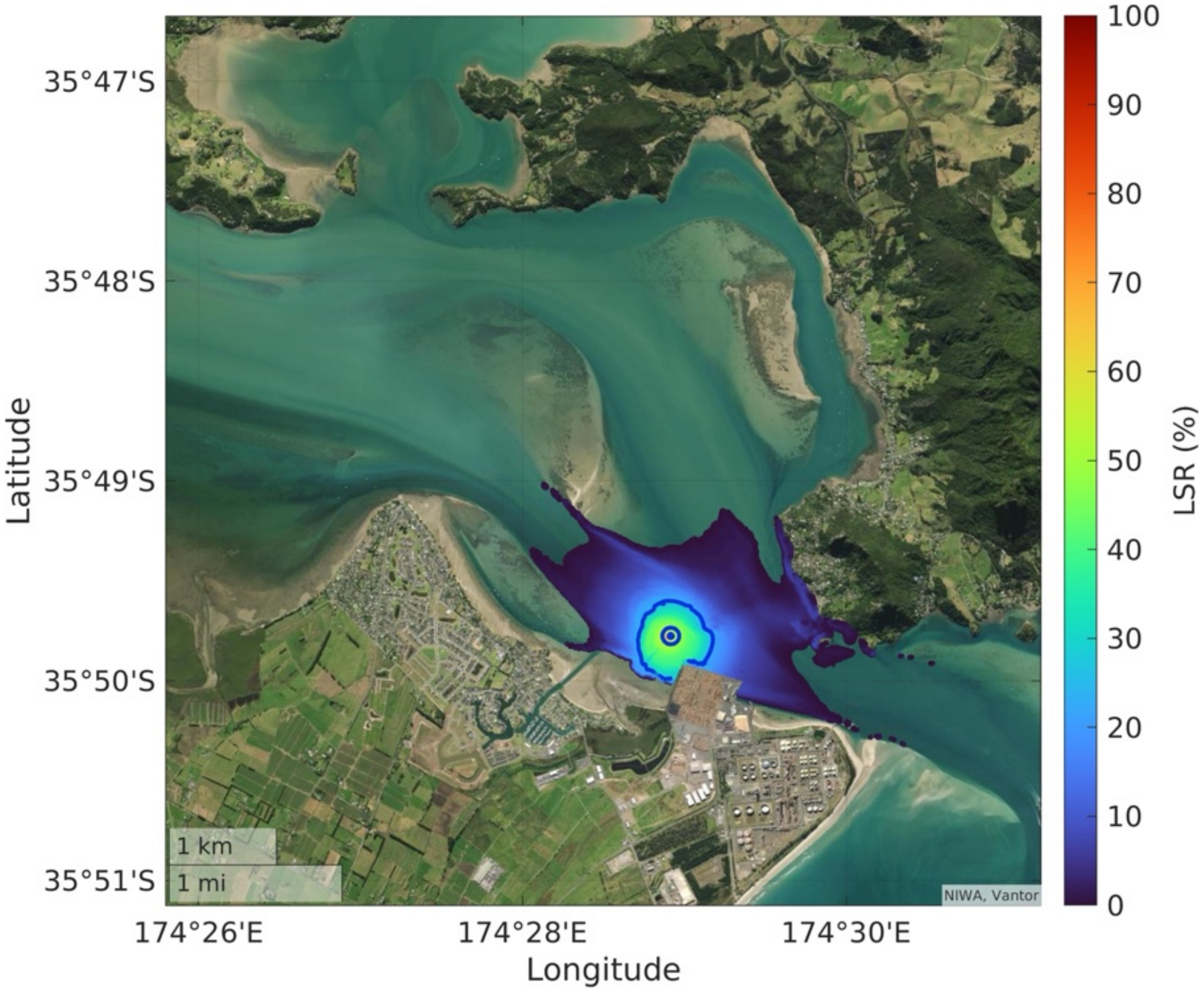


Figure 75 Map showing the listening space reductions (%) for HF cetaceans from a large BHD. The contours represent LSRs of 75%, 50% and 25% LSRs.

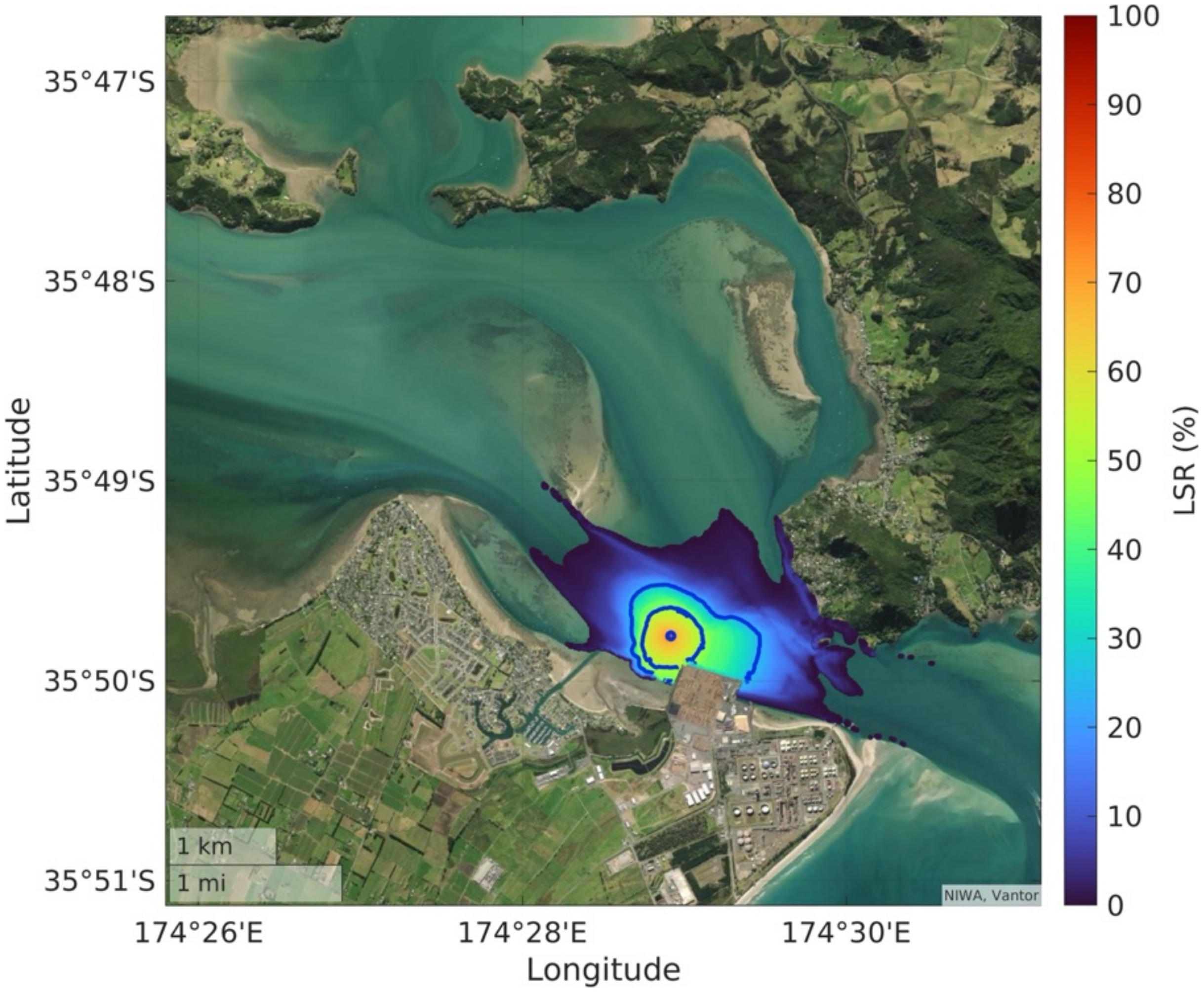


Figure 76 Map showing the listening space reductions (%) for PW pinnipeds from a large BHD. The contours represent LSRs of 75%, 50% and 25% LSRs.

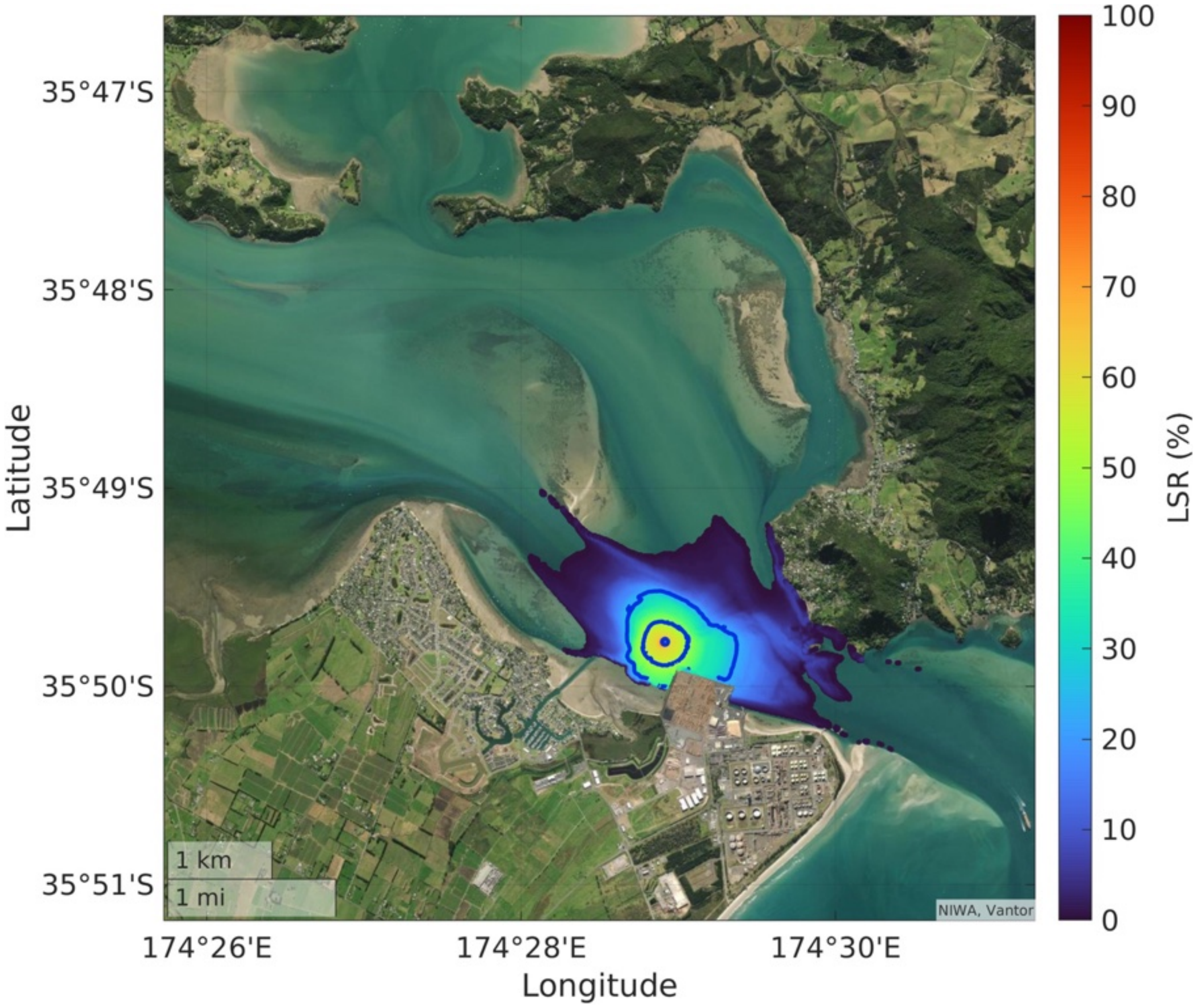


Figure 77 Map showing the listening space reductions (%) for OW pinnipeds from a large BHD. The contours represent LSRs of 75%, 50% and 25% LSRs.

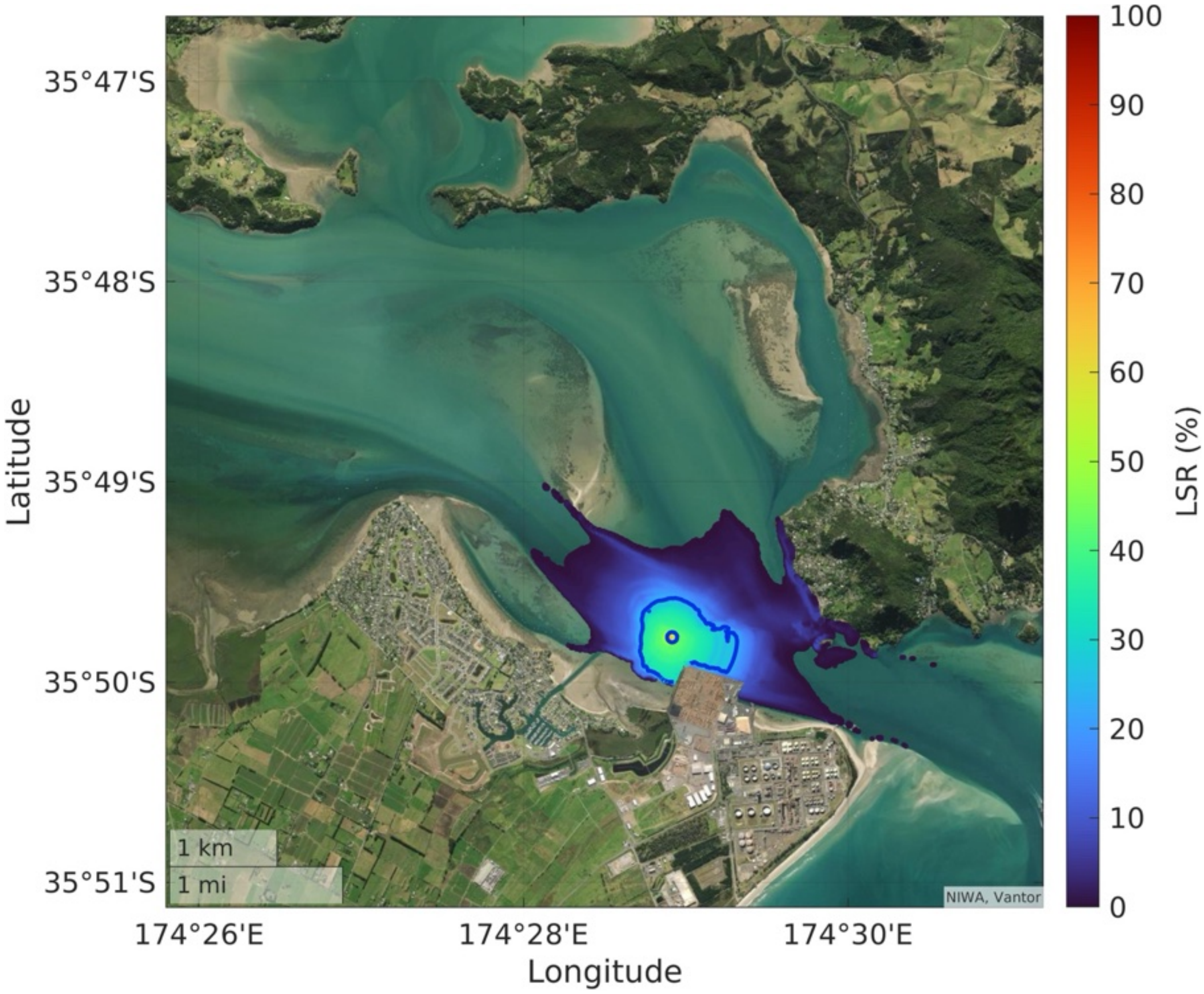


Figure 78 Map showing the listening space reductions (%) for kororā/little penguins from a large BHD. The contours represent LSRs of 75%, 50% and 25% LSRs.

Appendix J Vibro-core/borehole data sheets

Core-data showing the sediment type and depths used for locations V1 through V8. The locations match those from the figure below.

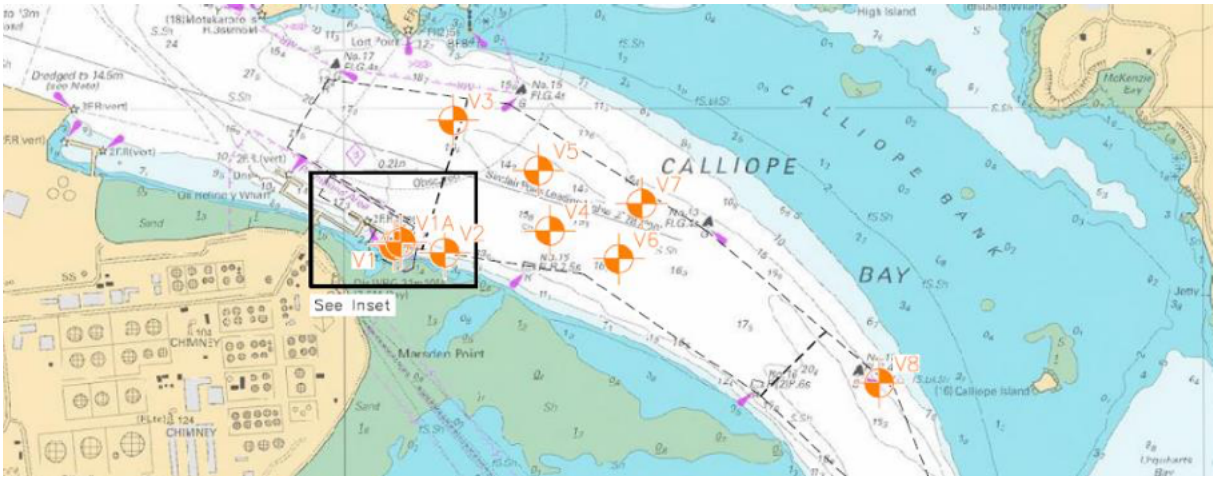


Figure 79: Borehole locations

Borehole log data for these locations were used in the noise model (taken directly from Tonkin & Taylor 2016).

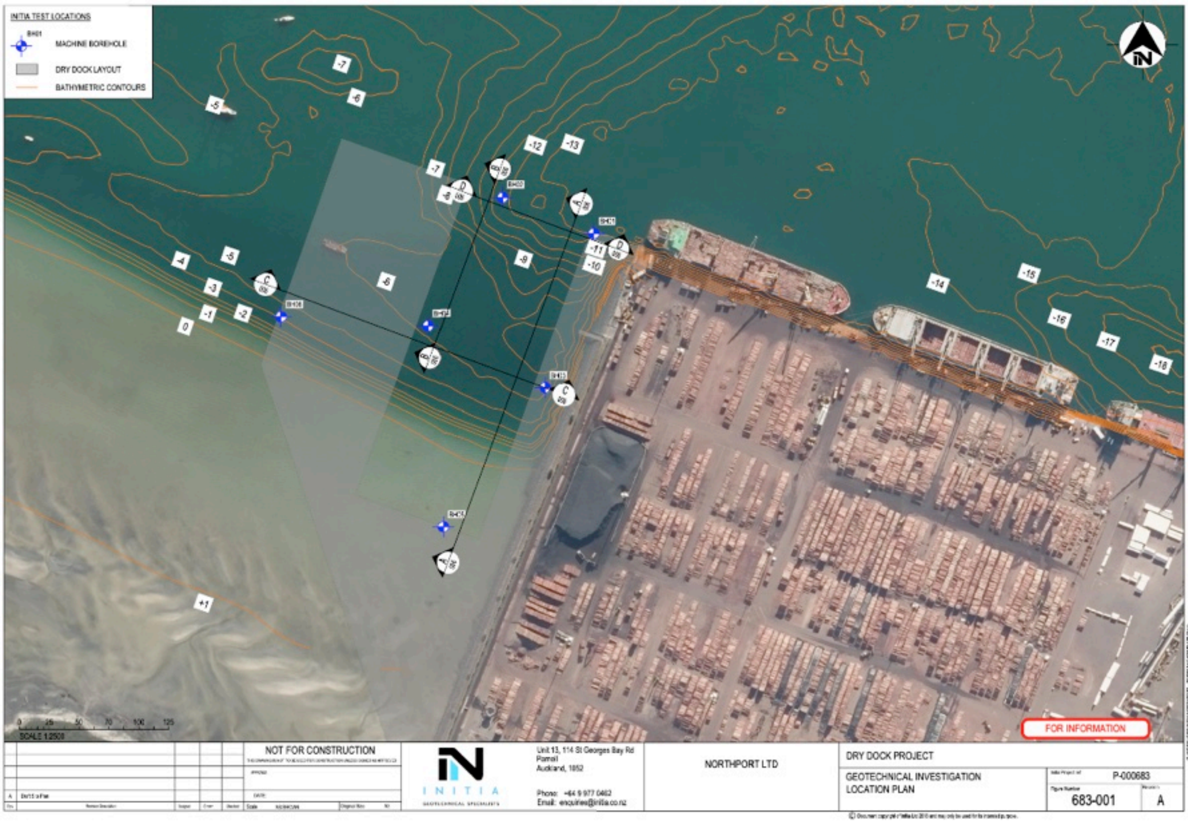


Figure 80: Borehole locations

Borehole log data for the BH-02 location was used in the noise model (taken directly from **Initia 2019**).

Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No:V01
Hole Location: Dolphin Pile

SHEET 1 OF 1

PROJECT: Crude Freight	LOCATION: Marsden Point	JOB No: 30488.1000
CO-ORDINATES: 35.83769 °S 174.5019 °E	DRILL TYPE: P5 VIBROCORE	HOLE STARTED: 27/2/16
	DRILL METHOD: VIBROCORE	HOLE FINISHED: 27/2/16
R.L.:		DRILLED BY: NZDS
DATUM:	DRILL FLUID: N/A	LOGGED BY: JWY CHECKED: RGK

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
MARINE SEDIMENTS		N/A	67	VIBROCORE		0-0.5m: Contam sample			0.0–0.15			W	LP				Fine to medium SAND; light yellowish grey. Loosely packed, uniformly graded.
						0.5-1m: Contam sample			0.15–1.0				TP				Fine SAND, some medium sand, trace coarse sand sized (2mm) shells; dark grey. Well graded, tightly packed, wet; sand grains angular to sub-angular.
Box 1									1.0								**END OF HOLE AT 1.0m.** Refusal (drilled to 1.5m).

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5

T+T DATATEMPLATE.GDT jwy

Log Scale 1:25 BORELOG 30488.1000.GPJ 30-Mar-2016

Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No:V01A
Hole Location: Dolphin Pile

SHEET 1 OF 1

PROJECT: Crude Freight	LOCATION: Marsden Point	JOB No: 30488.1000
CO-ORDINATES: 35.83759 °S 174.50226 °E	DRILL TYPE: P5 VIBROCORE	HOLE STARTED: 27/2/16
	DRILL METHOD: VIBROCORE	HOLE FINISHED: 27/2/16
R.L.:		DRILLED BY: NZDS
DATUM:	DRILL FLUID: N/A	LOGGED BY: JWY CHECKED: RGK

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
MARINE SEDIMENTS			60	VIBROCORE		0-0.5m: Contam sample			0.0–0.85			W	TP				Fine to medium SAND, trace medium sand sized shell fragments; dark grey. Tightly packed, wet; sand fraction sub-angular to angular.
						0.5-1m: Contam sample			0.5								
						1-2m: Contam sample			0.85–2.4								Shelly, medium SAND, with some fine sand; dark grey speckled white. Tightly packed.
																	1.25m: 10cm shell bed. Shells are broken, coarse sand to medium gravel sized.
																	1.8-1.9m: shell beds.
Box 1																	2-2.4m: very poor recovery at base of core.
									2.4								**END OF HOLE AT 2.4m.** Refusal. Drilled to 4m, recovered 2.4m.

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5

T+T DATATEMPLATE.GDT jwy

Log Scale 1:25

BORELOG 30488.1000.GPJ 30-Mar-2016

Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No:V02
Hole Location:

SHEET 1 OF 1

PROJECT: Crude Freight	LOCATION: Marsden Point	JOB No: 30488.1000
CO-ORDINATES: 35.83791 °S 174.50395 °E	DRILL TYPE: P5 VIBROCORE	HOLE STARTED: 28/2/16
	DRILL METHOD: VIBROCORE	HOLE FINISHED: 28/2/16
R.L.:		DRILLED BY: NZDS
DATUM:	DRILL FLUID: N/A	LOGGED BY: JWY CHECKED: RGK

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
MARINE SEDIMENTS			34	VIBROCORE		0-0.5m: Contam sample			0–0.1			W	LP	Medium SAND, some fine sand; light brownish grey. Loosely packed, wet.
						0.5-1m: Contam sample			0.1–1.1				TP	Medium SAND, some fine sand, trace borken shell fragments; dark grey. Tightly packed, wet; grains sub-angular, poorly graded.
Box 1						1-1.7m: Contam sample			1.1–1.7					Shelly, fine to medium SAND; dark grey speckled white. Tightly packed, wet, shells broken coarse sand to medium gravel sized, gap graded.
									1.7					**END OF HOLE AT 1.7m.** Drilled to 5m, recovered 1.7m.

ENGINEERING DESCRIPTION — SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling. Columns also: SHEAR STRENGTH (kPa), COMPRESSIVE STRENGTH (MPa), DEFECT SPACING (mm).

Depth scale (m): 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5

T+T DATATEMPLATE.GDT jwy

Log Scale 1:25 BORELOG 30488.1000.GPJ 30-Mar-2016

Styles Group
Underwater Acoustics

Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No: V03
Hole Location: Inner Harbour
SHEET 1 OF 1

PROJECT: Crude Freight	LOCATION: Marsden Point	JOB No: 30488.1000
CO-ORDINATES: 35.83374 °S 174.5043 °E	DRILL TYPE: P5 VIBROCORE	HOLE STARTED: 25/2/16
R.L.:	DRILL METHOD: VIBROCORE	HOLE FINISHED: 25/2/16
		DRILLED BY: NZDS
DATUM:	DRILL FLUID: N/A	LOGGED BY: JWY CHECKED: RGK

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
			73	VIBROCORE		0-0.5m: Contam sample			0.0			W	LP				Fine SAND, minor medium sand and shells, trace silt; dark grey. Loosely packed, poorly graded, wet. Strong sulfide odour (anoxic decomposition).
						0.5-1m: Contam sample			0.5								
						1-2m: Contam sample			1.0								
									1.3				TP				Fine to medium SAND, minor shells; grey. Tightly packed, poorly graded, wet; sand grains, angular to sub-angular.
									1.75								Shelly medium SAND, minor fine sand; dark grey. Tightly packed, wet; shells grading coarser with depth (up to coarse gravel sized); sand, sub-angular.
Box 1									2.0–2.5								
Box 2									2.8								Shelly medium SAND; light greyish brown. Tightly packed, wet; shells, fine to medium gravel sized, typically broken.
									2.9								**END OF HOLE AT 2.9m.** Drilled to 4.0m, recovered 2.9m.
									3.0–5								

T+T DATATEMPLATE.GDT JWY

Log Scale 1:25 BORELOG 30488.1000.GPJ 30-Mar-2016

Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No:V04
Hole Location: Turning Basin

SHEET 1 OF 1

PROJECT: Crude Freight	LOCATION: Marsden Point	JOB No: 30488.1000
CO-ORDINATES: 35.83724 °S 174.50804 °E	DRILL TYPE: P5 VIBROCORE	HOLE STARTED: 29/2/16
R.L.:	DRILL METHOD: VIBROCORE	HOLE FINISHED: 29/2/16
		DRILLED BY: NZDS
DATUM:	DRILL FLUID: N/A	LOGGED BY: JWY CHECKED: RGK

GEOLOGICAL / ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
MARINE SEDIMENTS			85	VIBROCORE		0-0.5m: Contam sample			0.0–0.7			W	LP				Shelly, fine to medium SAND, minor coarse sand; dark grey speckled white. Loosely packed, wet; shells, broken, fine gravel sized. 0.5m: lens of fine to medium grey SAND. 0.6m: shell bed 10cm thick.
						0.5-1m: Contam sample			0.5								
						1-2m: Contam sample			0.7–3.3			Sat (from 1.0)					Fine SAND, minor silt, trace shell fragments; dark brownish grey. Loosely packed, saturated; Shell uniformly graded, coarse sand sized. Strong sulfide odour. 1.5m: grades coarser sand, silt fraction becomes trace. - shell become minor, some unbroken.
Box 1									2.3								
Box 2									3.3								**END OF HOLE AT 3.3m.** Drilled to 3.9m, recovered 3.3m.

Log Scale 1:25

T+T DATATEMPLATE.GDT JWY

BORELOG 30488.1000.GPJ 30-Mar-2016

Styles Group
Underwater Acoustics

Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No:V05
Hole Location:

SHEET 1 OF 1

PROJECT: Crude Freight	LOCATION: Marsden Point	JOB No: 30488.1000
CO-ORDINATES: 35.83533 °S 174.5076 °E	DRILL TYPE: P5 VIBROCORE	HOLE STARTED: 27/2/16
	DRILL METHOD: VIBROCORE	HOLE FINISHED: 27/2/16
R.L.:		DRILLED BY: NZDS
DATUM:	DRILL FLUID: N/A	LOGGED BY: JWY CHECKED: RGK

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	CORE RECOVERY (%)	METHOD	TESTS	DEPTH (m)	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	ENGINEERING DESCRIPTION
MARINE SEDIMENTS	60	VIBROCORE	0-0.5m: Contam sample; 0.5-1: Contam sample; 1-2.4: Contam sample	0–1.3	W	TP	Shelly, fine to medium SAND; light grey. Tightly packed, well graded, wet; shells, broken, coarse sand to gravel sized; sand, sub-angular grains.
Box 1				1.3–2.4	Sat	LP	Fine SAND, trace broken shells; dark brownish grey. Loosely packed, uniformly graded, saturated; shells coarse sand to fine gravel sized.
				2.4			**END OF HOLE AT 2.4m.** Drilled to 4.0m, recovered 2.4m.

Other column headings (empty): FLUID LOSS, WATER, CASING, SAMPLES, RL (m), GRAPHIC LOG, CLASSIFICATION SYMBOL, SHEAR STRENGTH (kPa), COMPRESSIVE STRENGTH (MPa), DEFECT SPACING (mm).

SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour.
ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.

Log Scale 1:25 — BORELOG 30488.1000.GPJ 30-Mar-2016 — T+T DATATEMPLATE.GDT jwy

Styles Group
Underwater Acoustics

Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No:V06
Hole Location: Turning Basin

SHEET 1 OF 1

PROJECT: Crude Freight	LOCATION: Marsden Point	JOB No: 30488.1000
CO-ORDINATES: 35.83813 °S 174.51071 °E	DRILL TYPE: P5 VIBROCORE	HOLE STARTED: 28/2/16
	DRILL METHOD: VIBROCORE	HOLE FINISHED: 28/2/16
R.L.:		DRILLED BY: NZDS
DATUM:	DRILL FLUID: N/A	LOGGED BY: JWY CHECKED: RGK

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	CORE RECOVERY (%)	METHOD	TESTS	DEPTH (m)	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
MARINE SEDIMENTS	86	VIBROCORE	0-0.5m: Contam sample	0–0.5	W	LP	Shelly, fine to medium SAND; light grey. Loosely packed, wet; shells, broken, coarse sand to medium gravel sized; sand, sub-angular to angular, well graded.
			0.5-1m: Contam sample	0.5–1.0			Fine SAND, minor shells, trace silt; dark brownish grey. Loosely packed, wet, gap graded; shells, broken, coarse sand sized.
			1-2m: Contam sample	1.7			1.7m: 5cm thick SILT bed; dark brown.
				1.85			1.85m: shells becoming trace.
Box 1				2.4			2.4m: grades siltier, minor intact shells, medium to coarse gravel sized.
Box 2				2.9			2.9m: grades sandier.
				3.0			**END OF HOLE AT 3m.** Drilled to 3.5m, recovered 3m.

Other column headings: FLUID LOSS, WATER, CASING, SAMPLES, RL (m), GRAPHIC LOG, CLASSIFICATION SYMBOL, WEATHERING, SHEAR STRENGTH (kPa), COMPRESSIVE STRENGTH (MPa), DEFECT SPACING (mm). Soil type, minor components, plasticity or particle size, colour. Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5

T+T DATATEMPLATE.GDT jwy

Log Scale 1:25 BORELOG 30488.1000.GPJ 30-Mar-2016

Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No:V07
Hole Location: Turning Basin

SHEET 1 OF 1

PROJECT: Crude Freight	LOCATION: Marsden Point	JOB No: 30488.1000
CO-ORDINATES: 35.83638 °S 174.5116 °E	DRILL TYPE: P5 VIBROCORE	HOLE STARTED: 26/2/16
R.L.:	DRILL METHOD: VIBROCORE	HOLE FINISHED: 26/2/16
		DRILLED BY: NZDS
DATUM:	DRILL FLUID: N/A	LOGGED BY: JWY CHECKED: RGK

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
MARINE SEDIMENTS			60	VIBROCORE		0-0.5m: Contam sample						W	LP				Shelly, fine to medium SAND, minor coarse sand; light greyish brown. Loosely packed, wet, well graded; shells, broken, fine gravel sized.
						0.5-1m: Contam sample			0.5				TP				Fine to medium SAND, trace coarse sand, some shells; lightly packed, wet, well graded; sand, sub-rounded.
Box 1									1.6								**END OF HOLE AT 1.6m.** Drilled to 2.0m, recovered 1.6m.

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5

T+T DATATEMPLATE.GDT jwy

Log Scale 1:25

BORELOG 30488.1000.GPJ 30-Mar-2016

Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No:V08
Hole Location:

SHEET 1 OF 1

PROJECT: Crude Freight	LOCATION: Marsden Point	JOB No: 30488.1000
CO-ORDINATES: 35.84207 °S 174.52081 °E	DRILL TYPE: P5 VIBROCORE	HOLE STARTED: 28/2/16
	DRILL METHOD: VIBROCORE	HOLE FINISHED: 28/2/16
R.L.:		DRILLED BY: NZDS
DATUM:	DRILL FLUID: N/A	LOGGED BY: JWY CHECKED: RGK

GEOLOGICAL — ENGINEERING DESCRIPTION

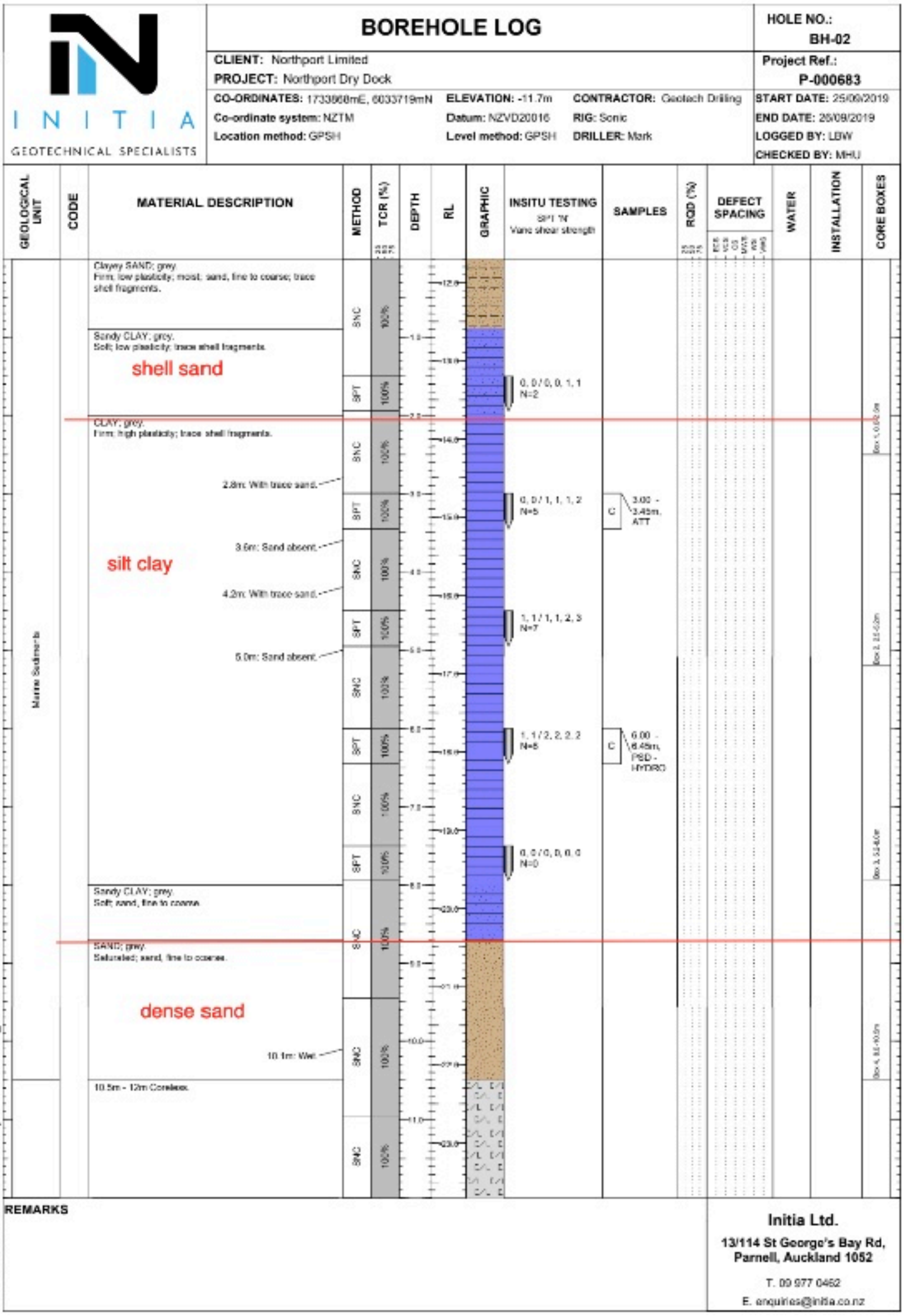
Column headings: GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION. | FLUID LOSS | WATER | CORE RECOVERY (%) | METHOD | CASING | TESTS | SAMPLES | R.L. (m) | DEPTH (m) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MOISTURE CONDITION / WEATHERING | STRENGTH/DENSITY CLASSIFICATION | SHEAR STRENGTH (kPa) | COMPRESSIVE STRENGTH (MPa) | DEFECT SPACING (mm) | SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.

Geological unit	Core recovery (%)	Method	Tests	Depth (m)	Moisture	Strength/Density	Description
MARINE SEDIMENTS	72	VIBROCORE	0-0.5m: Contam sample	0–0.1	W	TP	Shelly SAND; light brown. Loosely packed, wet.
				0.1–1.3		LP	Fine to medium SAND, minor fine gravel sized shell clasts up to 8mm; dark grey. Looely packed, wet.
			0.5-1m: Contam sample	~0.85			- grades light grey.
			1-2m: Contam sample	~1.15			- grades dark grey.
				1.3–2.0			Medium SAND, some coarse sand and medium sand sized shell fragments. Loosely packed, wet. Very sensitive, dilatant behaviour.
Box 1			2-3m: Contam sample	2.0–3.55		TP	Shelly, medium to coarse SAND; light grey streaked brown/white. Tightly packed, wet; shells, broken, coarse sand to medium gravel sized up to 20mm; sand, well graded, sub-angular to sub-rounded.
Box 2				3.55			**END OF HOLE AT 3.55m.** Drilled to 5.0m, recovered 3.55m.

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5

T+T DATATEMPLATE.GDT jwy

Log Scale 1:25 BORELOG 30488.1000.GPJ 30-Mar-2016



INITIA GEOTECHNICAL SPECIALISTS

BOREHOLE LOG

HOLE NO.: BH-02

CLIENT: Northport Limited
PROJECT: Northport Dry Dock
Project Ref.: P-000683

CO-ORDINATES: 1733868mE, 6033719mN | **ELEVATION:** -11.7m | **CONTRACTOR:** Geotech Drilling | **START DATE:** 25/09/2019
Co-ordinate system: NZTM | **Datum:** NZVD2016 | **RIG:** Sonic | **END DATE:** 26/09/2019
Location method: GPSH | **Level method:** GPSH | **DRILLER:** Mark | **LOGGED BY:** LBW
CHECKED BY: MHU

GEOLOGICAL UNIT	CODE	MATERIAL DESCRIPTION	METHOD	TCR (%)	DEPTH	RL	GRAPHIC	INSITU TESTING (SPT 'N', Vane shear strength)	SAMPLES	RQD (%)	DEFECT SPACING	WATER	INSTALLATION	CORE BOXES
Marine Sediments		Clayey SAND; grey. Firm; low plasticity; moist; sand, fine to coarse; trace shell fragments.	SNC	100%		-12.0								
		Sandy CLAY; grey. Soft; low plasticity; trace shell fragments. shell sand	SNC / SPT	100%	1.0	-13.0		0, 0 / 0, 0, 1, 1 N=2						Box 1, 0.0-2.5m
		CLAY; grey. Firm; high plasticity; trace shell fragments. 2.8m: With trace sand. 3.6m: Sand absent. silt clay 4.2m: With trace sand. 5.0m: Sand absent.	SNC / SPT	100%	2.0 – 8.0	-14.0 – -20.0		0, 0 / 1, 1, 1, 2 N=5; 1, 1 / 1, 1, 2, 3 N=7; 1, 1 / 2, 2, 2, 2 N=8; 0, 0 / 0, 0, 0, 0 N=0	C 3.00 - 3.45m, ATT; C 6.00 - 6.45m, PSD - HYDRO					Box 2, 2.5-5.2m; Box 3, 5.2-8.0m
		Sandy CLAY; grey. Soft; sand, fine to coarse.	SNC	100%										
		SAND; grey. Saturated; sand, fine to coarse. dense sand 10.1m: Wet.	SNC	100%	9.0 – 10.0	-21.0 – -22.0								Box 4, 8.0-10.5m
		10.5m - 12m Coreless.	SNC	100%	11.0	-23.0								

REMARKS

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BOREHOLE LOG

HOLE NO.: BH-02	**Project Ref.:** P-000683	
CLIENT: Northport Limited	**PROJECT:** Northport Dry Dock	
CO-ORDINATES: 1733868mE, 6033719mN	**ELEVATION:** -11.7m	**CONTRACTOR:** Geotech Drilling
Co-ordinate system: NZTM	**Datum:** NZVD2016	**RIG:** Sonic
Location method: GPSH	**Level method:** GPSH	**DRILLER:** Mark
START DATE: 25/09/2019	**END DATE:** 26/09/2019	
LOGGED BY: LBW	**CHECKED BY:** MHU	

INITIA
GEOTECHNICAL SPECIALISTS

GEOLOGICAL UNIT: Marine Sediments

MATERIAL DESCRIPTION: SAND, with trace clay; grey. Wet; sand, fine to medium.

dense sand

15.0m: With minor clay. Becoming fine to coarse grained.

EOH: 19.95m

METHOD	TCR (%)	INSITU TESTING (SPT 'N' / Vane shear strength)	SAMPLES
SPT	100%	2, 4 / 7, 11, 30, 2 for 15mm N=50+ for 240mm	C 12.00 - 12.45m, PSD
SNC	100%		
SPT	100%	8, 7 / 8, 8, 7, 8 N=27	
SNC	100%		
SPT	100%	2, 4 / 8, 9, 10, 11 N=38	C 15.00 - 15.45m, PSD
SNC	100%		
SPT	100%	14, 16 / 16, 20, 16 for 65mm N=50+ for 215mm	
SNC	100%		
SPT	100%	10, 13 / 23, 27 for 55mm N=50+ for 130mm	
SNC	100%		
SPT	100%	8, 10 / 13, 18, 15, 4 for 20mm N=50+ for 245mm	

Other columns: CODE, DEPTH, RL, GRAPHIC, RQD (%), DEFECT SPACING, WATER, INSTALLATION, CORE BOXES

REMARKS

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