CRUDE SHIPPING PROJECT

PROPOSED DEEPENING AND REALIGNING OF THE WHANGAREI HARBOUR ENTRANCE AND APPROACHES

VOLUME FOUR:

ANNEXURE TWO (e) TO ANNEXURE TWO (l)

Prepared for:
ChanceryGreen on behalf of the New Zealand Refinery Company Limited **August 2017**

Prepared by:
Ryder

Crude Shipping Project

Proposed Deepening and Realigning of the Whangarei Harbour Entrance and Approaches

Prepared for: New Zealand Refining Company Limited

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Date Finalised: August 2017

Annexure Two: Technical Reports

e) **Crude Shipping Project – Mid-point multi-criteria alternatives assessment. T & T. Monique Cornish. Dated March 2017**
f) **Report in Support of an Assessment of Effects on the Environment – Navigational Risk Assessment of Engineered Channel Designs. Navigatus. Geraint Bermingham and Paul Dickinson. Dated 15 August 2017**
g) **Environmental Spill Risk Assessment for Proposed Tanker Operations Associated with Engineered Channel. Navigatus. Kevin Oldham, Matt Bilderbeck and Geraint Bermingham. Dated 14 August 2017**
h) **Whangarei Harbour Entrance and Marsden Point Channel Realignment and Deepening: Assessment of Environmental (Airborne) Noise Effects. Styles Group. Jon Styles. Dated 31 July 2017**
i) **Assessment of effects on marine mammals from proposed deepening and realignment of the Whangarei Harbour entrance and approaches ('Marine Mammals Assessment'). Cawthron Institute. Deanna Clement and Deanna Elvines. Dated August 2017**
j) **AEE Report – Coastal Birds – Final. Bioresearches Group Limited. Graham Don. Dated 09 August 2017**
k) **Assessment of Marine Ecological Effects excluding Seabirds and Marine Mammals. Brian T Coffey and Associates. Brian Coffey. Dated 10 August 2017**
l) **Recreation and Tourism Effects Assessment. Rob Greenaway and Associates. Rob Greenaway. Dated August 2017**

Annexure Two: Technical Reports

e) Crude Shipping Project – Mid-point multi-criteria alternatives assessment. T & T. Monique Cornish. Dated March 2017

REPORT

Tonkin+Taylor

Crude Shipping Project

Mid-point multi-criteria alternatives assessment

Prepared for
ChanceryGreen for Refining NZ
Prepared by
Tonkin & Taylor Ltd
Date
March 2017
Job Number
30488.3000.v2.5



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Table of contents

1 Executive summary 1

2 Introduction 6
- 2.1 Report structure 6
- 2.2 Business need 6
- 2.3 Initial options assessment 7
  - 2.3.1 Channel options 7
  - 2.3.2 Disposal options 8
- 2.4 Mid-point options assessment 8

3 Assessment methodology 12
- 3.1 Aspects and weightings 12
- 3.2 Impact assessment 15
- 3.3 Normalisation 15
- 3.4 Sensitivity assessment 15

4 Summary of key issues 16
- 4.1 Marine mammals 17
- 4.2 Shore and pelagic birds 18
- 4.3 Marine ecology (excluding marine mammals and avifauna) 19
- 4.4 Turbidity 21
- 4.5 Physical environment 22
- 4.6 Social impact 23
- 4.7 Tangata whenua 25
- 4.8 Archaeology 27
- 4.9 Indirect economic impacts 28
- 4.10 Navigational and programme safety 29
- 4.11 Direct economic impacts 30

5 Results 32
- 5.1 Preferred channel alignment 32
- 5.2 Preferred disposal options 34
- 5.3 Preferred dredge methodology 38

6 Applicability 40

Appendix A : Poten & Partners | Crude Shipping Alternatives

Appendix B : Channel alignment options

Appendix C : Expert panel

Appendix D: Key literature

Appendix E: MCA summary

1 Executive summary

Tonkin + Taylor was engaged by ChanceryGreen on behalf of Refining NZ (RNZ) to undertake a mid-point review of the potentially viable options to expand the depth and improve the navigability of the shipping channel (both at the entrance and outside of Whangarei Harbour) into the refinery at Marsden Point (the Crude Shipping project). The scope of the engagement was to document the process to-date and to consolidate the findings to support confirmation of a set of preferred options to be taken forward for more detailed assessment as part of a formal Assessment of Environmental Effects (AEE).

Clients of Refining NZ currently import crude oil using Aframax and Suezmax tankers. The harbour has a draught restriction of 14.7 meters Chart Datum (CD). These restrictions mean that only fully laden Aframax tankers (carrying 80,000 to 100,000 tons of crude oil) or partially loaded Suezmax tankers (with 100,000 to 120,000 tons cargo size) can access Refining NZ's discharge terminal. In order to reduce freight costs and impact per tonne transported, the Marsden Point facility could be upgraded to allow fully laden Suezmax tankers to deliver crude oil.

Initially there were three feasible approaches to enable the use of larger tankers explored[1]:

a) dredge the access channel and the RNZ berth

b) install a Single Point Mooring (SPM) system in deeper water offshore connected by an underwater pipeline to the refinery

c) use Ship to Ship transfer in deep water to transfer cargo into smaller tankers for final discharge at the refinery.

The work initially undertaken by Poten & Partners[1] (see Appendix A) found that the dredging alternative (Option A) is preferred from a financial perspective, as the initial the investment can be recovered over a relatively short timeframe, while the added operating costs are relatively small. While all three alternatives have good environmental records, the dredging of the harbour channel allows the continued use of the existing terminal and provides access for more efficient, fully laden Suezmax tankers. This potentially reduces the number of port calls compared to the other options using larger vessels, while having the advantage of discharging in a location that is sheltered from seas and swells, and allows for the most effective emergency response in case of an incident.

In order to understand the feasibility of dredging the access to the channel and the RNZ berth and disposal of dredged material (Option A above), RNZ established an expert team to characterise the existing environment, develop and refine options, and to consider the potential effects associated with the proposal in the context of natural, social, cultural and economic costs and benefits.

Five channel alignment options were considered:

- *Option 1:* alignment keeps within the existing buoyed navigation area ("fairway") and closely follows the current shipping channel centreline, resulting in five heading changes.
- *Option 2:* aimed to increase the distance between changes in channel alignment through the Home Point stretch and follows the existing channel route, resulting in five heading changes.
- *Option 3:* provides a further increase in the distance between changes in channel alignment through the Home Point stretch and reduces the total number of changes in heading to four.

[1] Poten & Partners (August, 2016), Crude Shipping Alternatives Marsden Point, NZ. 28 pp.

- *Option 4:* characterised by a straight mid-section, this was a refinement to Option 3 resulting from the Channel Design Workshop. The channel route is simplified to three main headings, two bends and further increasing the distance between changes in channel alignment through Home Point stretch.
- *Option 5:* developed as an alternative to Option 4 which aimed to avoid any dredging adjacent to Buoy 12/14 by moving the alignment to the east. The alignment therefore extends closer to, and requires dredging at, Home Point.

Option 4, was refined twice (Options 4.1 and 4.2) to further improve navigability. Options 2, 4.2 and 5 were considered the most appropriate to be carried forward for further refinement and this analysis.

Six options were initially considered for assessment as potential dredge disposal sites:

- *Option 1:* ebb delta
- *Option 2:* nearshore water depth (around 25 m CD)
- *Option 3:* intermediate water depth (around 45 m CD)
- *Option 4:* Land based options such as reclamation where possible and consented
- *Option 5:* local beach nourishment
- *Option 6:* deep water off Ocean Beach (around 70 m CD)
- *Option 7:* unspecified location outside the EEZ.

The locations of Options 1, 2 and 3 were refined twice (to Options 1.2, 2.2 & 3.2 respectively) as part of the ongoing investigations. The disposal options sites can be broadly split into three categories: land-based disposal or beach nourishment (Options 4 & 5); inner sites (Options 1.2, 2.2 & 3.2); and offshore sites (Options 6 & 7).

The refined options for channel alignment, dredge disposal and dredge methodology considered in this assessment are summarised in Table 1 below.

Table 1: Summary of options assessed as part of the mid-point multi criteria assessment

Channel options	
Option 2: existing mid-section	Maintains the current channel alignment.
Option 4.2: straight mid-section (west)	Removes the s-bend from the current alignment meaning significant improvement in navigation for arriving ships.
Option 5: straight mid-section (east)	Straightens the alignment by moving the channel closer to Home Point to the east.
Disposal options	
Area 1.2: ebb delta	Situated on the south-eastern edge of the ebb delta to the south of the inner harbour entrance.
Area 2.2: nearshore	Situated in 20-30m of water off the mid-coast of Bream Bay to the west of the channel.
Area 3.2: intermediate	Situated in moderately deep water to the south-east of the channel.
Area 4: land based reclamation	Land based options such as reclamation where possible and consented.
Area 5: beach nourishment	Beach nourishment options.
Area 6: deep water	A broadly defined location in 60-80m water depth off Ocean Beach and north of Lady Alice Island.
Area 7: outside the EEZ	An undefined location outside New Zealand's Exclusive Economic Zone (EEZ).
Dredge methodology	
1a: trailer hopper suction dredge, THSD (with controlled overflow via central weir)	A long suction pipe that is 'trailed' along behind the dredge vessel, dragging and sucking up sediment into its hopper. Overflow via a central weir (or 'green valve') reduces the air entrainment so any dredge material in the overflow falls to the seabed, minimising discharge plumes.
1b: trailer hopper suction dredge, THSD (actual overflow)	A long suction pipe that is 'trailed' along behind the dredge vessel, dragging and sucking up sediment into its hopper. As the ship hopper fills, it "spills over" the side.
2: cutter suction dredge (CSD)	A long cutter head breaks up the sea bed substrate before pumping the sediment into the hopper.
3: backhoe	An excavator is mounted to a vessel, barge, or pontoon. The boom and bucket goes into the water to scoop sediment up from the bottom then brings it to the surface for removal.
i: ebb tide dredging	Restricts dredging to the ebb tide which reduces disturbed sediment accumulating in the harbour. Extends the duration of operations.
ii: all tide dredging	No restriction on dredging operations. Duration of dredging would be shorter.

A multi criteria assessment (MCA) approach was used to provide a systematic and transparent way to evaluate options in the context of potential impacts on natural, social, cultural and economic aspects to derive the best practicable options.

Initial input as to the aspects which may be impacted, weightings for each aspect and potential magnitude and duration of impact was provided by the appropriate expert team members(s) based on their work to-date. Interim results were presented back to the expert team for discussion and agreement at an initial findings workshop in June 2016. As a result of the workshop, further input was provided by the expert team and the results of ongoing research and modelling were incorporated into the assessment.

As a result of the process, and based on the information available as at October 2016, the following are recommended:

Channel Alignment: the key consideration in the selection of the channel alignment is the outcome from a navigational safety perspective. Option 4.2 has been found to perform the best from a navigational safety perspective due to the reduction in the number of headings required, and notably ensuring no course changes around the rocky outcrop at Home Point, which is reflected in the economic sphere of the MCA. The 4.2 alignment is also the furthest from the known areas of high conservation value and hard shore biological diversity, which is reflected in the natural sphere of the assessment, especially when compared with Option 5. Avoiding Home Point also means that Option 4.2 is also likely to result in fewer temporary amenity impacts (light, noise and visual) on the local community. The combination of reduced impact on marine ecology and the headland also mean that this option performs well from a cultural perspective, but concerns remain with regards to the impact on taonga species. As this is perceived by iwi as a new alignment (as opposed to deepening the existing channel as characterised by Option 2), they have concerns as to their ability to perform their role as kaitiaki / stewards of the area.

Dredge Disposal Options: the land based disposal and beneficial reuse option (Options 4 & 5) were assessed as preferential overall, and it is therefore recommended that they are progressed where practicable. However, it is noted that as there are no specific land based disposal or beneficial reuse options defined at present, there will likely be a range of additional costs and benefits associated with these options when specific locations are identified. It is also unlikely to be practicable or economic to dispose of the entire capital dredge volume to land, therefore additional marine disposal sites need to be considered.

Overall, the inner sites (Options 1.2, 2.2 & 3.2) are better characterised than the offshore sites (Options 6 & 7), and the granularity of the information available for these two groups influenced the results of the MCA.

Overall, the offshore options are less feasible than the inner sites from a time, cost and environmental risk perspective, and it is therefore recommended that the inner sites are considered for consenting. Of the three sites, Option 3.2 performed the best in the MCA assessment and is designed to be able to take the full volume of the capital dredge. Option 3.2 is preferred due to a smaller footprint and less potential impact on sea-floor flora and fauna. Being further offshore, there is less potential impact on birdlife and known areas of conservation value. The site is also more removed from known areas of importance to recreational and commercial fishers, although there are still concerns about impacts on mahinga mataitai. Key aspects for assessment include the potential interaction with marine mammals and impacts on taonga species. It is also recommended that limited volumes of dredged material are placed in the ebb delta (Option 1.2) to provide resilience to the geomorphological system and Mair Bank, which is reflected in the MCA assessment of natural aspects.

Dredge Methodology: until a channel option is confirmed it is not possible to determine which of the available dredge methodologies are the most appropriate along the different parts of the transect (berth, inner-harbour and outer harbour). Controlling overflow via the central weir (also referred to as green valve technology) and / or ebb tide dredging should be considered where it is assessed that environmental and cultural effects warrant the use of these methods. However, as the sediment along the channel alignment is likely to settle quickly due to its generally sandy nature, these technologies may not be necessary during dredging and disposal as turbidity levels will already be low. There are also potential commercial, natural environment and social trade-offs due to the increase in dredge duration which come with the use of these dredge methodologies which should be taken into consideration in terms of cost and benefit.

Overall it is recommended that RNZ continues to engage with iwi to fully understand cultural effects and options for mitigation, as cultural aspects were consistently assessed by iwi representatives as being potentially significant both in terms of the weightings allocated to these aspects, as well as the perceived potential impact.

2 Introduction

2.1 Report structure

This report is structured as follows:

- Section 1: provides the background to the project and the purpose and scope of the mid-point review
- Section 2: details methodology used in the mid-point review, including weightings, impact assessment and normalisation
- Section 3: provides a high level summary of the impacts most material to each aspect based on the research and professional option of the expert panel
- Section 4: summarises the preferred options in the context of the multi-criteria assessment
- Section 5: applicability
- Appendix A: report on the feasibility of approaches to allow fully laden Suezmax tankers to deliver crude oil by Poten & Partners
- Appendix B: schematics of the channel alignment options considered as part of the min-point review
- Appendix C: list of contributors from the expert panel
- Appendix D: key literature to support the opinions in Sections 3 and results in Section 4
- Appendix E: complete tabularised MCA results.

2.2 Business need

RNZ is seeking to reduce crude product transportation costs through economies of scale to support RNZ's competitive position and long term business sustainability. As a result, a review of crude oil shipping efficiency was undertaken by RNZ. Clients of Refining NZ currently import crude oil using Aframax and Suezmax tankers. The harbour has a draught restriction of 14.7 meters Chart Datum (CD). These restrictions mean that only fully laden Aframax tankers (carrying 80,000 to 100,000 tons of crude oil) or partially loaded Suezmax tankers (with 100,000 to 120,000 tons cargo size) can access Refining NZ's discharge terminal. For clarity, the intention of the proposed dredging project is not to bring any larger vessels to the Refinery. In order to reduce freight costs and impact per tonne transported, the Marsden Point facility could be upgraded to allow fully laden Suezmax tankers to deliver crude oil.

Initially there were three feasible approaches explored[2]:

a) dredge the access channel and the RNZ berth

b) install a Single Point Mooring (SPM) system in deeper water offshore connected by an underwater pipeline to the refinery

c) use Ship to Ship transfer in deep water to transfer the cargo into smaller tankers for final discharge at the refinery.

[2] Poten & Partners (August, 2016), Crude Shipping Alternatives Marsden Point, NZ. 28 pp.

The work initially undertaken by Poten & Partners (see Appendix A) found that the dredging alternative (Option A) is preferred from a financial perspective, as the initial the investment can be recovered over a relatively short time frame while the added operating costs are relatively small. The other alternatives have either very high operating costs or involve high upfront investment costs which require Refining NZ to move to Very Large Crude Carriers (VLCC) – about 3 times the current delivery size – in order to offset these additional costs. While all three alternatives have good environmental records, the dredging of the harbour channel allows the continued use of the existing terminal but provides access to more efficient, fully laden Suezmax tankers. This potentially reduces the number of port calls while having the advantage of discharging in a location that is sheltered from seas and swells, and allows for the most effective emergency response in case of an incident.

2.3 Initial options assessment

In order to understand the likely effects associated with the proposal, RNZ assembled a team of appropriately qualified and experienced and well respected experts to:

- characterise the existing environment, including natural, social, cultural and economic aspects
- identify possible dredge channel configurations, dredge methodologies and disposal options
- consider the potential effects of these various options in the context of costs and benefits.

From November 2014 to December 2015 a comprehensive range of high level studies and investigations were carried out by the team to better understand and characterise the existing natural, social and cultural environments, and to identify possible channel alignment and disposal options. As a result of these investigations a number of options were not progressed due to potential natural and social impacts, navigational safety, project risks and / or economic viability, while other options were further refined. We outline that characterisation and refinement process below.

2.3.1 Channel options

Five channel alignment options were considered which fulfilled the requirements of increased depth and were in accordance with PIANC (World Association for Waterborne Transport Infrastructure) design principles (Royal HaskoningDHV, June 2016):

- *Option 1:* alignment keeps within the existing buoyed navigation area ("fairway") and closely follows the current shipping channel centreline, resulting in five heading changes.
- *Option 2:* aimed to increase the distance between changes in channel alignment through the Home Point stretch and follows the existing channel route, resulting in five heading changes.
- *Option 3:* provides a further increase in the distance between changes in channel alignment through the Home Point stretch and reduces the total number of changes in heading to four.
- *Option 4:* characterised by a straight mid-section, this was a refinement to Option 3 resulting from the Channel Design Workshop. The channel route is simplified to three main headings, two bends and further increasing the distance between changes in channel alignment through Home Point stretch.
- *Option 5:* developed as an alternative to Option 4 which aimed to avoid any dredging adjacent to Buoy 12/14 by moving the alignment to the east. The alignment therefore extends closer to, and requires dredging at, Home Point.

Option 4, was refined twice (Options 4.1 & 4.2) to further improve navigability. Options 2, 4.2 & 5 were considered the most appropriate to be carried forward for further refinement and analysis (see Appendix B).

2.3.2 Disposal options

Six options were initially considered for assessment as potential dredge disposal sites (see Figure 1-1):

- *Option 1:* ebb delta
- *Option 2:* nearshore water depth (around 25 m CD)
- *Option 3:* intermediate water depth (around 45 m CD)
- *Option 4:* Land based options such as reclamation where possible and consented (not shown on map)
- *Option 5:* local beach nourishment (not shown on map)
- *Option 6:* deep water (60-80 m CD)
- *Option 7:* unspecified location outside the EEZ (not shown on map).

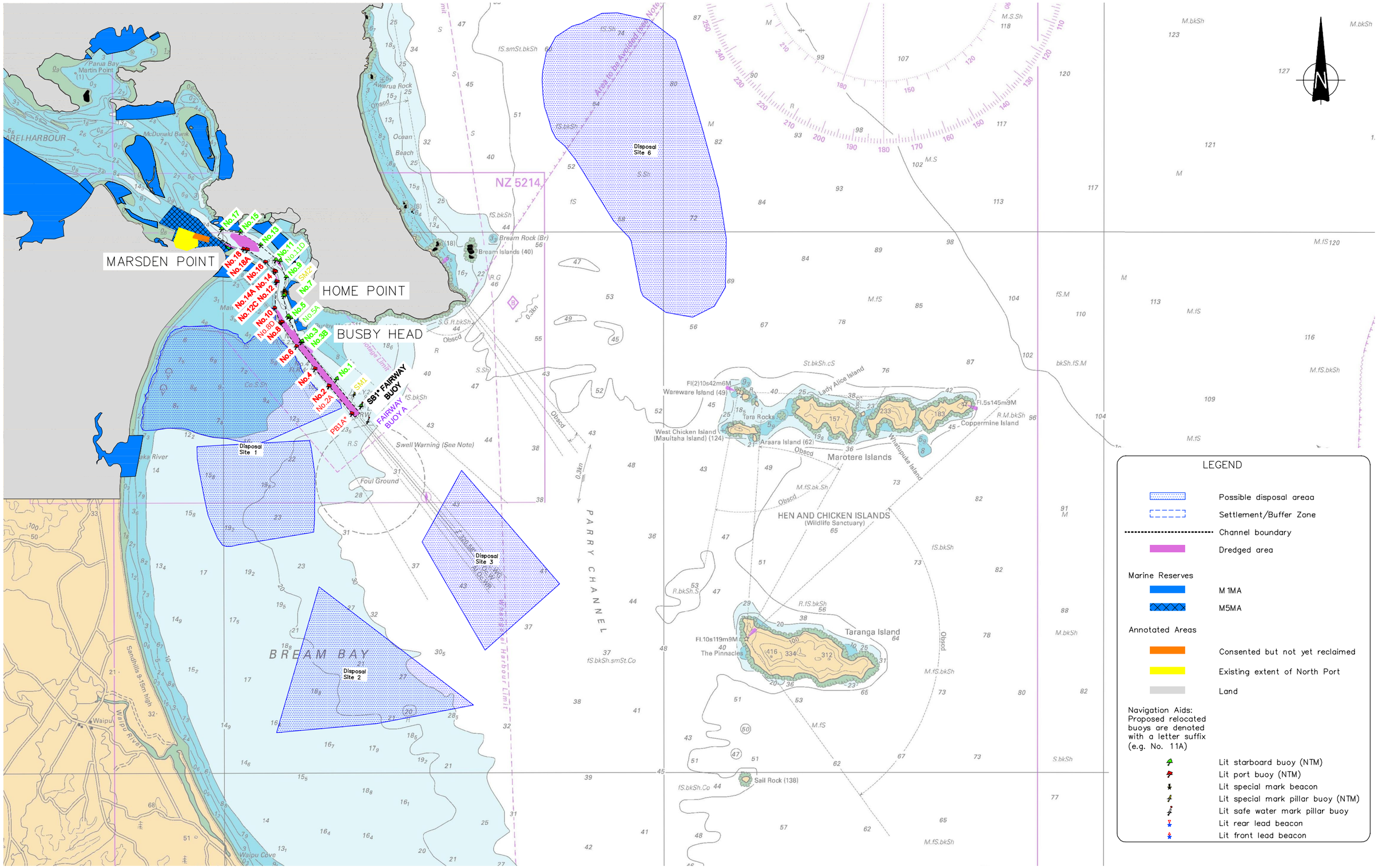
The location of Options 1, 2 & 3 were refined twice (to 1.2, 2.2 & 3.2 respectively) as part of the ongoing investigations. These locations (except Options 4, 5 and 7) are shown on Figure 1-2 below.

2.4 Mid-point options assessment

More detailed studies, investigations and analyses were undertaken on the refined options to further the understanding as to how they could affect the environment, as well as the cost and feasibility of implementation.

In April 2016, ChanceryGreen on behalf of Refining NZ commissioned Tonkin & Taylor Ltd ("Tonkin + Taylor" or "T+T") undertake a mid-point review of the options for dredging and disposal which were considered feasible at that time, which included three channel options, seven disposal sites and six aspects of dredge methodology (see Table 1-1).

The assessment aimed to consolidate the information generated for each of the options to-date, and provide a transparent process for agreeing the preferred options to be taken forward for further, more detailed assessment, as part of a formal Assessment of Environmental Effects. The assessment process also aimed to highlight where the most important potential impacts lie for each of the options, so that effort can be placed in the right areas in terms of finalising the preferred options, and if necessary, the development of mitigation strategies in order to ensure that any adverse effects are acceptable.



LEGEND

- Possible disposal areaa
- Settlement/Buffer Zone
- Channel boundary
- Dredged area

Marine Reserves

- M 1MA
- M5MA

Annotated Areas

- Consented but not yet reclaimed
- Existing extent of North Port
- Land

Navigation Aids: Proposed relocated buoys are denoted with a letter suffix (e.g. No. 11A)

- Lit starboard buoy (NTM)
- Lit port buoy (NTM)
- Lit special mark beacon
- Lit special mark pillar buoy (NTM)
- Lit safe water mark pillar buoy
- Lit rear lead beacon
- Lit front lead beacon

NOTES :

1. Hydrographic chart sourced from Linz Data Service (NZ 5214/5219)
2. Navigation aids and relocation placements from Royal HaskoningDHV drawing PA1028/MA/1121 rev K.

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CRUDE FREIGHT PROJECT
MARSDEN POINT NORTHLAND
Initial Disposal Sites

FIG. No. Figure 1– 1

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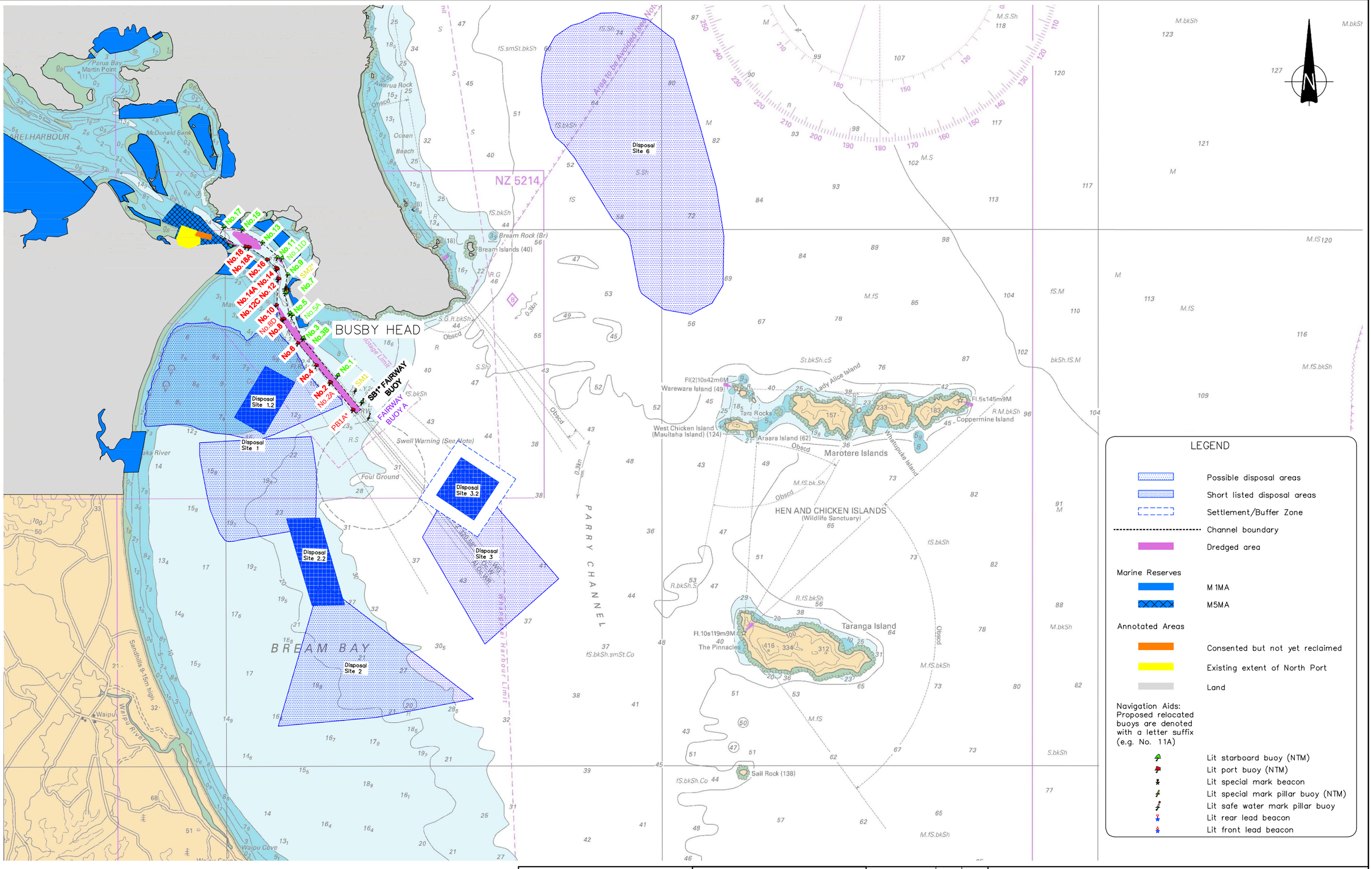

LEGEND

- Possible disposal areas
- Short listed disposal areas
- Settlement/Buffer Zone
- Channel boundary
- Dredged area

Marine Reserves

- M 1MA
- M5MA

Annotated Areas

- Consented but not yet reclaimed
- Existing extent of North Port
- Land

Navigation Aids: Proposed relocated buoys are denoted with a letter suffix (e.g. No. 11A)

- Lit starboard buoy (NTM)
- Lit port buoy (NTM)
- Lit special mark beacon
- Lit special mark pillar buoy (NTM)
- Lit safe water mark pillar buoy
- Lit rear lead beacon
- Lit front lead beacon

SCALE 1: 120000

0 1.0 2.0 3.0 4.0 5.0 (km)

NOTES :

1. Hydrographic chart sourced from Linz Data Service (NZ 5214/5219)
2. Navigation aids and relocation placements from Royal HaskoningDHV drawing PA1028/MA/1121 rev K.

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CRUDE FREIGHT PROJECT
MARSDEN POINT NORTHLAND
Midpoint Refine

FIG. No. Figure 1–2

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Table 1-1: Summary of options assessed as part of the mid-point multi criteria assessment

Channel options[3]	
Option 2: existing mid-section	Maintains the current channel alignment.
Option 4.2: straight mid-section (west)	Removes the s-bend from the current alignment meaning significant improvement in navigation for arriving ships.
Option 5: straight mid-section (east)	Straightens the alignment by moving the channel closer to Home Point to the east.
Disposal options	
Area 1.2: ebb delta	Situated on the south-eastern edge of the ebb delta to the south of the inner harbour entrance.
Area 2.2: nearshore	Situated in around 25m of water off the mid-coast of Bream Bay to the west of the channel.
Area 3.2: intermediate	Situated in moderately deep water (around 45m) to the south-east of the channel.
Area 4: land based reclamation	Land based options such as reclamation where possible and consented.
Area 5: beach nourishment	Beach nourishment options.
Area 6: deep water	A broadly defined location 60-80m water depth off Ocean Beach and north of Lady Alice Island.
Area 7: outside the EEZ	An undefined location outside New Zealand's Exclusive Economic Zone (EEZ).
Dredge methodology	
1a: trailer hopper suction dredge, TSHD (with controlled overflow via central weir)	A long suction pipe that is 'trailed' along behind the dredge vessel, dragging and sucking up sediment into its hopper. Overflow via a central weir (or 'green valve') reduces the air entrainment so any dredge material in the overflow falls to the seabed, minimising discharge plumes.
1b: trailer hopper suction dredge, TSHD (actual overflow)	A long suction pipe that is 'trailed' along behind the dredge vessel, dragging and sucking up sediment into its hopper. As the ship hopper fills, it "spills over" the side.
2: cutter suction dredge (CSD)	A long cutter head breaks up the sea bed substrate before pumping the sediment into the hopper.
3: backhoe	An excavator is mounted to a vessel, barge, or pontoon. The boom and bucket goes into the water to scoop sediment up from the bottom then brings it to the surface for removal.
i: ebb tide dredging	Restricts dredging to the ebb tide which reduces disturbed sediment accumulating in the harbour. Extends the duration of operations.
ii: all tide dredging	No restriction on dredging operations. Duration of dredging would be shorter.

[3] See Appendix B for schematics of channel alignment options.

3 Assessment methodology

A multi criteria assessment (MCA) methodology was used to provide a systematic and transparent approach for evaluating shortlisted options in the context of potential impacts on various natural, social, cultural and economic aspects to robustly test those options, and to derive the preferred (best practicable) option. An initial MCA matrix was developed to:

- capture all important aspects from an natural, social, cultural and economic perspective which could be impacted by the channel, disposal or dredge methodology options,
- agree weightings for each of the aspects based on stakeholder and expert opinion, and
- agree potential impacts (positive and negative) on each of the aspects for each of the options based on stakeholder and expert opinion.

The assessment is based on the research and findings of the expert team working collectively on behalf of RNZ (see Appendix C for a list of contributors).

Initial feedback on the aspects, weightings and impacts was solicited from the expert team via a formal written information request and one-on-one interviews. Subsequently, interim results were presented back to the expert team at an initial findings workshop in June 2016. As a result of the workshop, further input was provided by the expert team, and the results of ongoing research and modelling were incorporated into the assessment (see Appendix D for details of key reports contribution to the findings of this assessment).

3.1 Aspects and weightings

The aspects included in the assessment are provided in Table 2-2. Particular attention was placed on ensuring that impacts were not double counted, as well as accurately reflecting interdependencies and feedback loops.

Weightings are used as a multiplier to reflect the importance of each of the aspects to communities of interest which include local residents, businesses and iwi, as well as the potential to impact ecosystem services. Weightings were initially proposed by the member(s) of the expert panel who were best placed to assess the perceived criticality of each of the aspects to stakeholders. Weightings were discussed and agreed or revised as part of the initial findings workshop as summarised in Table 2-1.

Table 2-1: Weighting descriptions

0.5	1	2	3
Minor importance to a small number of stakeholders OR Aspect does not impact or have an interdependency with other aspects	Minor importance to a wide range of stakeholders OR Interdependency with other aspect. Does not impact the functioning of the community or ecosystem	Moderate importance to stakeholders OR Interdependency with other number of other aspects. Impacts the functioning of the community or ecosystem	Major importance to stakeholders OR Significant interdependency with other aspects. Aspect is critical to the health or welbeing of communities (human or ecological)

Table 2-2: Summary of aspects and weightings

Aspect	Description	Weighting
Natural		
Direct impacts		
Impact on benthic flora & fauna at site	Direct impacts on ecological communities removed or smothered	2
Impact on local fish stocks	Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)	2
Impact on marine mammals	Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)	2
Impact on shore birds & pelagic birds	Direct impact on feeding and nesting sites and indirect impacts on mating due to noise, light and general activity in the area	2
Sediment matching	Degree to which the deposit would match the existing substrate	2
Contamination	Potential for any existing contaminants to be spread	3
Impact on intertidal and subtidal flora and fauna	Impact on sensitive coastal flora (e.g. seagrass beds) and sensitive soft bottomed communities	2
Impact on significant ecological habitats or species of flora and fauna within those habitats	Potential to impact areas with important conservation value	3
Impact on reef	Potential to impact known area of hard shore biological diversity	2
Turbidity (dredge location)	Potential for movement of sand from site and impacts on water quality (colour and clarity) and associated impacts on phyto / zooplankton	2
Turbidity (disposal location)	Potential for movement of sand from site and impacts on water quality (colour and clarity) and associated impacts on phyto / zooplankton	2
Indirect impacts		
Coastline formation	Potential for deposition to occur to a level greater than normal coastal processes	1
Natural Character & underwater seascape (biophysical)	Significance of the impact on the natural character values & 'landscape' of the sea floor	1
Coastal erosion	Potential for erosion to occur to a level greater than normal coastal processes	2
Resilience	Impact on resilience of the coastal system based on volume of sand removed / deposited	3
Social		
Permanent impacts		
Fishing	Impact on recreational fishing (access or stocks) by boat, from shore or diving. Includes fin and shellfish	3
Hunting	Impact on duck hunting on- or near-shore	3
Watercraft sports	Impact on on-water sports (e.g. yachting, rowing, waka ama, windsurfing, canoeing, jet skiing, boating)	3
Watercraft sports	Impact on boating communities associated with relocation of the navigation buoys	0.5
Wave sports	Impact on wave sports (e.g. kite surfing, wind surfing and surfing) due to changes in surf breaks	3
In-water activities	Impact on in-water activates (e.g. diving, swimming) due to changes in turbidity, currents, wave profile	3
Beach access and use	Changes to beach access	3
Natural Character & underwater seascape (perceptual)	Significance of the impact on the natural character values & 'landscape' of the sea floor	1
Permanent effects of navigation lights	Impact on local and visitor communities associated with new Navaid structures	1
Temporary impacts		
Temporary amenity effects (light spill & noise emissions above water)	Impact on local community from light and noise associated with dredge operations	2
Temporary visual amenity & landscape	Aesthetic impacts on local community associated with dredging operations	2

Cultural		
Kaimoana at Mair Bank	Impact on the ability to collect kaimoana from Mair Bank (based on erosion of Mair Bank) which may impact the ability to collect kaimoana (particularly pipi) sustainability	3
Kaimoana at Marsden Bank	Impact on the ability to collect kaimoana from Marsden Bank (based on erosion of Marsden Bank) which may impact the ability to collect kaimoana sustainability	3
Taonga species	Impact on native birds, plants and animals of special cultural significance and importance to tangata whenua	3
Mahinga Mataitai	Impacts on other key traditional mahinga mataitai and fishing grounds	3
Mauri of Harbour	Impact on the mauri of the harbour, including the potential impact of sand removal from system	3
Cultural Landscapes and Seascapes	Impacts on important markers including Manaia, Matariki, Te Whara, the Takahiwai and Pukekauri Ranges and islands including Tatanga	3
Kaitiakitanga	Impact on the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga in regard to resources	3
Subsurface Archaeological Sites	Impact on subsurface archaeological sites, including shipwrecks	3
Land-based Archaeological sites	Impact on natural and physical resources that contribute to an understanding and appreciation of New Zealand's history and cultures	3
Economic		
Indirect impacts		
Impact on intakes and outfalls	Potential impact on intakes and/or outfalls (blocking) excluding NIWA operations	0.5
NIWA Operations	Potential impact on NIWA aquaculture operations (Abalone)	2
Commercial Fishing	Shellfish and fish	3
Navigation	Potential effects on navigational safety due to channel alignment	3
Project Safety	Risk associated with undertaking the option [environmental and workplace health and safety (WHS)] linked to methodology and programme duration	3
Direct impacts		
Legal	Jurisdictional and practical issues associated with consenting each option	2
Maintenance	Degree to which deposition site or channel alignment impacts cost of maintenance	2
Revenue	The amount of revenue generated via beneficial reuse	0.5
Cost	Total cost of option	3

3.2 Impact assessment

The expert team provided an impact assessment across each of the aspects, for each of the channel alignment, dredge disposal site and dredge methodology options based on the categories summarised in Table 2.3. Impacts were discussed and agreed or revised as part of the initial findings workshop.

Table 2-3: Summary of impact categories

-1	0	1	2	3
Positive impact on the aspect being considered	Neutral or no impact on the aspect being considered	Minor impact on the aspect being considered Impact is can be avoided or remediated. Recovery expected to occur in less 1-2 years	Moderate impact of the aspect being considered Impact is difficult to avoid or remediate. Recovery expected to occur over up to 5-years	Major negative impact on the aspect being considered Impact is very difficult to avoid or remediate. Impact permanent or recovery expected to take longer than 5-years

Impact scores are combined with the weighting to provide an overall score for each aspect. The weighted impact assessment scores are reported in the following sections. Results can be interpreted as a lower number being more favourable.

3.3 Normalisation

Results are normalised so that natural, social, cultural and economic criteria are treated equally within the assessment, regardless of the number of aspects identified within each of the four environments.

Results are also provided excluding direct costs to RNZ linked to consenting (legal), project and maintenance costs, as well as any revenue (if any) which could be derived from the beneficial reuse of dredge material. This allows a view of the project as perceived by external stakeholders, who are less sensitive to RNZ costs / benefits, and potentially more interested in the balance of broader costs and benefits.

3.4 Sensitivity assessment

Three aspects of data treatment were explored with regards to the impact on results:

- weighted versus unweighted results
- normalised versus normalised results
- inclusion versus exclusion of direct project costs.

The overall ranking of the options was not impacted by weightings or normalisation. There is an impact of excluding direct costs on the relative difference between the options for channel alignment, which is due to project and navigational safety being better expressed when direct costs are removed. As there is an impact, results are presented including and excluding direct costs for full transparency.

4 Summary of key issues

The following section summarises the key issues for each aspect as determined by the relevant expert team member(s), and agreed with the full group at the findings workshop. The complete tabularised MCA results are provided in Appendix E

The following aspects were raised across the expert team as key potential impacts, and were weighted highly:

Mair Bank: the importance of retaining sediment within the system, and in particular the impact on the stability of Mair Bank. Mair Bank has been an important location for the collection of pipi by iwi and local residents. Over recent years the pipi population has been in decline, and the mussel population has been increasing. It is important to recognise that this system is going through a period of change in advance of the commencement of this project, which has heighted iwi and community concerns regarding any impact of the project on Mair Bank. Disposal of dredge material at the inner locations (Option 1.2, 2.2 & 3.2), and in particular disposal Option 1.2, allows for the retention of material within the system to potentially replenish Mair Bank (see section 3.5).

Areas with special ecological or conservation value: there are four areas designated as having particular conservation value within the Regional Coastal Plan (i.e. M1MA) which extend from Home Point to Busby Head. Of particular note are the hard-bottomed communities, comprising sponge gardens and kelp beds[4], which are subject to smothering by disturbed sediment. When compared to channel alignment options 2.2 and 5, option 4.2 has the widest clearance of these communities. The nature of the sandy substrate means that disturbed material will likely settle quickly and not travel to the point it will interact with these communities. The proposed dredge and disposal sites are soft bottomed areas of seabed that support a benthic community that is considered typical of the coastal environment off the north east coast of the North Island, which is not of regional or national significance[4].

Cultural values: a range of potential impacts have been identified as part of the Cultural Values Assessment and engagement with Patuharakeke Te Iwi Trust Board), including impacts on traditional fishing areas (Mahinga Mataitai) and access to kaimoana, taonga species and the mauri of the harbour. It is recommended that RNZ continue to engage with iwi to fully understand perceived impacts and options for mitigation.

Navigational and project safety: a key consideration in the selection of the channel alignment is the outcome from a navigational safety perspective. Option 4.2 has been found to perform the best from a navigational safety perspective due to the reduction in the number of headings required, and notably ensuring no course changes around the rocky outcrop at Home Point. From a project safety perspective the offshore disposal options present increased environmental risk, as well as increased cost, and hence inner options are considered preferable for the majority of the capital dredge disposal.

[4] Brian T. Coffey and Associates Limited (October, 2016), AEE: RNZ Marine Ecology 3. 67 pp.

4.1 Marine mammals

Expert input on weightings and potential impacts on marine mammals was provided by Cawthron Institute. Impacts on marine mammal navigation and feeding were considered the most material. Baleen Whales are likely to be the most impacts based on the frequency of nose predicted to be associated with the project. Overall, key aspects identified from a marine mammals perspective included:

- increased noise may lead to a permanent or temporary threshold shift or auditory masking which may impact behaviour of marine mammals
- the physical presence of dredge vessels presents the risk of entanglement or strike
- turbidity plumes may impact behaviour and feeding patterns due to the changes in prey distribution.

The options assessment (summarised in Table 3-1) concluded that from a marine mammal perspective:

Disposal: beach nourishment is preferred, with the nearshore option the next best alternative due to limited likely interaction with marine mammals. Ebb Delta and Intermediate sites are the least preferred options due to the potential for physical interaction with marine mammals.

Alignment: limited difference in the impacts associated with channel alignment.

Methodology: operational noise levels are fairly similar across the methods, with backhoe dredges sometimes 'noisier' due to their use in excavating fractured rock and coarser gravels[5]. Any reduction in sediment in the water column is considered important. Ebb tide preferable to all tide dredging, due to the respite in operations; however, it is recognised that this may be offset by the overall duration of the project.

Table 4-1: Summary of potential effects on marine mammals

Category			Natural
Aspect			Direct impacts Impact on marine mammals
Description			Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)
Dredge Disposal	1.2	Ebb Delta	4
	2.2	Nearshore	2
	3.2	Intermediate	4
	4	Land based disposal	0
	5	Beach nourishment	0
	6	Deep water	2
	7	Outside EEZ	2
Channel	2	Existing mid-section	2
	4.2	Straight mid-section (west)	2
	5	Straight mid-section (east)	4
Dredge Methodology	1a	Trailer (with central weir)	4
	1b	Trailer (actual overflow)	4
	2	Cutter	4
	3	Backhoe	4
	i	Ebb Tide Dredging	0
	ii	All Tide Dredging	2

[5] Central Dredging Association, CEDA, (2011) Underwater Sound in Relation to Dredging, CEDA Position Paper 7 November 2011. 6 pp.

4.2 Shore and pelagic birds

Table 4-2: Summary of potential effects on Shore and pelagic birds

Category			Natural
			Direct impacts
Aspect			Impact on shore birds & pelagic birds
Description			Direct impact on feeding and nesting sites and indirect impacts on mating due to noise, light and general activity in the area
Dredge Disposal	1.2	Ebb Delta	4
	2.2	Nearshore	4
	3.2	Intermediate	2
	4	Land based disposal	0
	5	Beach nourishment	4
	6	Deep water	2
	7	Outside EEZ	2
Channel	2	Existing mid-section	2
	4.2	Straight mid-section (west)	2
	5	Straight mid-section (east)	4
Dredge Methodology	1a	Trailer (with central weir)	2
	1b	Trailer (actual overflow)	4
	2	Cutter	2
	3	Backhoe	2
	i	Ebb Tide Dredging	2
	ii	All Tide Dredging	4

Expert input on weightings and potential impacts on shore and pelagic birds (including species which are targeted by recreational hunters) was provided by Bioresearches based on research undertaken over numerous breeding seasons.

Impacts on habitat (feeding and roosting) were considered, as well as potential collision with dredge operations. Key issues identified included:

- proximity of dredge disposal sites to nesting and feeding sites (e.g. Bream Bay Beach, Ruakaka and Waipu Estuaries, Marsden Bay)
- impact of beach nourishment on areas of potential high ecological value
- proximity to Home Point Shag nesting colony which is home to the Pied Shag which is nationally threatened
- an illuminated dredger off Busby Head may present a collision risk for (juvenile) Grey Faced Petrels.

The options assessment (summarised in Table 3-2) concluded that from a shore and pelagic birds' perspective:

Disposal: land based disposal (not beach nourishment) preferred, with the Intermediate and Deep Water options the next best alternatives.

Alignment: limited difference in the impacts associated with channel alignment. Option 5 least preferred due to the proximity to Home Point.

Methodology: all tide dredging least preferred due to overall greater risk of disturbance of shore and pelagic birds' habitat and behaviour.

4.3 Marine ecology (excluding marine mammals and avifauna)

Table 4-3: Summary of potential effects on marine ecology (excluding marine mammals and avifauna)

Category			Natural						
Aspect			Direct impacts						
			Impact on benthic flora & fauna at site	Impact on local fish stocks	Sediment matching	Contamination	Impact on intertidal and subtidal flora and fauna	Impact on significant ecological habitats or species of flora and fauna within those habitats	Impact on reef
Description			Impact on ecological communities removed or smothered	Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)	Degree to which the deposit would match the existing substrate	Potential for any existing contaminats to be spread	Potential to impact areas with important conservation value	Potential to impact areas with important conservation value	Potential to impact known area of hard shore biological diversity
Dredge Disposal	1.2	Ebb Delta	4	2	2	0	-2	6	4
	2.2	Nearshore	4	2	0	0	2	3	2
	3.2	Intermediate	2	2	0	0	2	3	2
	4	Land based disposal	0	0	0	0	0	0	0
	5	Beach nourishment	0	0	0	0	0	0	0
	6	Deep water	4	2	4	0	2	0	0
	7	Outside EEZ	2	2	4	0	2	0	0
Channel	2	Existing mid-section	2	2		0	2	6	4
	4.2	Straight mid-section (west)	2	2		0	2	6	4
	5	Straight mid-section (east)	4	4		0	4	9	6
Dredge Methodology	1a	Trailer (with central weir)	2	2		0	2	3	0
	1b	Trailer (actual overflow)	4	4		0	4	9	4
	2	Cutter	2	2	0	0	4	3	0
	3	Backhoe	4	4	0	0	4	3	0
	i	Ebb Tide Dredging	2	2	0	0	2	3	2
	ii	All Tide Dredging	4	4	0	0	4	9	4

Expert input on weightings and potential impacts on marine and coastal ecology was provided by Brian Coffey & Associates. Potential impact on the areas of important conservation value is of particular concern. Key Issues from an ecological perspective included:

- potential impact on the four areas of important conservation value set out in the Operative Northland Coastal Management Plan, including the high value hard-bottomed communities from Home Point to Busby Head which are vulnerable to smothering
- potential impact on Three Mile Reef from increased turbidity
- sand supply to Mair Bank and flow-on impacts on biodiversity on the bank.

Contamination is an important aspect considered within the assessment (note a weighting of 3 in Table 2-2). A number of different sampling exercises were undertaken by members of the expert panel as part of characterising the existing environment including sampling of the proposed channel alignment area: Bioresearches identified 107 sampling points to characterise the seabed sediment quality and biota present in or near the area to be dredged, with an additional five sites up-harbour from the dredge area, and five sites beyond the dredge area offshore[6].

[6] Bioresearches (September, 2016) Existing Environment Assessment: Ecology of the Dredge Area, Whangarei Heads. 210 pp.

Sediment chemistry and particle size were assessed at all sites to ascertain the risk associated with the disturbance of this material during dredging. The chemistry results were compared against the ANZECC interim sediment quality guidelines (where available). None of the surface sediment samples exceeded the ANZECC ISQG Low values with exception of Fluoranthene, Phenanthrene and Pyrene at site C26S (located 250 m seawards of the Refining NZ wharf along the slope of the channel edge). This minor exceedance was not considered material and the study concluded that no adverse effects are expected to occur from the redistribution of sediments during dredging or from the disposal of the dredge spoil at a nearby marine disposal site[7].

In a separate sampling exercise, a suite of 26 Vibrocore samples were taken from the dredging area to characterise the existing environment[8]. Interpretation of the contamination results by Brian T. Coffey and Associates[9] included that the thresholds of potential concern for heavy metals (as defined by ANZECC guidelines) were approached for Nickel in sample V19A and exceeded for sample V20 (both samples were taken in the outer reaches of the dredge footprint on approach to the harbour). Sample V20 also exceeded the *Effects Range-Low*. The analysis of back-up samples for both cores were submitted for additional elutriate testing and a full range of organic analyses, the results of which support the conclusion there are no issues with the potential contamination status of material to be disposed of from the proposed dredging footprint[9].

The options assessment (summarised in Table 3-3) concluded that from an ecology perspective:

- Disposal: onshore disposal is preferred with Intermediate option the next best alternative. Outside the EEZ is also considered a preferable option due to no potential impact on areas of important conservation value. For the same reason the ebb delta option is the least preferred option. Overall there is the need to balance the overall footprint of the disposal area with avoiding the complete smothering of benthic communities.
- Alignment: channel option 5 is the least preferred due to the proximity to Home Point, and option 4.2 is preferred due to overall reduction of risk during operation.
- Methodology: consideration should be given to using methods which reduce turbidity when this is an issue based on substrate density, particularly when in proximity of the areas of important conservation value and Home Point.

7 Bioresearches (September, 2016) Existing Environment Assessment: Ecology of the Dredge Area, Whangarei Heads. 210 pp.

8 Tonkin & Taylor (April, 2016) Marsden Point Refinery – Crude Freight Project. Geotechnical Factual Report. 255 pp.

9 Brian T. Coffey and Associates Limited (October, 2016) AEE: RNZ Marine Ecology 3. 67 pp.

4.4 Turbidity

Table 4-4: Summary of potential turbidity impacts

Category			Natural	
			Direct impacts	
Aspect			Turbidity (dredge location)	Turbidity (disposal location)
Description			Potential for movement of sand from site and impacts on water quality (colour and clarity)	Potential for movement of sand from site and impacts on water quality (colour and clarity)
Dredge Disposal	1.2	Ebb Delta		2
	2.2	Nearshore		2
	3.2	Intermediate		2
	4	Land based disposal		0
	5	Beach nourishment		0
	6	Deep water		2
	7	Outside EEZ		2
Channel	2	Existing mid-section	2	
	4.2	Straight mid-section (west)	2	
	5	Straight mid-section (east)	2	
Dredge Methodology	1a	Trailer (with central weir)	2	4
	1b	Trailer (actual overflow)	4	4
	2	Cutter	4	4
	3	Backhoe	4	2
	i	Ebb Tide Dredging	2	0
	ii	All Tide Dredging	4	0

Expert input on weightings and potential turbidity impacts were provided by Royal HaskoningDHV[10] and Tonkin + Taylor (using data modelled by MetOcean).

Impacts are split to reflect different potential turbidity impacts from dredging and disposal. While it is recognised that turbidity is a key issue for all marine flora and fauna, and the local community from ecological, recreational, cultural and aesthetic perspectives, the predominance of coarser, heavier sediments across the dredge area indicate that disturbed sediment will generally fall out of the plume quickly causing minimal impact (see MetOcean, 2016).

The options assessment (summarised in Table 3-4) concluded that:

Disposal: minimal turbidity changes are anticipated at all ocean disposal sites, although beach nourishment and land based disposal options are preferred, as there are potentially very limited turbidity impacts associated with these options.

Alignment: minimal turbidity changes are anticipated at all dredge locations.

Methodology: it is recognised that all tide dredging could create more turbidity than ebb tide dredging, although this is dependent on the substrate type. Equally, as a general methodology, controlling overflow via a central weir reduces turbidity plumes, but this is unlikely to be an issue across the project site due to sediment composition.

CSD and backhoe both have potential to affect turbidity in particular ways; however, these methodologies are not necessarily interchangeable or mutually exclusive and may have to be used at different points along the alignment for different purposes.

[10] Royal HaskoningDHV (May, 2016) Technical Memo: Dredging Assessment Methodology. Reference M&APA1028N006D04. 42 pp.

4.5 Physical environment

Table 4-5: Summary of potential impacts on the physical environment

Category			Natural				
Aspect			Direct impacts	Indirect impacts			
			Sediment matching	Coastline formation	Natural character and underwater seascape (biophysical)	Coastal erosion	Resilience
Description			Degree to which the deposit would match the existing substrate	Potential for deposition to occur to a level greater than normal coastal processes	Significance of the impact on the natural character values & 'landscape' of the sea floor	Potential for erosion to occur to a level greater than normal coastal processes	Impact on resilience of the coastal system based on volume of sand removed / deposited
Dredge Disposal	1.2	Ebb Delta	2	-2	1	-2	-3
	2.2	Nearshore	0	0	1	2	6
	3.2	Intermediate	0	0	2	2	6
	4	Land based disposal	0	-2	0	0	0
	5	Beach nourishment	0	-2	0	-2	-3
	6	Deep water	4	0	1	2	6
	7	Outside EEZ	4	0	1	2	6
Channel	2	Existing mid-section		0	1	0	
	4.2	Straight mid-section (west)		0	1	0	
	5	Straight mid-section (east)		0	2	0	
Dredge Methodology	1a	Trailer (with central weir)					
	1b	Trailer (actual overflow)					
	2	Cutter	0				
	3	Backhoe	0				
	i	Ebb Tide Dredging	0				
	ii	All Tide Dredging	0				

Expert input on weightings and potential impacts on coastal geomorphology was provided by Tonkin + Taylor using data provided by MetOcean. Information on changes to natural character was also provided by Brown Ltd.

Overall, the potential impacts are driven by the location of dredge disposal site(s). Key findings from a physical environment perspective included:

- the benefits of keeping sediment within the system including:
  - aiding the long term stability of Mair Bank
  - creating long term resilience to storms and climate change effects
  - conserving the sediment budget on the ebb delta.
- matching 'like with like' minimises biological and geomorphological effects

- negligible impact on natural character and the underwater seascape (biophysical)[11].

The options assessment (summarised in Table 3-5) concluded that from a resilience perspective there is merit in utilising the ebb delta site (Option 1-2) for disposal of at least some small proportion of the capital dredge material (recognising that the site is not suitable to take the entire volume of the capital dredge), and for disposal of ongoing maintenance dredging[12]. The Nearshore option is the next best alternative for the remaining capital volume. Offshore options are the least preferred due to sediment matching and the dredged material leaving the system.

4.6 Social impact

It is recognised that the area is significant recreation area, particularly with regards to boating and fishing. Expert input on issues of importance to the community and weightings was provided by Rob Greenaway & Associates. Potential impact scores were provided by:

- Brian Coffey & Associates: fishing
- Bioresearches: wildfowl hunting
- Tonkin + Taylor (based on data provided by MetOcean): coastal landform and currents and subsequent impacts on recreation
- Brown Ltd: natural character, visual amenity and the impact of light and noise.

The options assessment (summarised in Table 3-6) concluded that:

- there is the potential for a temporary decrease in fish stocks in the disturbed areas, but there will be no permanent impact on fishing. It is noted that the disturbance will cause fish to relocate, as opposed to reducing overall fish numbers.
- there is the possibility of improved beach access in the longer term if ebb delta and / or beach nourishment options are utilised.
- impact on natural character (perceptual) is likely to be limited.
- all channel options will result in the addition of new navigational aids, which may be considered a change in amenity value by some; however, these will be dwarfed by the existing character. There will also be temporary amenity impacts (light and noise) associated with dredge activities. For this reason channel alignment option 5 is the least preferred due to its proximity to shore and required dredging of hard rocky material at Home Point.
- there is a preference for all tide dredging over ebb tide dredging due to the decreased duration of temporary impacts on amenity values.

[11] Brown and Associates (October, 2016) Landscape & Natural Character Effects – Key Findings. 3 pp.

[12] Tonkin & Taylor (November, 2016). Crude Freight Shilling Project, Whangarei Harbour: Coastal Processes Assessment – Consultation Draft. Version 6. 160 pp.

Table 4-6: Summary of potential social impacts

Category			Social										
Aspect			Longer-Term Impacts									Temporary Impacts	
			Fishing	Hunting	Watercraft sports	Watercraft sports	Wave sports	In-water activities	Beach access	Natural Character & underwater seascape (perceptual)	Permanent effects of navigation lights	Temporary amenity effects (light spill & noise emissions above water)	Temporary visual amenity & landscape
Description			Impact on recreational fishing (access or stocks) by boat, from shore or diving. Includes fin and shellfish	Impact on duck hunting on- or near-shore	Impact on on-water sports (e.g. yachting, rowing, waka ama, windsurfing, canoeing, jet skiing, boating)	Impact on boating communities associated with relocation of the navigation buoys	Impact on wave sports (e.g. kite surfing, wind surfing and surfing) due to changes in surf breaks	Impact on in-water activates (e.g. diving, swimming) due to changes in turbidity, currents, wave profile	Changes to beach access	Significance of the impact on the natural character values & 'landscape' of the sea floor	Impact on local and visitor communities associated with new Navaid structures	Impact on local community from light and noise associated with dredge operations	Aesthetic impacts on local community associated with dredge operations
Dredge Disposal	1.2	Ebb Delta	3	0	3		3	0	-3			0	0
	2.2	Nearshore	3	0	0		3	0	0			0	0
	3.2	Intermediate	3	0	0		0	0	0			0	0
	4	Land based disposal	0	0	0		0	0	0			0	0
	5	Beach nourishment	0	0	0		0	0	-3			0	2
	6	Deep water	3	0	0		3	0	0			0	0
	7	Outside EEZ	3	0	0		0	0	0			0	0
Channel	2	Existing mid-section	3	0	0		0	0	0	1	1	2	2
	4.2	Straight mid-section (west)	3	0	0		0	0	0	1	1	2	2
	5	Straight mid-section (east)	6	0	0		0	3	0	1	1	4	4
Dredge Methodology	1a	Trailer (with central weir)	3	0	0		0	0	0			2	2
	1b	Trailer (actual overflow)	6	0	0		0	0	0			4	4
	2	Cutter	3	0	0		0	0	0			2	4
	3	Backhoe	6	0	0		0	0	0			4	4
	i	Ebb Tide Dredging	6	0	0		0	0	0			4	4
	ii	All Tide Dredging	3	0	0		0	0	0			2	2

4.7 Tangata whenua

There have been eight hui held since 2014, resulting in the publication of the Cultural Values Assessment[13] which considers short and longer term potential impacts across the four wellbeing's (natural, social, cultural and economic). This report formed the basis of the MCA assessment, with additional input from the report's co-author, Juliane Chetham on behalf of the hapu represented by the Patuharakeke Te Iwi Trust Board. There are real concerns from tangata whenua that the project may impact:

- their ability to collect kaimoana from Mair Bank[14], Marsden Bank and from other key traditional mahinga mataitai and fishing grounds
- taonga species
- the mauri of the harbour, and in particular the impact of sand removal from system
- important markers including Manaia, Matariki, Te Whara, the Takahiwai and Pukekauri Ranges and islands including Tatanga
- the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga in regard to resources.

As Table 3-7 shows, potential impacts are perceived to be generally high for all dredge disposal and channel options:

- Disposal: there is concern that fishing areas (other than Mair Bank) may be affected to a greater extent by ebb delta (Option 1.2) and nearshore disposal (Option 3.2). Overall, land based disposal (Option 4) or disposal outside the EEZ (Option 7) are preferred.
- Alignment: Option 5 is the least preferred, and Options 2 and 4.2 are perceived to have similar impacts. Option 2 slightly preferable based on impacts on taonga species and the ability of iwi to perform their role as kaitiaki (i.e. because there will be benthic communities removed (even if they will recover) iwi do not consider that they are able to fulfil their role as kaitiaki / stewards). There may be options to mitigate and monitor direct impacts of the project and restore iwi role as kaitiaki.
- Methodology: ebb tide dredging is preferred to all tide dredging, as is controlling overflow via a central weir, due to the potential decrease in turbidity generated.

[13] Patuharakeke Te Iwi Trust Board Inc (January, 2015) Cultural Values Assessment Report: Refining NZ Ltd – Crude Freight Proposal. 23 pp.

[14] It has been reported that the population of pipis on Mair Bank has been decreasing for some time, and that the mussel population has been subsequently increasing. While the cause of these changes is not fully documented, the fact that the ecosystem is in change needs to be noted in the context of future expectations of collecting pipi from Mair Bank, with or without this dredging project.

Table 4-7: Summary of potential cultural impacts from a tangata whenua perspective

Category			Cultural								
Aspect			Kaimoana at Mair Bank	Kaimoana at Marsden Bank	Taonga species	Impact on Mahinga Mataitai	Mauri of Harbour	Cultural Landscapes and Seascapes	Kaitiakitanga	Subsurface Archaeological Sites	Land-based Archaeological Sites
Description			Impact on the ability to collect kaimoana from Mair Bank (based on erosion of Mair Bank) which may impact the ability to collect kaimoana (particularly pipi) sustainability	Impact on the ability to collect kaimoana from Marsden Bank (based on erosion of Marsden Bank) which may impact the ability to collect kaimoana sustainability	Impact on native birds, plants and animals of special cultural significance and importance to tangata whenua	Impacts on other key traditional mahinga mataitai and fishing grounds	Impact on the mauri of the harbour, and in particular the potential impact of sand removal from system	Impacts on important markers including Manaia, Matariki, Te Whara, the Takahiwai and Pukekauri Ranges and islands including Tatanga	Impact on the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga in regard to resources	Impact on subsurface archaeological sites, including shipwrecks	Impact on natural and physical resources that contribute to an understanding and appreciation of New Zealand's history and cultures
Dredge Disposal	1.2	Ebb Delta	3	6	6	6	6	3	3	0	0
	2.2	Nearshore	3	3	6	6	3	3	3	0	0
	3.2	Intermediate	3	3	3	6	3	3	3	0	0
	4	Land based disposal	0	0	0	0	3	0	0	0	0
	5	Beach nourishment	0	0	3	3	3	3	3	0	0
	6	Deep water	0	0	3	3	3	0	3	0	0
	7	Outside EEZ	0	0	0	0	3	0	0	0	0
Channel	2	Existing mid-section	6	6	3	6	6	3	3	0	0
	4.2	Straight mid-section (west)	6	6	6	6	6	3	6	0	0
	5	Straight mid-section (east)	6	6	9	9	9	6	9	0	0
Dredge Methodology	1a	Trailer (with central weir)	6	6	6	3	3	3	3		
	1b	Trailer (actual overflow)	9	9	9	9	9	6	6		
	2	Cutter	6	6	6	6	6	3	3		
	3	Backhoe	6	6	6	3	6	3	3		
	i	Ebb Tide Dredging	6	6	3	3	3	3	3		
	ii	All Tide Dredging	9	9	6	6	6	6	6		

4.8 Archaeology

Information on potential impacts on archaeological sites was provided by Clough & Associates.

There is not perceived to be any likely direct impact to either subsurface or land-based archaeological sites as a result of any of the proposed options (see Table 3-8). This finding is based on a study completed for Northland Regional Council in 2015[15] as well as additional desktop research undertaken on behalf of RNZ.

Consideration of indirect impacts of changes to currents and wave heights as a result of the project was also considered to be minimal[16].

Table 4-8: Summary of potential impacts on archaeological sites or other areas of cultural significance

Category			Cultural	
Aspect			Subsurface Archaeological Sites	Land-based Archaeological Sites
Description			Impact on subsurface archaeological sites, including shipwrecks	Impact on natural and physical resources that contribute to an understanding and appreciation of New Zealand's history and cultures
Dredge Disposal	1.2	Ebb Delta	0	0
	2.2	Nearshore	0	0
	3.2	Intermediate	0	0
	4	Land based disposal	0	0
	5	Beach nourishment	0	0
	6	Deep water	0	0
	7	Outside EEZ	0	0
Channel	2	Existing mid-section	0	0
	4.2	Straight mid-section (west)	0	0
	5	Straight mid-section (east)	0	0
Dredge Methodology	1a	Trailer (with central weir)		
	1b	Trailer (actual overflow)		
	2	Cutter		
	3	Backhoe		
	i	Ebb Tide Dredging		
	ii	All Tide Dredging		

[15] Brown, A., R. Clough with S. Bickler. 2015. Northland Coastal and Freshwater Heritage Survey: Identification of Historic Heritage Resources (Draft report for Northland Regional Council) cited in Clough & Associates (April, 2016). Marsden Refinery Whangarei Harbour Dredging: Archaeological Assessment. Draft. 25 pp.

[16] Clough & Associates (April, 2016). Marsden Refinery Whangarei Harbour Dredging: Archaeological Assessment. Draft. 25 pp.

4.9 Indirect economic impacts

Table 4-9: Summary of potential broader economic impacts

Category			Economic		
Aspect			Indirect Impacts		
			Impact on intakes and outfalls	NIWA Operations	Commercial Fishing
Description			Potential impact on intakes and/or outfalls (blocking). Excluding NIWA operations.	Potential impact on NIWA aquaculture operations (Abalone)	Shellfish and fish
Dredge Disposal	1.2	Ebb Delta	1	2	0
	2.2	Nearshore	0	0	6
	3.2	Intermediate	0	0	3
	4	Land based disposal	0	0	0
	5	Beach nourishment	0	0	0
	6	Deep water	0	0	0
	7	Outside EEZ	0	0	0
Channel	2	Existing mid-section	0	0	0
	4.2	Straight mid-section (west)	0	0	0
	5	Straight mid-section (east)	0	0	3
Dredge Methodology	1a	Trailer (with central weir)	0	0	0
	1b	Trailer (actual overflow)	0	0	0
	2	Cutter	0	0	0
	3	Backhoe	0	0	0
	i	Ebb Tide Dredging	0	0	0
	ii	All Tide Dredging	0	0	0

These aspects are intended to cover the impacts on broader economic activity in the area. Expert input on weightings and potential impacts was provided by:

- Tonkin + Taylor: impact on commercial intakes and outfalls, including those that are connected to NIWA's commercial abalone production facility, with input from RNZ.
- Brian Coffey & Associates: impact on commercial fishing, with input from Rob Greenaway & Associates, Juliane Chetham (Patuharakeke Te Iwi Trust Board) and RNZ.

Potential impacts are limited to:

- impacts on intakes and outfalls, which will be minimised by further refinements in the location of disposal sites
- impacts on commercial fish / shellfish stocks. A range of species are taken by commercial fisheries, including scallops as well as fin fish. While there may be a decrease of catch in the dredging and disposal areas, fin fish will move, as opposed to being depleted, and the impact of smothering may be minimised at the disposal site(s) by controlling the depth of the dredge material deposited and harvesting prior to dredging.

In addition, broader economic cost / benefit assessment undertaken by NZIER confirmed a positive impact on the regional economy as a result of the continued operation of the refinery.

4.10 Navigational and programme safety

Impacts on programme and long-term navigational safety were provided by Royal HaskoningDHV.

Navigational safety is a project non-negotiable.

Navigational and project safety both have been allocated a weighting of three to reflect the environmental, social and cultural values at stake.

As summarised in Table 3-10, and by Royal HaskoningDHV in their channel design report (June 2016), channel alignment option 4.2 has significant advantages over Options 2 and 5. It is important to note it that it has been determined that Option 4.2 is the only option which significantly improves navigational safety from the status quo.

Equally, programme safety is a non-negotiable, as this covers the safety of the crew and vessels involved in dredge operations, as well as potential interaction with other vessels and their crews.

Programme duration is also included as an aspect of programme safety, as the likelihood of an incident occurring naturally increases with time at sea. As noted in previous sections, aspects of methodology, such as ebb tide dredging, impact the duration of the programme. The distance of the disposal site from the dredge location also has the potential to significantly influence the programme.

The assessment in Table 3-10, excludes the direct costs associated with programme duration, such as vessel hire and crew time, as these are accounted for in Section 3.11 (direct economic impacts).

Table 4-10: Summary of potential broader safety issues

Category			Economic	
Aspect			Indirect Impacts	
			Navigation	Project Safety
Description			Potential effects on navigational safety due to channel alignment	Risk associated with undertaking the option (environmental and WHS) linked to methodology and programme duration
Dredge Disposal	1.2	Ebb Delta		6
	2.2	Nearshore		3
	3.2	Intermediate		3
	4	Land based disposal		6
	5	Beach nourishment		6
	6	Deep water		6
	7	Outside EEZ		9
Channel	2	Existing mid-section	0	3
	4.2	Straight mid-section (west)	-3	3
	5	Straight mid-section (east)	9	9
Dredge Methodology	1a	Trailer (with central weir)	0	3
	1b	Trailer (actual overflow)	0	3
	2	Cutter	0	9
	3	Backhoe	0	6
	i	Ebb Tide Dredging	0	6
	ii	All Tide Dredging	0	3

The options assessment (summarised in Table 3-10) concluded that from a programme safety perspective:

Disposal: Nearshore and Intermediate disposal sites are preferred due to the reduced time and costs (as well as risk) associated with shorter transit distances. The EEZ is the least favoured disposal site due to extra time and cost (and risk) associated with transport of dredge material.

Alignment: Options 2 and 4.2 result in similar project safety and programme outcomes. Option 5 raises some technical difficulties with regards to the potential for requiring either removal of boulders and/or drill and blasting.

Methodology: methodologies which speed up operations and improve mobility result in better programme outcomes, due to reduced risk exposure time. Therefore all tide dredging is preferred and the CSD and backhoe don't score as well.

4.11 Direct economic impacts

Impacts on costs and other direct project elements, including legal and planning considerations, were provided by Royal HaskoningDHV (cost), ChanceryGreen (legal) and RNZ.

Legal, revenue and cost aspects (Figure 3-11) cover potential impacts associated with the capital dredging programme only. The maintenance aspect covers how channel alignment and capital dredge disposal may impact the need for maintenance dredging in the future.

The options assessment (summarised in Table 3-11) shows that for:

Disposal: overall Nearshore and Intermediate disposal sites are preferable.

Alignment: channel alignment options 2 and 4.2 result in similar impacts, and Option 5 is least preferred overall.

Methodology: the more complex methodologies (CSD and backhoe) increase time and cost in this case. All tide dredging is most effective from a time and cost perspective.

Table 4-11: Summary of potential direct economic impacts as a result of the project

Category			Economic			
Aspect			Direct Impacts			
			Legal	Maintenance	Revenue	Cost
Description			Potential effort associated with consenting each option	Degree to which deposition site or channel alignment impacts cost of maintenance	The amount of revenue generated via beneficial reuse	Total cost of option
Dredge Disposal	1.2	Ebb Delta	2	-2	0	6
	2.2	Nearshore	0	0	0	3
	3.2	Intermediate	0	0	0	3
	4	Land based disposal	4	0	-0.5	6
	5	Beach nourishment	4	0	-0.5	6
	6	Deep water	2	0	0	6
	7	Outside EEZ	6	0	0	9
Channel	2	Existing mid-section	2	2		3
	4.2	Straight mid-section (west)	2	2		3
	5	Straight mid-section (east)	4	2		9
Dredge Methodology	1a	Trailer (with central weir)				3
	1b	Trailer (actual overflow)				3
	2	Cutter				6
	3	Backhoe				9
	i	Ebb Tide Dredging				6
	ii	All Tide Dredging				3

5 Results

5.1 Preferred channel alignment

Options 2 and 4.2 performed very similarly in the assessment overall (Table 4-1), while Option 5 is the least preferred option. The key consideration in the selection of the channel alignment is the outcome from a navigational safety perspective. As Option 4.2 has been found to perform the best from a navigational safety perspective due to the reduction in the number of headings required, and notably ensuring no course changes around the rocky outcrop at Home Point, it is recommended that this option is progressed over Option 2.

Table 4-1: Channel alignment options (weighted)

Options	Natural	Social	Cultural	Economic	Total normalised	Total (excluding RNZ direct economic impacts)
2	1.9	0.9	3.7	1.3	7.7	7.1
4.2	1.9	0.9	4.3	0.9	8.0	7.2
5	3.3	1.9	6.0	4.5	15.7	15.4
* direct economic impacts include legal, revenue and cost and implications for ongoing maintenance						

From a natural and social perspective, Options 2 and 4.2 are identical in terms of scoring and potential impacts. Option 4.2 is the furthest away from the known areas of high conservation value and hard shore biological diversity. Avoiding Home Point also means that Option 4.2 is also likely to result in fewer temporary amenity impacts (light, noise and visual) on the local community.

From an economic perspective, the impacts are also perceived to be the same for all aspects, other than navigational safety.

From a cultural perspective Option 2 did raise fewer concerns for taonga species and the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga, with regards to resources due to the perception that channel Option 2 follows the existing alignment more closely than Option 4.2.

In progressing channel Option 4.2, the most material issues to address are:

- potential impacts on areas of important conservation value and taonga species
- impact on the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga with regards to resources.

As shown in Figure 4-1, there is particular concern about the potential cultural impacts. It is recommended that RNZ continue to work proactively with tangata whenua when defining both the potential and actual effects, and the measures that are advanced to ensure that any adverse effects are appropriately avoided, remedied or mitigated.

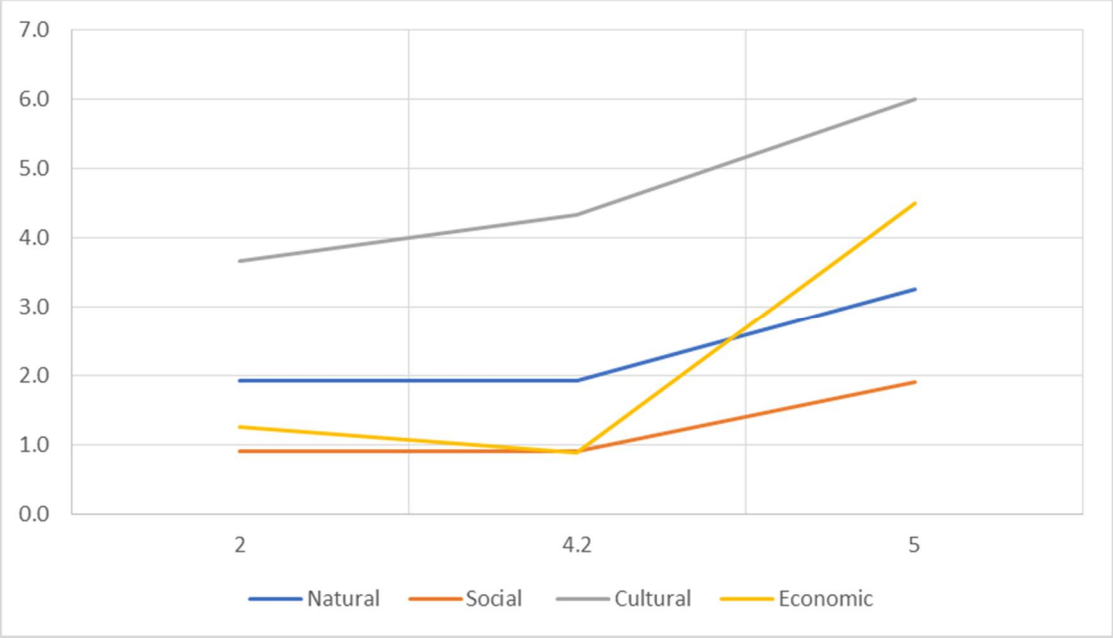


Figure 5-1: Channel alignment options (weighted)

Recommendations: progress channel alignment Option 4.2 paying particular attention to effects and mitigation options for impacts on areas of important conservation value, taonga species and the role of iwi as kaitiaki. Continue to engage with iwi to fully understand impacts and options for mitigation.

5.2 Preferred disposal options

Land based disposal options (Options 4 & 5) are preferred overall (Table 4-2), and it is therefore recommended that they are progressed where practicable. However, as there are no specific land based disposal or beneficial reuse options defined at present, there will likely be a range of additional costs and benefits associated with these options if and when specific locations are identified. Further, at this the stage of the proposal, the aspects identified as part of the MCA are necessarily focused on the marine area being studied. If and when sites for land based disposal are identified, and subject to detailed assessment, there will likely be additional aspects identified which would not apply to marine based disposal sites. Therefore the differential between land based and marine disposal sites may be reduced in subsequent assessments. It is also not possible to dispose of the entire capital dredge to land, therefore marine disposal sites need to be considered.

Overall, the offshore options (Option 6: deep water & Option 7: outside the EEZ) performed well in the assessment (Table 4-2); however, at the initial findings workshop it was agreed that these options are not feasible as that they would add significant time, cost and environmental risk. Option 6, 60-80m water depth off Ocean Beach, requires slightly greater travel time/distance to access than the inner sites and is adjacent to the main shipping channel, which increases the risk associated with disposal at this site. It would also result in a greater mismatch of sediment properties, and is subject to higher south-easterly tidal flows and wave energy, which would increase the risk of sediment plumes impacting sensitive areas. Option 7 has the greatest amount of uncertainty, as there is no specific area identified, but all areas are likely to result in a sediment mismatch, more complex (and possibly unfeasible) monitoring, as well as longer and higher risk sail times. Therefore it is recommended that the inner sites are considered for consenting.

Of the three inner sites, Option 3.2 (the Intermediate site) performed the best in the assessment across all four wellbeing's (Table 4-2), and is designed to be able to take the full volume of the capital dredge. It is therefore recommended that Option 3.2 is progressed for consenting to receive the full capital dredge. Option 3.2 is particularly preferred due to a smaller footprint and less potential impact on sea-floor flora and fauna. Being further offshore, there is less potential impact on birdlife and known areas of conservation value. The site is also more removed from known areas of importance to recreational and commercial fisheries.

The Nearshore option (Option 2.2) does not perform as well as Option 3.2 (Table 4-2) from a social, cultural or economic perspective due to closer proximity to recreational areas and traditional and commercial fishing areas.

While the ebb delta disposal option (Option 1.2) does not perform as well as Option 3.2, it performs comparatively well from an environmental perspective because of the benefits identified in disposing a proportion of dredged material at this site. Retaining that material within the system, and in particular, supporting the resilience of Mair Bank (Figure 4-2) is seen as important from a coastal process perspective. For this reason it is recommended that provision for some capital- and maintenance-dredge material be made at the ebb delta site.

Table 4-2: Disposal options (weighted)

Options		Natural	Social	Cultural	Economic	Total normalised	Total (excluding RNZ direct economic impacts)
Ebb Delta	1.2	1.4	0.8	3.7	1.9	7.7	8.1
Nearshore	2.2	2.1	0.8	3.0	1.5	7.4	8.1
Intermediate	3.2	2.1	0.4	2.7	1.1	6.2	6.6
Land based disposal	4	-0.1	0.0	0.3	1.9	2.1	1.7
Beach nourishment	5	-0.2	-0.1	1.7	1.9	3.3	2.8
Deep water	6	1.9	0.8	1.3	1.8	5.8	5.5
Outside EEZ	7	1.8	0.4	0.3	3.0	5.5	4.7

In progressing Option 3.2, the most important issues identified through the MCA assessment are:

- the potential impact on areas of important conservation value and taonga species
- the impact on resilience of sediment leaving the system on geomorphology
- the impact on mahinga mataitai and commercial fisheries.
- the potential interaction with or impact on marine mammals

It is recommended that these aspects are expressly explored as part of the AEE process.

Of the inner site options, Option 3.2 also raises the fewest concerns from tangata whenua stakeholders (Figure 4-2). Concerns about impacts on sites of cultural value (including mahinga mataitai) remain generally high. This supports the recommendation in Section 4.1 for RNZ to continue to engage with iwi to ensure that perceptions about impacts are accurate, and that options for mitigating impacts are well understood.

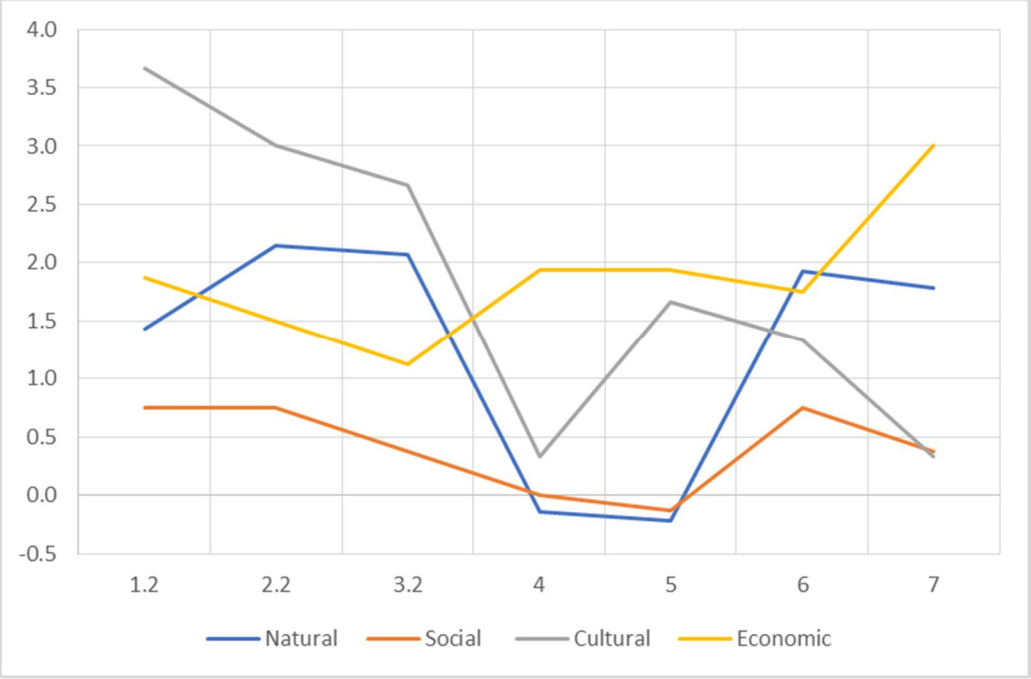


Figure 5-2: Disposal options (weighted)

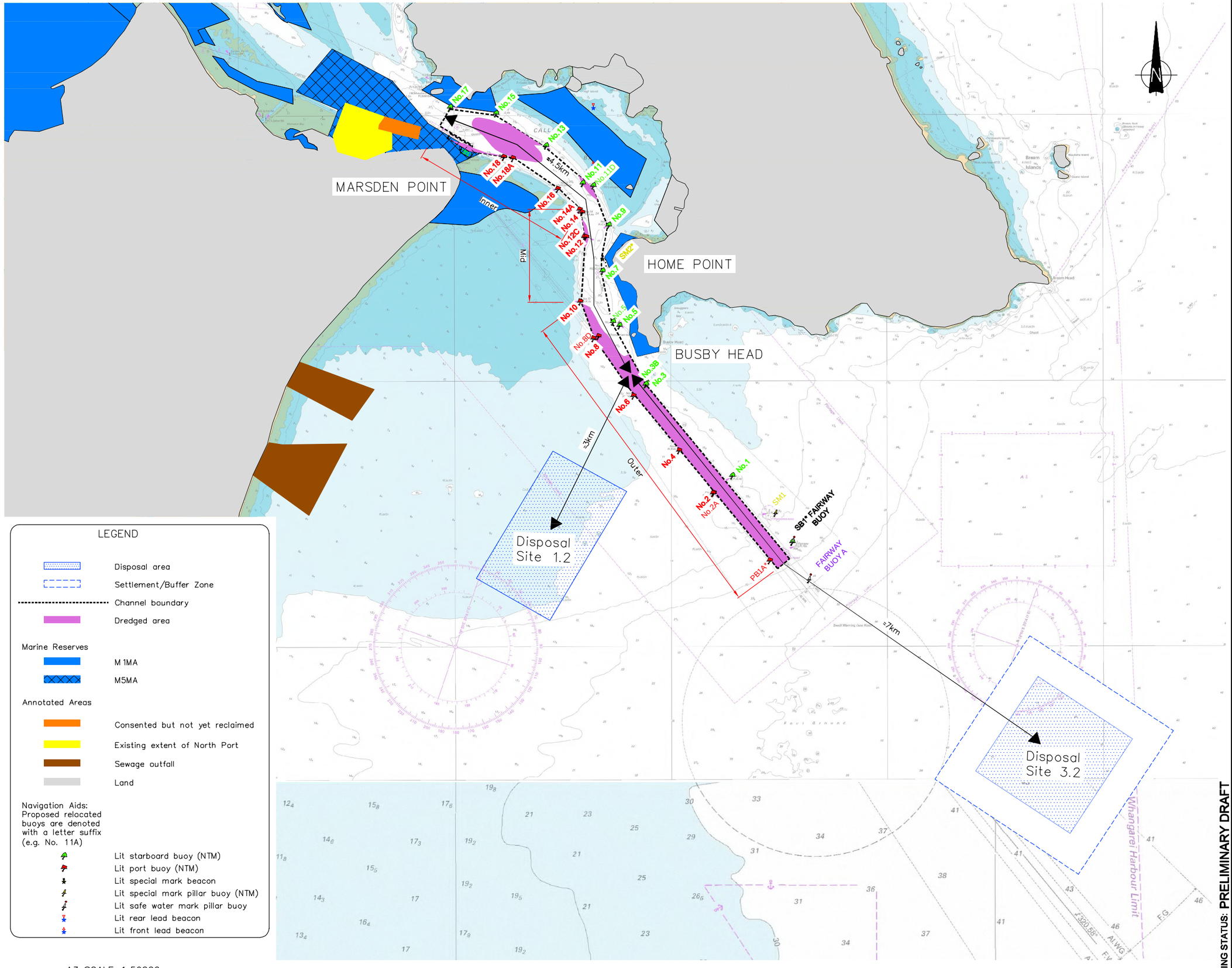
In progressing Option 1.2 (ebb delta) the following potential impacts should be considered within the AEE:

- impact on areas of important conservation value in close proximity and impact on taonga species
- impacts on the the mauri of the harbour
- impact of the ability to access to kaimoana at Marsden Bank and in other mahinga mataitai
- interaction with marine mammals
- impact on pelagic and shore bird nesting and roosting habitat
- temporary changes in access to recreational areas
- impacts on intakes and outfalls (noting that these issues have already largely been designed out)
- dredge disposal safety risks.

A plan of the recommended disposal sites is provided in Figure 4-3.

Recommendations:

- progress land based for beneficial reuse options (Options 4 & 5) where practicable.
- progress consenting for the bulk of the capital dredge to be deposited at the Intermediate site (Option 3.2) paying particular attention to mitigating or avoiding the potential interaction with marine mammals, impact on areas of important conservation value and taonga species, and impact on Mahinga Mataitai and commercial fisheries.
- progress the option for a limited volume of capital dredge and maintenance dredge disposal in the ebb delta (Option 1.2) to provide resilience to the geomorphological system and Mair Bank in particular.



LEGEND

- Disposal area
- Settlement/Buffer Zone
- Channel boundary
- Dredged area

Marine Reserves

- M 1MA
- M5MA

Annotated Areas

- Consented but not yet reclaimed
- Existing extent of North Port
- Sewage outfall
- Land

Navigation Aids:
Proposed relocated buoys are denoted with a letter suffix (e.g. No. 11A)

- Lit starboard buoy (NTM)
- Lit port buoy (NTM)
- Lit special mark beacon
- Lit special mark pillar buoy (NTM)
- Lit safe water mark pillar buoy
- Lit rear lead beacon
- Lit front lead beacon

A3 SCALE 1:50000

0 1.0 2.0 3.0 (km)

NOTES :

1. Hydrographic chart sourced from Linz Data Service (NZ 5214/5219)
2. Navigation aids and relocation placements from Royal HaskoningDHV drawing PA1028/MA/1121 rev K.

0	First Issue		
REVISION DESCRIPTION		BY	DATE
DESIGNED :		RRH	Feb. 17
DRAWN :		BMAN	Feb. 17
DESIGN CHECKED :			
DRAFTING CHECKED :			

REFERENCE :

CADFILE : \\30488-01.dwg

APPROVED :

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NZ REFINING COMPANY LTD

CRUDE FREIGHT PROJECT

MARSDEN POINT NORTHLAND

Proposed Works Plan

DRAWING STATUS: PRELIMINARY DRAFT

SCALES (AT A3 SIZE) 1:50,000

Figure 3

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5.3 Preferred dredge methodology

This study provided the expert panel with a better understanding of the options for dredge methodology, and how these might be used across the options for the project:

- the key finding with regards to dredge methodology is that the nature of the dredge material is such that turbidity is unlikely to be a significant issue[17]. The sandy substrate will likely settle quickly both along the channel alignment and at the disposal site(s). This means that the technologies and methodologies used to control turbidity (such as the THSD green valve and ebb tide dredging) may not actually deliver any significant environmental benefit from a turbidity perspective, but would increase the duration of the project overall. Controlling overflow via a green valve, ebb tide dredging or other measures should be considered where it is assessed that environmental and cultural effects warrant the use of these methods along the transect.
- the cutter suction dredge (CSD) and backhoe perform similarly overall (Table 4-3), but have different characteristics with regards to noise, vibration, turbidity and impacts on benthic flora and fauna. It is recognised that these dredge types perform different functions so are not mutually exclusive, and it is anticipated that a mix of dredge types would be used for a project of this type and scale. There may still be some need to use a CSD in in some locations, such as in the inner channel area, although less likely to be a preferred option. It may also be necessary to use a backhoe in place of the TSHD around the berth area given proximity to marine structures. It is recommended that when channel alignment is confirmed, the dredge methodologies most appropriate along the different reaches of the transect (from berth to inner-harbour and outer-harbour) are finalised.
- ebb tide dredging is preferred from an environmental and cultural perspective because of perceptions that this will help reduce turbidity. All tide dredging is preferable from a social and economic perspective because it will reduce the duration of project overall. Increased duration is not favourable from a cost perspective, and often communities prefer for projects to proceed as quickly as possible from an aesthetic and amenity perspective. However, ebb tide dredging in particular areas identified as potentially sensitive (for example, around Home Point), may be a potential mitigation strategy.

Recommendations:

- finalise the preferred dredge methodology based on the final channel design
- Examine whether ebb tide dredging and/or other measures are necessary at particular locations along the Option 4.2 transect to reduce natural, social or cultural impacts from turbidity.

[17] Bioresearches (September, 2016) Existing Environment Assessment: Ecology of the Dredge Area, Whangarei Heads. 210 pp.
Tonkin & Taylor (November, 2016). Crude Freight Shilling Project, Whangarei Harbour: Coastal Processes Assessment – Consultation Draft. Version 6. 160 pp.

Table 4-3: Dredge methodology (weighted)

Category			Natural	Social	Cultural	Economic	Total normalised	Total (excluding RNZ direct economic impacts)
Description							Total normalised to give equal weighting to four impacts	Total normalised (excluding costs to RNZ)
Dredge Methodology	1a	Trailer (with central weir)	2.1	0.9	4.3	1.0	8.3	7.9
	1b	Trailer (actual overflow)	4.1	1.8	8.1	1.0	15.0	14.6
	2	Cutter	2.3	1.1	5.1	2.5	11.0	10.3
	3	Backhoe	2.5	1.8	4.7	2.5	11.4	10.1
	i	Ebb Tide Dredging	1.4	1.8	3.9	2.0	9.0	8.2
	ii	All Tide Dredging	3.2	0.9	6.9	1.0	11.9	11.5

6 Applicability

This report has been prepared for the exclusive use of our client ChanceryGreen for Refining NZ, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that Refining New Zealand may use this report in support of an application for resource consent and that the consenting authority will rely on this report for the purpose of assessing that application.

Tonkin & Taylor Ltd

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
	
.....	.....
Monique Cornish	Richard Reinen-Hamill
Senior Sustainability Specialist	Director

MRC
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Appendix A: Poten & Partners | Crude Shipping Alternatives



POTEN & PARTNERS

Crude Shipping Alternatives

Marsden Point, NZ

Prepared for

REFINING NZ

August 2016

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Table of Contents

Table of Contents 2
Executive Summary 3
Introduction 4
1. Deepen Access Channel and Berth Area 6
2. Single Point Mooring oil discharge systems 9
3. Ship to Ship Transfer Operations (Lightering) 12
Conclusion 18
Dredge Existing Channel 18
SPM Discharge System 18
Ship to Ship Transfer (Lightering) 19
References 20
Poten and Partners Overview 21
Contact Details: 28

Executive Summary

Refining NZ, a refinery located at Marsden Point, in the northern part of New Zealand operates as a tolling refinery for oil companies which deliver crude oil and receive refined petroleum products for marketing in New Zealand. The refining fee is based on the spread between delivered crude oil and the landed cost of imported petroleum products. The refinery competes with imported products and efficiency is critical for its profitability.

New Zealand is far from most oil producing regions and transportation costs affect the refining margins. Therefore, the ability to use larger tankers is an important lever in generating freight cost savings. Larger tankers offer significant freight cost savings on a per barrel basis compared to smaller tankers.

The clients of Refining NZ currently import crude oil using Aframax and light loaded Suezmax tankers. The harbor currently has a draught restriction of 14.7 meters Chart Datum (CD), which means that only fully laden Aframax tankers (carrying 80,000 to 100,000 tons of crude oil) or partially loaded Suezmax tankers (with 100,000 to 120,000 tons cargo size) can access Refining NZ's discharge terminal. In order to reduce freight cost, the Marsden Point facility could be upgraded to allow fully laden Suezmax tankers to deliver crude oil.

There are three feasible alternative approaches to enable the use of larger tankers:

- Dredge the access channel and the Refining NZ berth
- Install a Single Point Mooring (SPM) system in deeper water offshore connected by an underwater pipeline to the refinery
- Use Ship to Ship transfer in deep water to transfer the cargo into smaller tankers for final discharge at the refinery

In Poten's view, the dredging alternative is the preferred option as the initial investment of about US$ 20-US$ 25 million can be recovered over a relatively short time frame while the added operating costs are relatively small. The other alternatives have either very high operating costs or involve high upfront investment costs which require Refining NZ to move to VLCC size cargoes (about 3 times the current delivery size) in order to offset these additional costs. Such large cargo sizes create issues for the refinery operations and require a significantly higher level of coordination between Refining NZ's customers, as well as investment in additional shore tankage.

While all three alternatives have good environmental records, the dredging of the harbor channel allows the continued use of the existing terminal but provide access to more efficient, fully laden Suezmax tankers. This reduces the number of port calls while also having the advantage of discharging in a location that is

sheltered from seas and swells and allows for the most effective emergency response in case of an incident.

The flowing table ranks the alternatives according to their suitability for Refining NZ (1 being most preferred):

	Conventional Terminal (Dredging)	Single Point Mooring	Ship To Ship	Comments
Environmental Risk	1	2	3	Conventional Terminal best sheltered from seas and swell
Refining Operational Considerations	1	2	3	Large parcels delivered via SPM and STS create size mismatch with refinery
Discharge Operations	1	2	3	More communication and coordination required for SPM and STS
Capital Investment	2	3	1	Initial investment costs highest for SPM
Ongoing Operational Costs	1	2	3	Conventional Terminal only requires periodic dredging
Customer Coordination	1	2	2	VLCC cargoes (SPM & STS) requires co-loading by customers
Weather Dependency	1	2	3	STS and to a lesser extent SPM operations can be disrupted by adverse weather

Introduction

Refining NZ, a refinery based at Marsden Point / Whangarei, in the north of New Zealand, operates as a tolling refinery for several oil companies: BP, ExxonMobil and Z-Energy. These oil companies provide the crude oil and Refining NZ processes the oil and returns refined products such as gasoline, diesel, jet fuel, etc. to the oil companies, who then market these products in New Zealand. Depending on the product type, Refining NZ supplies between 65 and 100% of the petroleum products consumed in New Zealand. Therefore, Refining NZ competes directly with imported petroleum products and maximizing operational efficiencies is critical.

As refiners have little influence on crude oil pricing, they need to minimize other costs to remain competitive. Transportation costs represent a significant factor influencing Refining NZ and its customers' profitability. Optimizing crude oil transportation costs includes providing efficient discharge port facilities and allowing large tankers to call at the port, in order to take advantage of freight savings from "economies of scale". Refining NZ's profitability is partially based on the freight cost differential between shipping crude oil on large tankers and the higher cost of shipping refined products on smaller tankers.

The larger the oil carrying capacity of a tanker, the lower the cost per transported barrel, especially for long haul crude oil supply routes. Large oil tankers offer significant economy of scale advantages as the operating expenses (crewing, stores, spares, maintenance, insurance, etc.) of larger vessels are relatively much lower than those of smaller vessels. The crew size of smaller tankers is similar to the one of larger vessels and as a result, the crew costs, which are the largest component of vessel operating expenses (expenses not directly related to a voyage), are also comparable. Bunker fuel expenses and vessel construction costs are other large cost factors, and both provide significant advantages for larger tankers over smaller ones. However, not all ports can accommodate large vessels. Load and discharge port restrictions and local logistical constraints, such as storage capacities, are also important factors that determine the optimal tanker size for a particular trade.



Marsden Point Refinery

Like other competitive refineries in the world, Refining NZ has been evaluating ways to utilize the economies of scale advantages of larger crude oil tankers.

The primary limitations of the existing discharge terminal at the Marsden Point refinery are the water depth at the berth and in the approach channel to the harbor. Currently, customers of Refining NZ are limited to fully laden Aframax size tankers (cargo capacity: 80,000-100,000 tons) or partially loaded Suezmax tankers (capacity: 100,000-120,000 tons). A fully laden Suezmax tanker cannot enter the harbor, due to the existing draught restrictions of 14.70 meters (CD).

The following three alternatives are commonly employed to overcome draught limitations:

1. Dredging the seabed to provide a deeper access channel and berth
2. Installing a Single Point Mooring (SPM) system off the coast in deeper water
3. Lightering the vessel by discharging the cargo fully or partially from a larger vessel into smaller tankers while at sea in deeper waters

At the request of Refining NZ Poten & Partners has made a high level assessment of the safety, environmental, economical, and operational aspects of these alternatives.

The report uses the following criteria to evaluate these alternatives:

- **Environmental Risk:** The risk of harming the environment during the implementation phase and during the operational phase
- **Refinery Operations:** The impact of the shipping solution on the refinery operations. For example: Using Very Large Crude Carriers (VLCCs) would affect the refinery operations and requires increased storage capacity.
- **Discharge Operations:** Includes aspects such as ship to shore communications, vessel access in case of an emergency, etc.
- **Capital Investment:** A large upfront investment would require a longer period to recover the investment or require other offsetting cost savings.
- **Ongoing Operational Costs:** The day to day costs involved in the maintenance and discharge operations
- **Customer Coordination:** Refining NZ refines crude for multiple customers who supply their own crude to the refinery. The use of VLCCs requires a significantly higher level of coordination among the customers.
- **Weather Dependency:** Unfavorable wind conditions can affect the mooring operations and create delays, and thus add shipping costs. Additionally, the refinery needs to maintain inventory to deal with such delays.

1. Deepen Access Channel and Berth Area

The Refining NZ refinery at Marsden Point currently imports crude oil using a berth that can accommodate Aframax tankers and partially laden Suezmax tankers.

A shore connected pier with load and/or discharge equipment is typically the default solution for oil importers, unless there are specific reasons why such a configuration is impractical or uneconomic. In the case of Refining NZ, much of the required infrastructure is already in place but, in order to accommodate larger tankers, dredging will be required.

In a study performed in May 2015, Poten & Partners estimated that the use of fully laden Suezmax tankers (1 million – 1.05 million barrels) would reduce freight costs by up to US$ 0.44 per barrel.

Environmental Risk

The use of larger vessels reduces the number of required port calls. By using a conventional pier, the vessel is sheltered from seas and swells inside the harbor during discharge operations. The vessel and the refinery are connected through an over-land pipeline, which is easy to maintain and inspect. Potential issues with the pipeline can be easily identified and quickly repaired, reducing the environmental impact in case of a leakage.

A potential risk of dredging is that the seabed is disturbed and that potential pollutants that may have settled into the soil are released, causing them to be distributed by the water. This risk is higher in industrial areas where environmental regulations were historically less strict than they are today. In the case of Refining NZ, this risk is very limited. The company has already performed extensive analyses of surficial sediment and core samples within the channel area. The sediment was generally free of contaminants.

Refining Operational Considerations

Using a conventional terminal provides maximum flexibility of tonnage up to the dimensions of the terminal. Due to the relatively low capital investment costs for dredging the approach channel and dredging around the existing berth, with ongoing operational costs and refining processes remaining the same, the terminal can be upgraded for fully laden Suezmax sized tankers. The delivery reliability would remain similar to current levels.

Currently Refining NZ receives mainly Aframax cargoes of about 700,000 barrels as well as some light-loaded Suezmax cargoes, which require one delivery about every 6 days. After switching to Suezmax cargoes of 1 million barrels, the refinery would require a cargo delivery approximately every 8 days, assuming they use 120,000 bbl/day. However, it is important to note that Refining NZ will only switch a proportion of its imports to Suezmax size tankers, because some crude oil imports from South East Asia require Aframax tonnage due to load port restrictions.

Discharge Operations

In case of an emergency while discharging, the ship would be readily accessible from land. In the event of a spill, it would be easier to implement emergency

response measures including, for example containment. In case of a spill, the escaped oil would be contained in a more protected area and would be less affected by wind and wave action than in an exposed open sea area, facilitating the cleanup process.

Refining NZ has existing protocols and procedures in place to quickly and effectively respond to a potential spill during discharge operations.

Capital Investment

Dredging has upfront costs involved in initially deepening the access channel. Refining NZ received initial estimates for the dredging work in the region of US$20 to US$25 million. Additionally, the use of fully laden Suezmax tankers would require a modification to the refinery's storage facilities.

Ongoing Operational Costs

Ongoing operational costs for the terminal would remain very similar to the current costs. There would be some additional costs in maintenance dredging in the future as a deepened channel often gradually fills with sediment that needs to be removed occasionally.

Customer Coordination

Upgrading import volumes from Aframax tankers to fully laden Suezmax tankers requires the least adjustment for Refining NZ customers. Several customers already use Suezmaxes on a regular basis (albeit light-loaded). Fully laden Suezmax tankers carry about 1 million barrel cargo lots (40% more than the current typical cargo size), reducing the overall number of port calls. The other two alternatives would require the use of VLCCs to optimize the higher investment (SPM) and operating costs (lightering). VLCCs carry about 2 million barrels, almost three times the current cargo size. These cargo sizes would likely be too large for an individual customer and would require the sharing of a vessel between multiple customers.

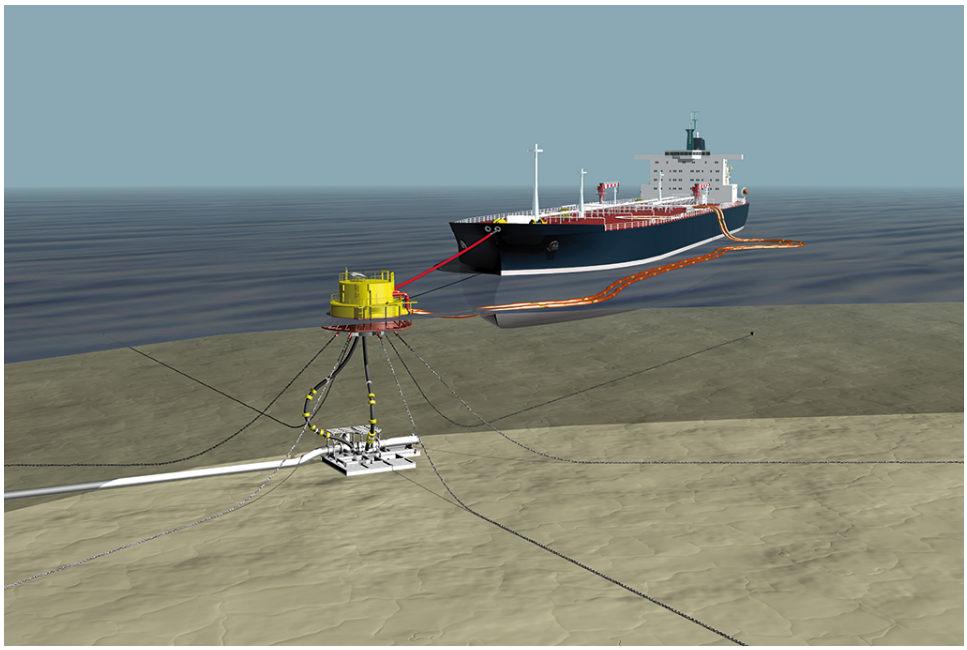
Weather Dependency

The Marsden Point terminal is located at the head of the Whangarei Harbour at the northern tip of Bream Bay. The location within the bay gives the jetty berths at Marsden Point protection from adverse weather conditions and therefore Poten considers discharging tankers at the Marsden Point terminal as the least weather dependent option. As is the case with the other alternatives, waves and swells can affect the timing of mooring and, in this case, entering the approach channel.

2. Single Point Mooring oil discharge systems

Installing a Single Point Mooring (SPM) system off the coast in deeper water is the second alternative that is also commonly employed to overcome draught limitations.

Single Point Mooring ("SPM") systems (also referred to as Single Buoy Mooring or SBM systems) can be used to import or export crude oil or petroleum products. They are manufactured and installed by well-established and specialized companies such as SBM Offshore, Bluewater and others. SPM systems consist of a buoy that is attached to the seabed and outfitted with a mooring facility for a tanker. In the case of an import facility, the buoy is equipped with an oil transfer system consisting of a pipeline between the buoy and the receiving terminal and hawsers to connect the tanker to the buoy. The system is designed so that the tanker can weathervane around the buoy while discharging.



SPM (Image Credit: Bluewater)

SPM systems are commonly employed; between the 1960's and 2012, SBM Offshore, one of the market leaders in SPM installations, built and delivered more than 450 SPMs to customers at locations worldwide. SPM systems are a cost effective option in shallow coastal areas where the construction of a marine terminal is expensive or unfeasible. However, in the case of Refining NZ, much of the required terminal infrastructure is already in place. SPMs are also commonly employed as loading terminals in offshore oil development projects.

The most common SPM design is the "Catenary Anchor Leg Mooring (CALM) system.



CALM SPM (Image credit: SOFEC)

A CALM SPM system consists of a floating buoy, which is anchored to the seabed by catenary chain legs that are secured to anchors or piles. The loading or offloading tanker is moored by one or two mooring hawsers to a turntable mounted on top of the buoy using a slewing bearing. The slewing bearing allows the tanker to freely weathervane around the SPM, always keeping the bow into wind and waves and thus keeping the windage area and wave exposure to a minimum.

In 1999, Refining NZ commissioned a study examining the feasibility of installing an SPM for the delivery of crude oil. The report investigated the installation of a CALM SPM in the Bream Bay with a 10 km underwater pipeline and a 3.5 km land based pipeline using existing right of way. The SPM would be anchored in water with a depth of about 30 m and would be suitable for tankers up to VLCC size. Two different pipeline scenarios were evaluated: a single 48” diameter pipeline and a dual 34” diameter pipeline. For cost reasons, the underwater pipeline would be built on shore in two 5 km sections and towed into position.

Refining NZ indicated that they did not further pursue the project due to the high cost estimates resulting from the initial feasibility study and due to the operational considerations discussed in this report.

Environmental Risk

A pipeline running over the seabed for several miles to connect the SPM to the refinery always creates some incremental risk. Indeed, ships mooring and offloading cargo off the coast of New Zealand represents a higher risk than tankers discharging in the more protected environment of a harbor, although entering and exiting the port also presents some risk.

Crude oil from the SPM flows through a submerged sea line. The tanker and the SPM are connected via two floating hoses which are attached to the manifold of the tanker. Although these components can be managed and are generally safe, they introduce a potential for problems.

SPMs are generally safe and efficient loading and off-loading systems. A 2010 risk assessment study by the International Organization of Oil and Gas Producers estimates that 1 event (tanker breakout or surge event) occurs for every 5,621 operating days. The mean volume of oil spilled in such incidents is estimated at 946 barrels.

Refining Operational Considerations

Single Point Mooring systems can be designed to accept all common types of crude oil tankers, including VLCCs. Due to the high initial investment of installing an SPM, VLCCs would be the optimal vessel size to minimize the transportation costs and offset the higher investment. However, regular use of VLCCs, which carry typically about 2 million barrels of crude oil, would require significant adjustments to the storage capacity of the refinery and the large cargo size would affect deliveries for the customers of the refinery. Presently, Aframax tankers typically carry a cargo of about 700,000 barrels for an individual customer.

Discharge Operations

Vessels secured to an SPM are generally able to continue load and discharge operations even under unfavorable weather and swell conditions. Mooring and unmooring operations normally do not require tugboat assistance. Some SPM discharge locations, such as buoys moored at sites with inadequate under keel clearance or unfavorable current condition, require "Stand by" tow back tugs to prevent the tanker from drifting into the SPM.

Capital Investment

The 1999 study investigated the cost of positioning an SPM into the Bream Bay, which at that time was estimated at about A$ 77.3 million (~US$ 50 million). This included the SPM and its installation connected to 10 km of underwater pipeline plus about 3.5 km of shore side pipeline, including the pipeline installation.

These costs did not include the required addition of crude storage tanks at the refinery. Deliveries of such large volumes will require significant modifications to the storage capacity, which will add to the initial investment.

Refining NZ has reviewed SPM cost estimates at a high level on a number of occasions, with the last review in 2013 suggesting costs of around US$150 million, including storage modifications.

Ongoing Operational Costs

Single Point Mooring maintenance and operating guidelines must be strictly enforced in accordance to the "Single Point Mooring Maintenance and Operations Guide" published by the "Oil Companies International Marine Forum"(OCIMF). OCIMF's mission is to be the foremost authority on safe and environmentally responsible operations of oil tankers and terminals, promoting continuous improvement of standards of design and operations.

SPM mooring systems are robust, generally maintenance friendly and do not experience excessive down time. However, safe and efficient operations of the system require a team of trained mooring masters, cargo coordination personnel, hose handling, mooring and maintenance crews, including divers. Suitable workboats are required as well, adding to the operating expenses of the system. The actual costs of these arrangements depend on the location and the prevailing weather and swell conditions as well as on the regulatory requirements in place once the SPM is operational.

The overall operating cost of an SPM is likely higher than the cost of maintaining a conventional terminal, but less expensive than maintaining a lightering operation. Refining NZ will need to maintain the existing infrastructure as a backup for the SPM and for loading products onto coastal vessels, in which case the SBM maintenance costs would be incremental.

Customer Coordination

As stated above, the high capital costs of the SPM would require customers to take advantage of the economies of scale provided by VLCC tankers. However, a two million barrel VLCC cargo would likely exceed the requirements of individual customers, and as a result, it would require them to co-load.

Weather Dependency

The SPM system is designed to operate safely in a wide range of weather conditions. As mentioned before, the offloading tanker can freely weathervane around the SPM, always keeping the bow into wind and waves and thus keeping the windage area and wave exposure to a minimum. However, there are weather circumstances, combining heavy winds with long-wave period swells and tidal currents, where SPM operations may need to be suspended.

3. Ship to Ship Transfer Operations (Lightering)

Another way of supplying long haul crude oil to refineries at locations with insufficient water depth and draught restrictions, while still benefiting from the economies of scale of VLCCs or Suezmaxes, is the employment of Ship to Ship Transfers, also known as lightering. This operation allows larger, deep drafted tankers to remain in offshore areas with sufficient water depth as close as permissible to the receiving refinery, where they offload their cargo into

smaller, draft suitable tankers (typically Aframax size) which deliver the crude oil to the refinery.



Source: Overseas Shipholding Group

The following map, produced by DYNAMARINe's Online STS, an organization that collects operational information from Ship to Ship (STS) transfer operators shows the worldwide locations where STS transfers occurred between 2011 and 2015. As the map clearly illustrates, STS operations are common in many locations.



Source: DYNAMARINe Online STS

Ship to ship transfer or lightering of crude oil from a Very Large Crude Carrier (VLCC) with a carrying capacity of about 280,000 tons onto a draft suitable Aframax size tanker of about 80,000 deadweight tons was successfully introduced by a major U.S. oil company at an offshore location in the U.S. Gulf around 1976.

The U.S. Gulf region has a huge amount of refining capacity in Texas and Louisiana. Prior to the introduction of lightering, crude oil supply to those refineries was restricted to smaller Aframax tankers, as only those vessels were able to meet the draft restrictions at U.S. Gulf ports of 40 feet. This made long haul transportation cost very high and uneconomical, especially for crude oil from the Arabian Gulf.

After the successful introduction of lightering, instead of shipping 80,000 tons of crude oil from the Arabian Gulf in Aframax tankers, VLCCs' were able to deliver about 280,000 tons to designated lightering positions, some 50 to 60 miles off the U.S. Gulf coast. Here they are lightered to completion by suitable Aframax tankers which make the final crude oil delivery to the refineries. It normally takes four Aframax loads to complete a VLCC discharge and, subject to weather conditions and availability of Aframax tonnage, the operation requires between 10 to 30 days to complete.

Since then, lightering operations have improved and are tightly regulated. Lightering is now a common way to provide long haul crude oil to refineries at draft restricted locations around the world.

Ship to ship oil transfer operations usually take place at designated, open, unrestricted sea areas with sufficient water depth (allowing adequate under keel clearance) to keep the interactive forces exerted during the approach of two vessels, to a minimum. Inadequate under keel clearance has a negative effect on a ship's maneuverability as well as the rudder and steering performance during the vessel's approach. About half of the lightering operations worldwide occur while the vessels are at anchor while about 30% occur by connecting the vessels while underway and anchoring for discharging. About 19% of the lightering operation are performed while the vessels continue to move at slow speed.

Typically, lightering operations can only be conducted in designated lightering areas, approved by respective National Authorities. Designated lightering areas must provide ample, unrestricted sea room to allow safe approach and maneuverability between off taker and mother ship (VLCC). Refining NZ would have to go through an approval process to obtain a designated lightering area.

Environmental Risk

Even though transshipment operations involve higher risk due to the increased number of cargo handling operations, lightering enjoys a good safety and spill

record. According to the online STS quality assessment (OSIS), 3.3% of all STS operations experience an incident, while the remaining 96.7% are incident free.

By far the most frequently occurring incident is the breakdown of the mooring lines between the vessels. The following table, covering the period from April 2011 to December 2015, shows the frequency of different types of incidents as a percentage of the operations with incidents.

Incident	*Frequency*
Mooring Lines Breakdown	62%
Vessel Collision	13%
Fender Breakdown	9%
Oil Spill on Deck	5%
Hose Breakdown	3%
Fail of Communications	3%
Main Engine Failure	3%
Damage by tug or Service boats	1%
Vessel Blackout	1%

Source: Online STS

Refining Operational Considerations

In order to offset the relatively high operational costs of lightering, Refining NZ would have to use VLCC sized tankers. This has the same disadvantages as the use of an SPM: larger storage requirement and coordination between customers.

Additionally, due to the weather dependence of lightering, there is an increased risk of refinery supply disruptions, though weather conditions in the area of Marsden Point are generally favorable. According to a NIWA study on the weather conditions in Northland, 40% of the time swells are less than 1 meter while only 8% of the time they exceed 2 meters along the East Coast of Northland. Average wind speeds at the airport of Whangarei are generally around 10-13 km/h.

The refinery needs to maintain additional storage to manage the possibility that ships cannot offload the cargo due to weather conditions. Deliveries will be affected if either the ship-to-ship transfer is not possible or if the lightering Aframaxes cannot enter or exit the harbor.

Discharge Operations

Lightering operations require a higher level of oversight from the refinery and shore based organization. The parties involved in a lightering operation are normally the tanker to be lightered (mother vessel) typically a VLCC, the vessels

to receive the oil (Off taker) typically an Aframax size tanker and the lightering service company who provides the lightering equipment such as a suitable work boat and fenders.

Either Refining NZ engages a lightering service provider who arranges an off taker for the lightering operation or Refining NZ needs to charter-in a vessel. It can be expected that not many Aframax tankers are trading in the New Zealand area, as Marsden Point is the only refinery in the country and petroleum product imports and local distribution are performed with smaller tankers due to the required volumes. Additionally, these tankers would not be suitable as the cleaning operations to switch between crude oil and clean petroleum product cargoes would be expensive and in some cases impossible. Therefore it will be difficult (or expensive) to arrange for a suitable Aframax tanker to be available when the VLCC arrives.

Capital Investment

The initial investment can be very low, as almost all the lightering costs are operational costs, especially if an outside lightering service is employed, as they typically charge an all-in fee per lightering operation. If Refining NZ decides to set up an in-house lightering operation, they would need to buy or charter in a workboat and acquire fenders, hoses, etc.

Ongoing Operational Costs

The operating expenses of lightering are higher than the alternatives discussed. Additional storage capacity would be required as well. Chartering in an Aframax to perform the lightering operation will be expensive as Aframax tankers will likely not be readily available, once most of the New Zealand bound crude oil is moved on larger tankers. It will be extremely difficult and costly to coordinate the use of Aframaxes that still discharge at Whangarei for lightering services. The following map shows the positioning of Aframax tankers on the 13th of July 2016. The map illustrates the limited availability of tonnage in the area. (The vessel heading for New Zealand is a BP owned tanker heading to the Refining NZ refinery)

The lightering operations require the use of a workboat to handle the required fenders and a mooring master who is experienced in mooring the ships. One of the existing lightering companies could establish a presence in New Zealand and manage the lightering operations or Refining NZ could decide to manage this in house.



Source: Lloyds List Intelligence

The lightering operations will be relatively inefficient unless more than one off-taker is used, as the VLCC is lying idle while the lightering vessel sails between the mother ship and the terminal. This results in higher costs for the Aframax tanker and demurrage for the VLCC. As a reference, on the U.S. West Coast, where Aframax tonnage is less common than in the U.S. Gulf area, lightering operations cost about US$200,000 per voyage for the off taker while VLCC demurrage typically costs around US$50,000 per day, depending on the freight market conditions. If only one off-taker is used, the optimum lightering time is about 11 days, this would add about US$450,000 – US$550,000 of demurrage cost per VLCC cargo, depending on the duration of the VLCC loading operations.

Customer Coordination

Operating costs involved in the lightering operation are very high. To offset these costs, the other transportation costs need to be reduced by using the largest possible vessels. However, VLCC carries about 2 million barrels of crude oil, which most likely exceeds the amount that can be managed by an individual customer. Therefore, two or more customers need to pool their crude to fill a VLCC. This complicates the logistics for the customers.

Weather Dependency

To perform safe lightering operations, operating parameters do not necessarily require dead calm seas with no wind. Although there is no fixed maximum wind speed and wave height limit established, lightering can be safely conducted by experienced mooring masters with wind speeds up to 20 knots and short period wave heights of up to six feet. However, if swell waves with long wave periods are experienced from one direction, and wind and wind waves come from another direction, on top of prevailing tidal currents, lightering operations are difficult to be conducted safely and should be suspended.

Conclusion

The following section summarizes the pros and cons of the various alternatives:

Dredge Existing Channel

Marsden Point approach channel realignment and berth dredging to a safe water depth, allowing fully laden Suezmax tankers to provide crude oil supply to the RNZ Whangarei refinery.

- Dredging costs are lower than installation of an SPM with a pipeline.
- Using fully laden Suezmax tankers is sufficiently comparable to current crude oil delivery volumes that refinery operations and storage facilities require less modification than for the alternative solutions.
- The expectation is that Refining NZ customers can easily deliver Suezmax cargoes (approximately 1 million barrels), typically without having to share tonnage, facilitating scheduling for the customers of the refinery.
- Dredging provides the best balance of costs and benefits; a limited investment combined with improved freight costs and requiring only minor operational modifications.

SPM Discharge System

Install an SPM and an underwater pipeline to connect the SPM to the refinery.

- The installation of an SPM, including the related pipeline system and infrastructure requires the highest upfront capital investment of all options.
- Once installed, the offshore SPM discharge system would provide cost effective crude oil deliveries without incurring excessive delays due to weather.
- VLCCs and Suezmax tonnage can be employed, taking advantage of economies of scale in freight costs.
- To meet larger cargo size deliveries, Refining NZ has to significantly increase its shore tank storage capacity.
- It is unlikely that Refining NZ's customers can individually supply crude oil by VLCCs on a consistent basis. Cooperation and closely coordinated co-loads among customers will likely be required.
- Even if an SPM discharge system is utilized, Refining NZ will need to maintain its existing jetty at Whangarei, in order to have an oil reception facility in the event the SPM system experiences any down time and to accommodate product loading onto coastal vessels.

- If not drained after discharge operations, the submerged sea line from the SPM to the shore tanks would contain crude oil. If the sea line integrity is compromised for unexpected reasons, oil seepage could occur.
- Refining NZ would have to train and maintain a team of mooring masters and discharge coordinators, hose handling, and maintenance crew including divers, as well as hire or acquire work boats and possibly pull back tugs.

Ship to Ship Transfer (Lightering)

Discharge the cargo at a designated lightering area from a larger mother vessel into smaller tankers that can transport the cargo to the refinery.

- Designated lightering areas have to be established and approved.
- To recover the higher cost involved in lightering, Refining NZ customers might have to use larger VLCC tankers. This would require significant additional storage capacity.
- Long term contracts with reputable Lightering companies have to be negotiated if possible, or in-house lightering operation has to be established.
- Lightering operations require a team of trained mooring masters and cargo coordinators as well as workboats, adequate and approved fender systems, cargo discharge hoses and hose handling crews.
- The utilization of Ship to Ship transfer operations, to provide crude oil to the Refining NZ refinery, will not reduce the number of tankers calling Marsden Point. The equipment has to be stored and properly maintained when not in use.
- Difficulties to obtain cost effective off takers due to lack of suitable tonnage in the Whangarei trading region.
- Refining NZs' customers have to coordinate co-load agreements for VLCC cargoes.
- An important disadvantage of lightering operations is the weather dependency. Long delays could be very costly and quickly eliminate the "economy of scale" gains. It could also create severe inventory problems for the refinery

In Poten’s view, of all the possible alternatives, the dredging option provides the best balance based on the evaluation criteria: The combination of limited initial investment and the modest on-going operating costs makes this a very cost competitive solution. As a result, the refinery can use fully laden Suezmax tonnage, which does not require significant changes to the refinery operations

or for the customers, while still providing significant transportation cost savings. Incremental transportation cost savings of using VLCCs would be offset by higher initial investments or operating costs, as well as requiring significant additional coordination among Refining NZ's customers.

The following table shows Poten's ranking of the alternatives:

	Conventional Terminal (Dredging)	Single Point Mooring	Ship To Ship	Comments
Environmental Risk	1	2	3	Conventional Terminal best sheltered from seas and swell
Refining Operational Considerations	1	2	3	Large parcels delivered via SPM and STS create size mismatch with refinery
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Ongoing Operational Costs	1	2	3	Conventional Terminal only requires periodic dredging
Customer Coordination	1	2	2	VLCC cargoes (SPM & STS) requires co-loading by customers
Weather Dependency	1	2	3	STS and to a lesser extent SPM operations can be disrupted by adverse weather

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DYNAMARINe Online STS: OSIS STS Statistics Report 2011 – 2015

NIWA: *The climate and weather of Northland*, P.R. Chapell, 2013

Poten and Partners Overview



Poten & Partners has been in business for more than 70 years, and while it originated as a ship brokerage firm it has expanded into providing a range of commercial and advisory services related to supply, cargo trading, and transportation of crude oil, petroleum products, condensates, naphtha, LPG, natural gas, and LNG. The company currently employs 170 staff members and has offices in New York, London, Athens, Houston, Perth, Singapore and Guangzhou.

Complementary businesses across the energy value chain


UPSTREAM


MIDSTREAM


MARINE


INFRASTRUCTURE


DOWNSTREAM

Our brokers continuously pursue business opportunities, which link us to the realities of energy transactions and provides primary source information. As

brokers for ships and commodities, we arrange more than a thousand transactions every year.

Poten & Partners consulting and project development staff provides strategic guidance and understanding of longer-range economic horizons.

Our economists monitor and analyze energy developments in key countries, and advise companies on strategy, objectives, and implementation. Our focus is on energy supply and transportation issues and strategies that can benefit our clients. Balance and synergy between these disciplines make us effective and unique. Our people are diverse, with planning, marketing, engineering, and executive backgrounds in oil and gas companies, banks, shipping companies, academia, and government service. These talented people have conceived and brought many projects to fruition.

We serve organizations of every size, industry leaders and smaller companies alike. Doing this right means we must — and we do — adhere to the highest standards of professionalism, business ethics, and discretion. Our assets are our people, their skills, and our valued relationships with an impressive list of clients and customers.

Tanker Research & Consulting

Poten's Tanker consulting team is comprised of senior marine logistics, petroleum, upstream and downstream experts who have been involved in advising on all stages of the petroleum supply chain.

In addition, our team is frequently called upon to prepare pricing analyses, global supply and demand projections, and tailored market analyses for leading energy companies and major world governments.

Crude Oil

With decades of combined experience, we are a leading provider of consulting services to the crude oil industry. Our staff combines years of experience in trading, brokerage, shipping and refining to assist our clients with the challenges and opportunities of commerce in the crude oil industry. Clients include oil companies, traders, financial institutions, pipeline owners, terminal operators and government agencies.

Our services include:

- Market analysis, long and short term forecasting and special studies in industry trends
- Analysis of trade regions, supply and demand, pricing and contracts
- Valuation of new crude oil production
- Plant-by-plant evaluations, competitor analysis and strategic planning
- Investor and lender due diligence

Fuel Oil

Poten is available to discuss and prepare single-client research reports on fuel oil related topics. Our consultants possess a wide range of experience and resources to assist clients in meeting essential business objectives associated with crude oil and refined products. Our consulting group combines experience in fuel oil trading, brokerage, shipping, refining and reporting.

Clients include oil companies, traders, financial institutions, pipeline owners, terminal operators and government agencies.

Clean Refined Petroleum Products

Poten & Partners offers comprehensive consulting and advisory services to the transportation fuels and condensates industries, including:

- Trade regions supply and demand analysis
- Price outlooks

Asphalt

We are leading advisors to companies and countries seeking assistance in the worldwide asphalt industry. Our consultants combine years of experience, decision tools, and organizational strategies to provide a comprehensive overview of the asphalt markets.

Our services and publications include:

- Comprehensive asphalt market information services
- Commercial intelligence and advice on pricing and marketing
- Assessments and forecasts spot prices, supply and demand, and global trends
- Analysis of global production and consumption
- Lender and investor due diligence
- Litigation support
- Customized training sessions

Clients include oil companies, government agencies, refiners, paving contractors, terminal operators, as well as financial institutions.

Asphalt Weekly Monitor®: The leading asphalt market price reference publication. Weekly analysis of the US and Canadian asphalt industry, including prices, market development and alternate values

Naphtha

With over thirty years of experience, we are a leading provider of consulting services to both naphtha producers and consumers. Our staff combines years of

experience in trading, brokerage, shipping and refining to assist our clients with the challenges and opportunities of commerce in the naphtha market. Clients include oil companies, traders, LNG companies, GTL companies and petrochemical companies.

Our services include:

• Market analysis, long and short term forecasting and special studies in industry trends

• Analysis of trade regions, supply and demand, pricing and contracts, quality trends

• Investor and lender due diligence

Natural Gas Liquids

Poten & Partners has over thirty years of experience and recognition as consultants and commercial brokers to the international LPG business. During this period, we have been retained by LPG producers including Saudi Arabia, Kuwait, Abu Dhabi, Venezuela, and Indonesia. Our assignments have ranged from analyzing long-term demand/supply to recommending short-term marketing strategies. We have also provided assistance to shipowners, traders, petrochemical end-users and other buyers around the world.

The Poten Project Team is staffed by individuals with substantial NGL and LPG, petrochemical, shipping and management knowledge and experience. All the consultants in the team have advised senior decision makers in international energy companies on strategy and corporate positioning. The advisors to the project include former industry executives with responsibility for taking significant LPG related business decisions.

Our LPG consulting activities include the publication of multi-client studies such as:

• LPG in World Trade (an annual publication)

• LPG in World Markets (a monthly publication)

Poten is a leading provider of commercial advisory and brokerage services to the energy and ocean transportation industries, including:

• Consulting services for LNG, shipping and natural gas, LPG, NGLs, condensates, light petroleum products, crude oil, petrochemicals, fuel oil and asphalt

• Capital services for financing of shipping and energy infrastructure projects

• Project development services for marine transportation and energy infrastructure transactions.

• Ship brokerage for crude oil, petroleum products, LNG and LPG

• Commodity brokerage for LPG, LNG, naphtha and condensates

LNG and Natural Gas

Available consulting services and publications include:

- Gas international trade
- Analysis and forecasts of:
    - Regional and worldwide gas supplies and markets,
    - International short- and long-term LNG/natural gas trades,
    - Regional and worldwide LNG, natural gas, and energy values,
    - Short- and long-term pricing for LNG/natural gas and competing fuels for the end-user markets (e.g., power generation),
- Evaluation of gas project cost-of-service, facilities, legal and regulatory activities, political considerations, and technological developments,
- Evaluation and forecasts of LNG terminals and LNG shipping,
- Corporate business strategies for entry and growth in the LNG business and international LNG trade.

Project Development & Finance and Capital Services

Ship and commodity brokerage transactions most often stem from short to medium-term market dynamics. Our Project Development professionals understand market fundamentals and have the expertise to structure and create innovative and practical solutions. We typically pursue long-range objectives that require time to mature. Our creativity, experience, preparation and perseverance contribute to the success of these projects.

Shipping Asset Projects

Poten has initiated shipping projects by taking a concept to a client, helping develop the component parts, and guiding the project to a conclusion. These projects include shipyard contracts for new construction and conversions, sale of existing ships and fleets, and various kinds of long-term transportation agreements.

Energy Projects

Poten has participated in many large energy asset-related projects. We have assisted clients in identifying and evaluating opportunities for investment in refineries, petrochemical plants, oil, gas, and gas liquids pipelines, petroleum products terminals, and retail distribution companies. We have acted as marketing advisor for new export projects involving LPG, LNG, condensates, refined fuels and petrochemicals. Some examples are:

Project Finance

Poten has assisted in the financing of energy and shipping ventures. Our staff is experienced in evaluating the earning potential of assets, preparing finance proposals, and negotiating with lenders and investors. In order to obtain optimum financing for our clients, we sometimes find supplementary equity capital. For ship financing, Poten can advise on foreign exchange hedging, alternative flags of registry, tax consequences of domiciling companies in particular countries, and the provision of surety through mortgages or assignment of revenues.

Brokerage Services

Ship and Commodity Brokerage

Crude Oil & Refined Products

Shipbrokers arrange marine transportation of crude and refined oil products on a spot and term charter basis. Our proprietary Internet portal provides our clients access to many of the same databases used by our brokers and analysts, including real-time vessel positions and information on fixtures.

Our brokers have extensive experience in tanker sale and purchase, including fleet sales, lease and charter-back transactions and transportation finance. Our real-time market information gives our clients timely advice on short and long-term trends, critical for vessel acquisition decisions.

LPG

Our LPG shipbrokers and commodity brokers are active throughout all vessel segments ranging from VLCCs to smaller semi-refrigerated vessels. We retain a team of professionals canvassing the market and providing clients with global intelligence on the ocean transportation of LPG, ammonia, and petrochemical gases. We routinely arrange spot and term charters and develop contracts of affreightment to suit clients' specific requirements. In addition, we are active in the sale and purchase of LPG carriers and offer project development and consulting services to our clients.

LNG

Members of Poten's commercial group have decades of LNG experience allowing them to understand short-term market dynamics and identify future trends. Our brokers are involved in all aspects of the midstream and downstream LNG delivery chain including supply, transportation and regasification.

Poten's client relationships and industry contacts build upon our experience in the sale and purchase of LNG carriers and in spot and term chartering arrangements.

Contact Details:

If you have any questions, please contact:

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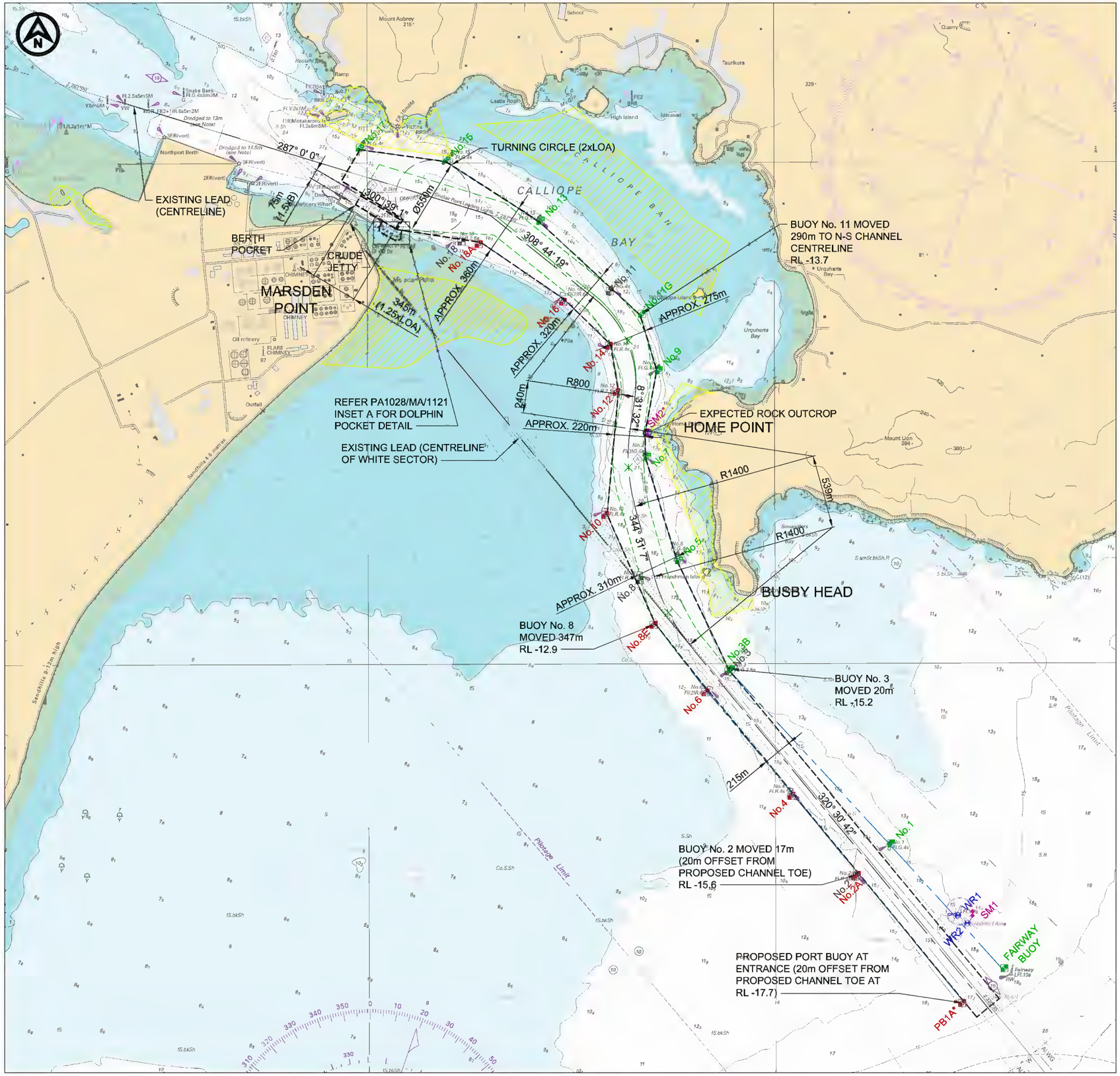
Appendix B: Channel alignment options

The following schematics detail channel alignment options 2, 4.2 and 5 as at the mid-point review in June 2016 (from RHDHV, 2016b).

DRAWING No. PA1028/MA/1201

DO NOT SCALE



LEGEND:

- DESIGN TOE LINE
- DESIGN CHANNEL CENTRELINE
- THEORETICAL TOE LINE
- THEORETICAL CHANNEL CENTRELINE
- BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)
- PROPOSED RELOCATED BUOYS (e.g. No. 11A)
- STARBOARD BUOYS
- PORTSIDE BUOYS
- WAVERIDER BUOYS
- SPECIAL MARK BUOYS
- EXISTING BUOYS TO BE RELOCATED
- MM1 BOUNDARY

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF DESIGN CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 276m AND BEAM (B) = 50m.

REV	DATE	DESCRIPTION	BY	CHK	APPD
D	02.12.15	BUOY No.8 MOVED	BAM	RM	
C	02.11.15	CHANGES CARRIED OVER FROM OPTION 4–2	BAM	RM	
B	22.07.15	RELOCATED BUOYS ADDED	BAM	MP	
A	20.07.15	DRAFT FOR REVIEW	BAM	MP	

REVISIONS

CLIENT
CHANCERYGREEN ON BEHALF OF:
REFINING NZ
Your Energy Hive

PROJECT:
REFINING NEW ZEALAND
CRUDE FREIGHT PROJECT

DRAWING TITLE:
CHANNEL DESIGN
OPTION 2
CHANNEL ALIGNMENT

CHART DATUM

NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m
1:15000 (A1) 1:30000 (A3)

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Telephone
Fax
Internet

DRAWN BAM	DATE 02/12/2015	JOB No. PA1028
AUTOCAD REF. PA1028–MA–OP2D–95%		
SCALE AT A1 1:15000		
DRAWING No. PA1028/MA/1201		REVISION D

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DRAWING No.
PA1028/MA/1121

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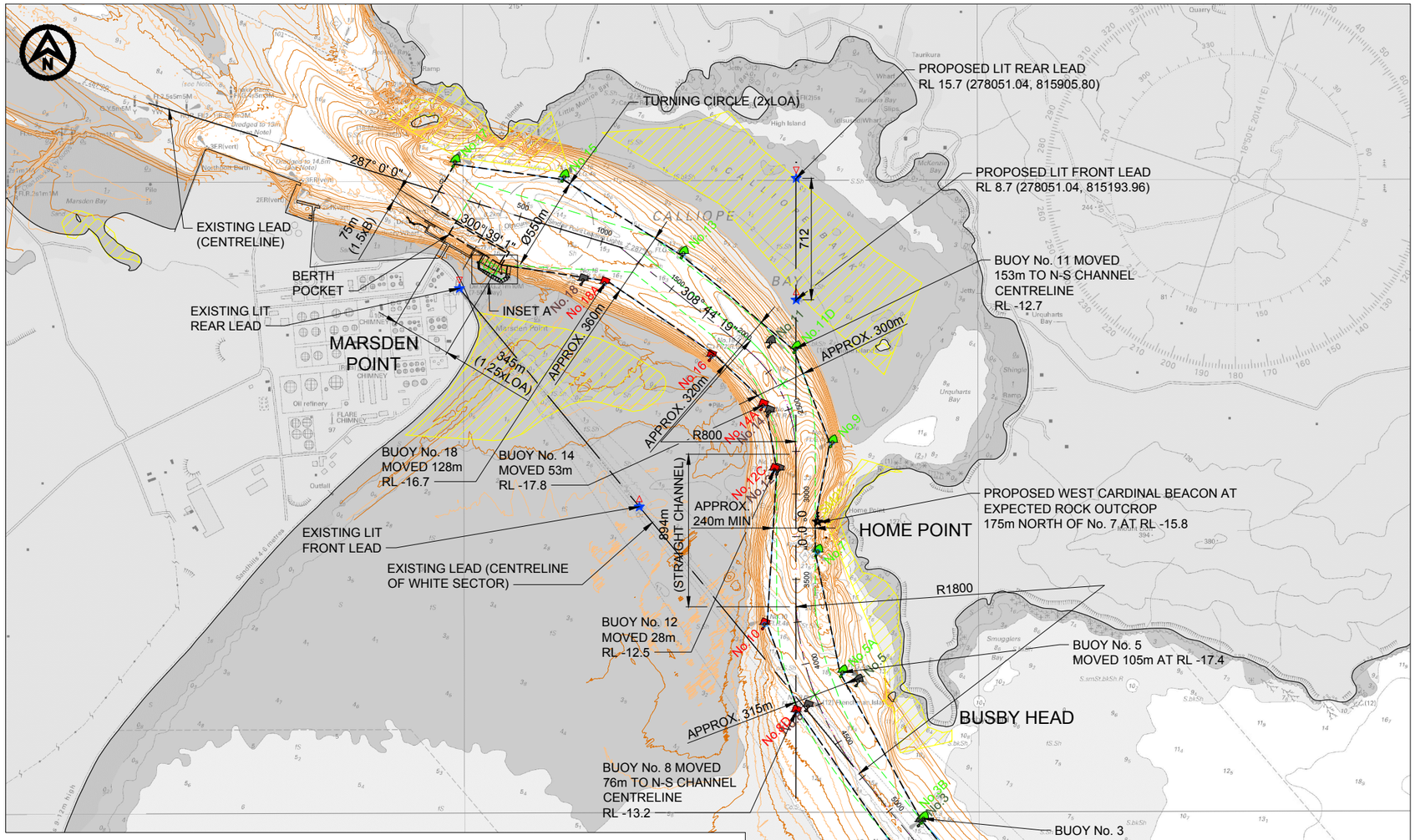

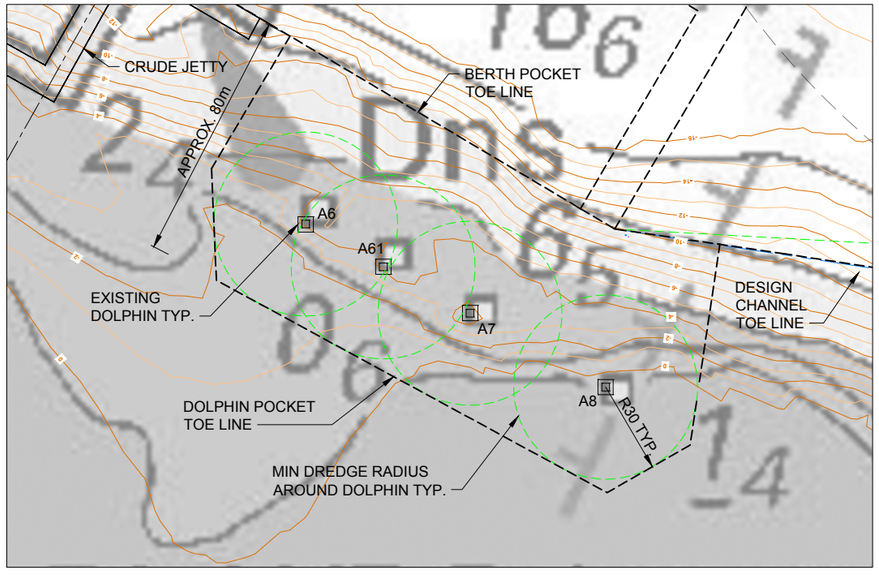

INSET A - DOLPHIN POCKET
1:1,000 (A1)

PLAN - CHANNEL ALIGNMENT
1:15,000 (A1)

LEGEND:

- DESIGN TOE LINE
- DESIGN CHANNEL CENTRELINE
- THEORETICAL TOE LINE
- THEORETICAL CHANNEL CENTRELINE
- BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)

NAVIGATION AIDS:
PROPOSED RELOCATED BUOYS ARE DENOTED WITH A LETTER SUFFIX (e.g. No. 11A)

- LIT STARBOARD BUOY (NTM)
- LIT PORT BUOY (NTM)
- LIT WEST CARDINAL BEACON
- LIT SPECIAL MARK PILLAR BUOY (NTM)
- LIT SAFE WATER MARK PILLAR BUOY
- EXISTING BUOY TO BE RELOCATED
- WAVERIDER BUOY
- LIT REAR LEAD BEACON
- LIT FRONT LEAD BEACON
- LEAD LINE

CONSTRAINTS:

- MM1 BOUNDARY

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF DESIGN CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 276m AND BEAM (B) = 50m.
5. THE DAYLIGHT LEADS ON THE OFFSHORE APPROACH CHANNEL BETWEEN THE FAIRWAY BUOY AND BUOYS 3/6 SHOULD BE MADE MORE SENSITIVE TO ADEQUATELY SHOW THE NAVIGATION LIMITS OF THE NEW CHANNEL AND BE BRIGHT ENOUGH TO SUPPORT OPERATIONS IN ADVERSE ENVIRONMENTAL CONDITIONS. AN ADDITIONAL FRONT LEAD SHOULD BE ESTABLISHED WITH DAY AND NIGHT LIGHTS IN THE CURRENT FRONT LEAD POSITION. THE EXISTING FRONT LEAD SHOULD BE REPLACED WITH A SIMPLE DAY\NIGHT LIGHT LEAD WITH NO DAY SHAPE.
6. NORTHPORT TO REMOVE THE DAY SHAPE TOP STRUCTURE FROM THE EXISTING FORE LEAD STRUCTURE AND PLACE A NEW 1.2m HIGH STRUCTURE (ON TOP) TO HOLD THE PROPOSED LIGHT. LIGHT COLOUR TO BE CONFIRMED.

REV	DATE	DESCRIPTION	BY	CHK	APPD
M	22.09.16	WEST CARDINAL MARK ADDED	BAM	JGC	
L	24.08.16	LEADS AND FAIRWAY BUOY MOVED	BAM	JGC	
K	23.06.16	LEADS MOVED	BAM	RM	
J	22.06.16	FAIRWAY BUOY MOVED	BAM	RM	
H	02.12.15	REISSUED FOR REVIEW	BAM	RM	
G	27.10.15	DREDGING AROUND DOLPHINS ADDED	BAM	RM	
F	23.10.15	LABELS REMOVED	BAM	RM	
E	22.10.15	REVISED SUEZMAX VESSEL	BAM	RM	
D	16.10.15	BUOYS No.2 AND PB1 SHIFTED	BAM	RM	
C	13.10.15	CHANNEL CENTRELINE ADDED	BAM	MP	
B	12.10.15	PROPOSED N–S LEAD ADDED	BAM	MP	
A	10.09.15	REVISED FROM OPTION 4–1	BAM	MP	

REVISIONS

CLIENT
CHANCERYGREEN ON BEHALF OF:
REFINING NZ
Your Energy Hive

PROJECT:
REFINING NEW ZEALAND
CRUDE FREIGHT PROJECT

DRAWING TITLE:
CHANNEL DESIGN
OPTION 4–2
CHANNEL ALIGNMENT

CHART DATUM

NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m
1:15000 (A1) 1:30000 (A3)

20 0 20 40 60 80 100m
1:1000 (A1) 1:2000 (A3)

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DRAWN BAM	DATE 26/08/2016	JOB No. PA1028	
AUTOCAD REF. PA1028–MA–OP4–2L–98%			
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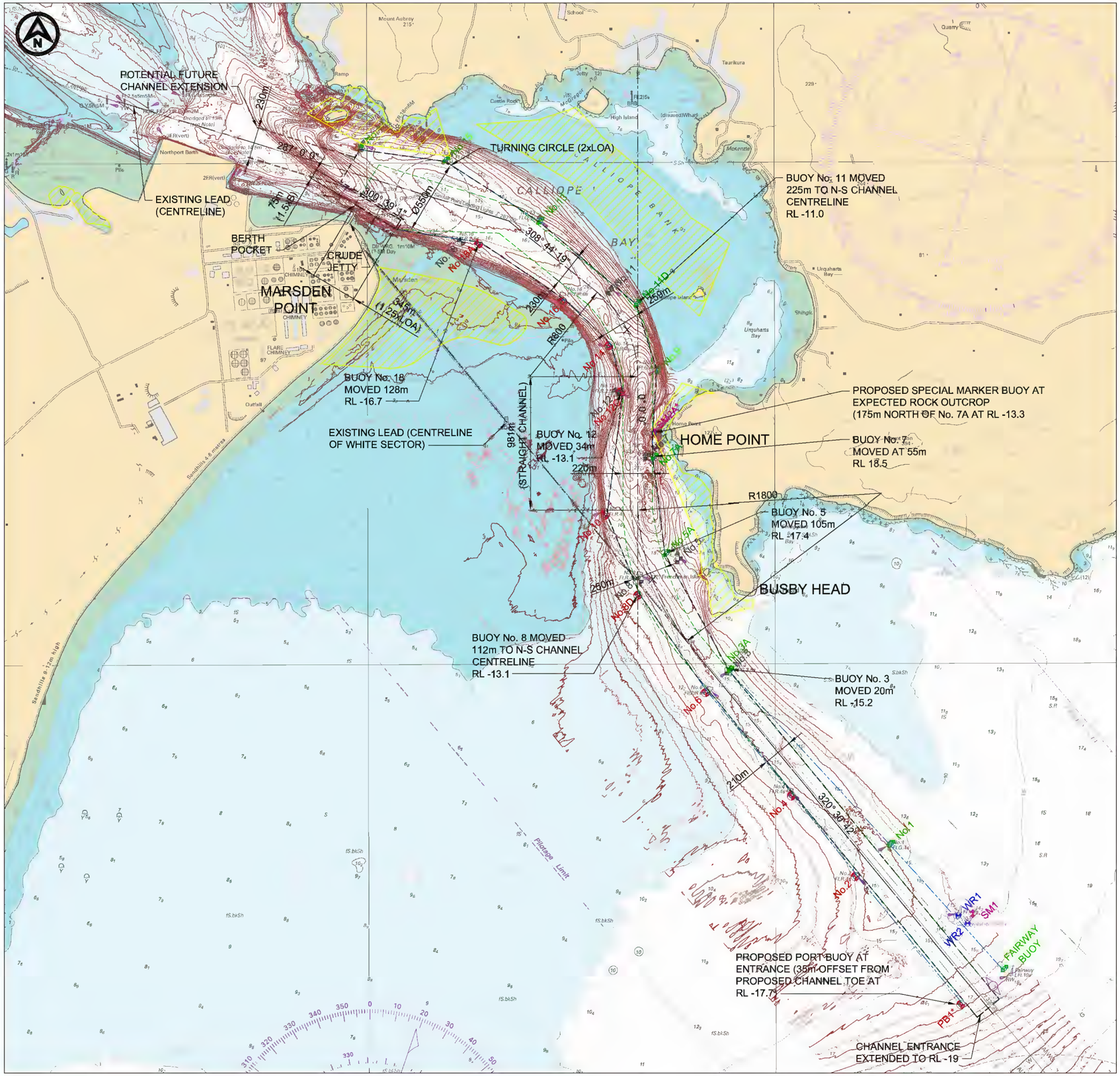
DRAWING No. PA1028/MA/1121		REVISION M	

DRAWING No. PA1028/MA/1301

DO NOT SCALE



LEGEND:

- PROPOSED CHANNEL TOE LINE
- DESIGN CHANNEL TOE LINE
- BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)
- OPTION 4-2 REV A DESIGN CHANNEL CENTRELINE
- STARBOARD BUOYS
- PORTSIDE BUOYS
- WAVERIDER BUOYS
- SPECIAL MARK BUOYS
- EXISTING BUOYS TO BE RELOCATED AND PREVIOUS REVISIONS
- RELOCATED BUOYS (e.g. No. 11A)
- MM1 BOUNDARY

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF DESIGN CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 274m AND BEAM (B) = 48m.
5. PROPOSED CHANNEL TOE FOLLOWS DESIGN CHANNEL TOE SOUTH OF BUOY No. 3, AND FOLLOWS BUOY BOUNDARY NORTH OF BUOY No. 3.

CHART DATUM

NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m

1:15000 (A1) 1:30000 (A3)

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REV	DATE	DESCRIPTION	BY	CHK	APPD
A	10.09.15	DRAFT FOR REVIEW	BAM	MP	

REVISIONS

CLIENT
CHANCERYGREEN ON BEHALF OF:
REFINING NZ
Your Energy Hive

PROJECT:
REFINING NEW ZEALAND
CRUDE FREIGHT PROJECT

DRAWING TITLE:
CHANNEL DESIGN
REALIGNMENT
OPTION 5
CHANNEL ALIGNMENT

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DRAWN	DATE	JOB No.
BAM	10/09/2015	PA1028

AUTOCAD REF. PA1028–MA–OP5A–DESIGN LEVEL

SCALE AT A1 1:15000

DRAWING No. PA1028/MA/1301

REVISION A

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WORKING DRAWINGS\PA1028-MA-OP5A-DESIGN LEVEL.DWG 9/10/2015 5:13

Appendix C: Expert panel

The following table records the participants in the four phases of the assessment:

- initial development of the MCA
- findings workshop
- MCA refinement
- peer review.

The asterisk (*) denotes the key contributor from each organisation (where applicable).

Table C-1: Contributors to the mid-point options assessment

Organisation	Specialist Area	Name	MCA development	Workshop	MCA refinement	Peer review
Refining NZ		Dave Martin* Greg McNeill Riaan Elliot	✓	✓	✓	
Chancery Green	Legal	Chris Simmons	✓	✓	✓	
Patuharakeke Te Iwi Trust Board	Cultural Values	Juliane Chetham	✓	✓	✓	
Ryder Consulting	Ecology Peer Review	Brian Stewart				
Tonkin + Taylor	Geomorphology MCA Assessment	Richard Reinen-Hamill Monique Cornish	✓	✓	✓	
MetOcean Solutions	Geomorphology modelling	Sarah Gardiner* Peter McComb		✓		
Royal HaskoningDHV	Channel alignment & dredging methodology	Richard Mocke* Justin Cross	✓	✓	✓	
Cawthron Institute	Ecology: marine mammals	Deanna Clement	✓	✓	✓	
Brian T Coffey & Associates	Ecology	Brian Coffey	✓	✓	✓	
Rob Greenaway & Associates	Recreation	Rob Greenaway	✓	✓	✓	
The University of Auckland	Geomorphology peer review	Paul Kench				
Bioresearches	Ecology: shore and pelagic birds	Graham Don			✓	
Brown Ltd	Landscape, visual and natural character matters	Stephen Brown			✓	
Clough & Associates	Heritage	Rod Clough			✓	

Appendix D: Key literature

Bioresearches (September, 2016) Existing Environment Assessment: Ecology of the Dredge Area, Whangarei Heads. pp 210.

Brown and Associates (October, 2016) Landscape & Natural Character Effects – Key Findings. 3 pp.

Brian T. Coffey and Associates Limited (October, 2016) AEE: RNZ Marine Ecology 3. 67 pp.

Central Dredging Association, CEDA, (2011) Underwater Sound in Relation to Dredging, CEDA Position Paper 7 November 2011. 6 pp.

Clough & Associates (April, 2016). Marsden Refinery Whangarei Harbour Dredging: Archaeological Assessmnet. Draft. 25 pp.

Patuharakeke Te Iwi Trust Board Inc (January, 2015) Cultural Values Assessment Report: Refining NZ Ltd – Crude Freight Proposal. 23 pp.

Poten & Partners (August, 2016), Crude Shipping Alternatives Marsden Point, NZ. 28 pp.

Royal HaskoningDHV, RHDHV (May, 2016a) Technical Memo: Dredging Assessment Methodology. Reference M&APA1028N006D04. 42 pp.

Royal HaskoningDHV, RHDVH (June, 2016b) Refining NZ Crude Freight Project: RNZ Channel Design. Revision 5. 237 pp.

Tonkin & Taylor (April, 2016) Marsden Point Refinery – Crude Freight Project. Geotechnical Factual Report. 255 pp

Tonkin & Taylor (November, 2016). Crude Freight Shilling Project, Whangarei Harbour: Coastal Processes Assessment – Consultation Draft. Version 6. 160 pp.

Appendix E: MCA summary

Table E-1: MCA results (weighted) for natural aspects considered

Category			Natural													
Aspect			Direct impacts										Indirect impacts			
			Impact on benthic flora & fauna at site	Impact on local fish stocks	Impact on marine mammals	Impact on shore birds & pelagic birds	Sediment matching	Contamination	Impact on intertidal and subtidal flora and fauna	Impact on significant ecological habitats or species of flora and fauna within those habitats	Impact on reef	Turbidity (dredge location)	Turbidity (disposal location)	Coastline formation	Natural character and underwater seascape (biophysical)	Coastal erosion	Resilience
Description			Impact on ecological communities removed or smothered	Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)	Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)	Direct impact on feeding and nesting sites and indirect impacts on mating due to noise, light and general activity in the area	Degree to which the deposit would match the existing substrate	Potential for any existing contaminats to be spread	Potential to impact areas with important conservation value	Potential to impact areas with important conservation value	Potential to impact known area of hard shore biological diversity	Potential for movement of sand from site and impacts on water quality (colour and clarity)	Potential for movement of sand from site and impacts on water quality (colour and clarity)	Potential for deposition to occur to a level greater than normal coastal processes	Significance of the impact on the natural character values & 'landscape' of the sea floor	Potential for erosion to occur to a level greater than normal coastal processes	Impact on resilience of the coastal system based on volume of sand removed / deposited
Dredge Disposal	1.2	Ebb Delta	4	2	4	4	2	0	-2	6	4		2	-2	1	-2	-3
	2.2	Nearshore	4	2	2	4	0	0	2	3	2		2	0	1	2	6
	3.2	Intermediate	2	2	4	2	0	0	2	3	2		2	0	2	2	6
	4	Land based disposal	0	0	0	0	0	0	0	0	0		0	-2	0	0	0
	5	Beach nourishment	0	0	0	4	0	0	0	0	0		0	-2	0	-2	-3
	6	Deep water	4	2	2	2	4	0	2	0	0		2	0	1	2	6
	7	Outside EEZ	2	2	2	2	4	0	2	0	0		2	0	1	2	6
Channel	2	Existing mid-section	2	2	2	2		0	2	6	4	2		0	1	0	
	4.2	Straight mid-section (west)	2	2	2	2		0	2	6	4	2		0	1	0	
	5	Straight mid-section (east)	4	4	4	4		0	4	9	6	2		0	2	0	
Dredge Methodology	1a	Trailer (with central weir)	2	2	4	2		0	2	3	0	2	4				
	1b	Trailer (actual overflow)	4	4	4	4		0	4	9	4	4	4				
	2	CSD	2	2	4	2	0	0	4	3	0	4	4				
	3	Backhoe	4	4	4	2	0	0	4	3	0	4	2				
	i	Ebb Tide Dredging	2	2	0	2	0	0	2	3	2	2	0				
	ii	All Tide Dredging	4	4	2	4	0	0	4	9	4	4	0				

Table E-2: MCA results (weighted) for social aspects considered

Category			Social										
Aspect			Longer-Term Impacts									Temporary Impacts	
			Fishing	Hunting	Watercraft sports	Watercraft sports	Wave sports	In-water activities	Beach access	Natural Character & underwater seascape (perceptual)	Permanent effects of navigation lights	Temporary amenity effects (light spill & noise emissions above water)	Temporary visual amenity & landscape
Description			Impact on recreational fishing (access or stocks) by boat, from shore or diving. Includes fin and shellfish	Impact on duck hunting on- or near-shore	Impact on on-water sports (e.g. yachting, rowing, waka ama, windsurfing, canoeing, jet skiing, boating)	Impact on boating communities associated with relocation of the navigation buoys	Impact on wave sports (e.g. kite surfing, wind surfing and surfing) due to changes in surf breaks	Impact on in-water activates (e.g. diving, swimming) due to changes in turbidity, currents, wave profile	Changes to beach access	Significance of the impact on the natural character values & 'landscape' of the sea floor	Impact on local and visitor communities associated with new Navaid structures	Impact on local community from light and noise associated with dredge operations	Aesthetic impacts on local community associated with dredge operations
Dredge Disposal	1.2	Ebb Delta	3	0	3		3	0	-3			0	0
	2.2	Nearshore	3	0	0		3	0	0			0	0
	3.2	Intermediate	3	0	0		0	0	0			0	0
	4	Land based disposal	0	0	0		0	0	0			0	0
	5	Beach nourishment	0	0	0		0	0	-3			0	2
	6	Deep water	3	0	0		3	0	0			0	0
	7	Outside EEZ	3	0	0		0	0	0			0	0
Channel	2	Existing mid-section	3	0	0		0	0	0	1	1	2	2
	4.2	Straight mid-section (west)	3	0	0		0	0	0	1	1	2	2
	5	Straight mid-section (east)	6	0	0		0	3	0	1	1	4	4
Dredge Methodology	1a	Trailer (with central weir)	3	0	0		0	0	0			2	2
	1b	Trailer (actual overflow)	6	0	0		0	0	0			4	4
	2	CSD	3	0	0		0	0	0			2	4
	3	Backhoe	6	0	0		0	0	0			4	4
	i	Ebb Tide Dredging	6	0	0		0	0	0			4	4
	ii	All Tide Dredging	3	0	0		0	0	0			2	2

Table E-3: MCA results (weighted) for cultural aspects considered

Category			Cultural								
Aspect			Kaimoana at Mair Bank	Kaimoana at Marsden Bank	Taonga species	Impact on Mahinga Mataitai	Mauri of Harbour	Cultural Landscapes and Seascapes	Kaitiakitanga	Subsurface Archaeological Sites	Land-based Archaeological Sites
Description			Impact on the ability to collect kaimoana from Mair Bank (based on erosion of Mair Bank) which may impact the ability to collect kaimoana (particularly pipi) sustainability	Impact on the ability to collect kaimoana from Marsden Bank (based on erosion of Marsden Bank) which may impact the ability to collect kaimoana sustainability	Impact on native birds, plants and animals of special cultural significance and importance to tangata whenua	Impacts on other key traditional mahinga mataitai and fishing grounds	Impact on the mauri of the harbour, and in particular the potential impact of sand removal from system	Impacts on important markers including Manaia, Matariki, Te Whara, the Takahiwai and Pukekauri Ranges and islands including Tatanga	Impact on the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga in regard to resources	Impact on subsurface archaeological sites, including shipwrecks	Impact on natural and physical resources that contribute to an understanding and appreciation of New Zealand's history and cultures
Dredge Disposal	1.2	Ebb Delta	3	6	6	6	6	3	3	0	0
	2.2	Nearshore	3	3	6	6	3	3	3	0	0
	3.2	Intermediate	3	3	3	6	3	3	3	0	0
	4	Land based disposal	0	0	0	0	3	0	0	0	0
	5	Beach nourishment	0	0	3	3	3	3	3	0	0
	6	Deep water	0	0	3	3	3	0	3	0	0
	7	Outside EEZ	0	0	0	0	3	0	0	0	0
Channel	2	Existing mid-section	6	6	3	6	6	3	3	0	0
	4.2	Straight mid-section (west)	6	6	6	6	6	3	6	0	0
	5	Straight mid-section (east)	6	6	9	9	9	6	9	0	0
Dredge Methodology	1a	Trailer (with central weir)	6	6	6	3	3	3	3		
	1b	Trailer (actual overflow)	9	9	9	9	9	6	6		
	2	CSD	6	6	6	6	6	3	3		
	3	Backhoe	6	6	6	3	6	3	3		
	i	Ebb Tide Dredging	6	6	3	3	3	3	3		
	ii	All Tide Dredging	9	9	6	6	6	6	6		

Table E-4: MCA results (weighted) for economic aspects considered

Category			Economic								
Aspect			Indirect Impacts					Direct Impacts			
			Impact on intakes and outfalls	NIWA Operations	Commercial Fishing	Navigation	Project Safety	Legal	Maintenance	Revenue	Cost
Description			Potential impact on intakes and/or outfalls (blocking). Excluding NIWA operations.	Potential impact on NIWA aquaculture operations (Abalone)	Shellfish and fish	Potential effects on navigational safety due to channel alignment	Risk associated with undertaking the option (environmental and WHS) linked to methodology and programme duration	Jurisdictional and practical issues associated with consenting each option	Degree to which deposition site or channel alignment impacts cost of maintenance	The amount of revenue generated via beneficial reuse	Total cost of option
Dredge Disposal	1.2	Ebb Delta	1	2	0		6	2	-2	0	6
	2.2	Nearshore	0	0	6		3	0	0	0	3
	3.2	Intermediate	0	0	3		3	0	0	0	3
	4	Land based disposal	0	0	0		6	4	0	-0.5	6
	5	Beach nourishment	0	0	0		6	4	0	-0.5	6
	6	Deep water	0	0	0		6	2	0	0	6
	7	Outside EEZ	0	0	0		9	6	0	0	9
Channel	2	Existing mid-section	0	0	0	0	3	2	2		3
	4.2	Straight mid-section (west)	0	0	0	-3	3	2	2		3
	5	Straight mid-section (east)	0	0	3	9	9	4	2		9
Dredge Methodology	1a	Trailer (with central weir)	0	0	0	0	3				3
	1b	Trailer (actual overflow)	0	0	0	0	3				3
	2	CSD	0	0	0	0	9				6
	3	Backhoe	0	0	0	0	6				9
	i	Ebb Tide Dredging	0	0	0	0	6				6
	ii	All Tide Dredging	0	0	0	0	3				3

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Annexure Two: Technical Reports

f) **Report in Support of an Assessment of Effects on the Environment – Navigational Risk Assessment of Engineered Channel Designs. Navigatus. Geraint Bermingham and Paul Dickinson. Dated 15 August 2017**

Report in Support of an Assessment of Effects on the Environment

Navigational Risk Assessment of Engineered Channel Designs

Prepared for Chancery Green on behalf of Refining NZ

by

Navigatus Consulting

Post Consultation Report Rev 0

15 August 2017

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Revision	Date	Authorised By	
		Name	Signature
Draft A	11 October 2016	G. Bermingham	
Draft B	1 November 2016	G. Bermingham	
Draft for Client review	2 November 2016	G. Bermingham	
Revised Draft	2 December 2106	G. Bermingham	
Public Consultation Draft	14 December 2016	G. Bermingham	p.p.
Post Consultation Report Rev 0 Improved explanations in places. Includes consideration of navigational effect of disposal areas	15 August 2017	G. Bermingham	

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Table of Contents

1. Executive Summary 1

2. Introduction 3

3. Risk Assessment Process 5

4. Context 6

4.1. Navigational Area Considered 6
4.2. Port/Pilotage Operation 12
4.3. Ship Navigation Paths 12
4.4. Types of Ships Considered 12
4.5. Number of Ship Visits 13
4.6. Probability and Potential Causes of Grounding 13
4.7. Typical Oil Tanker Operation 14

5. Risk Analysis 15

5.1. Undesirable Event 15
5.2. Operational Considerations 15
5.3. Channel Considerations 16
5.4. Detailed Reach Analysis – Existing Channel 18
5.5. Comparative Analysis 23
5.6. Consequences 27
5.7. Impact of dredged material disposal sites. 30

6. Findings 31

6.1. Risk Factors 31
6.2. Risk Profile - Channels 32
6.3. Overall Risk Assessment - Channels 36
6.4. Risk Assessment – Disposal Sites 37

7. Conclusions 38

7.1. Channel Design – Relative Risk 38
7.2. Disposal Sites – Absolute Risk 38

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Glossary

Term	Meaning
Aft	Towards the stern, or back, of a ship.
Aframax Tanker	A medium-sized crude oil tanker with a dead weight tonnage between 80,000 and 120,000.
ALARP	As Low As Reasonably Practicable. An internationally recognised term used within the context of managing risk.
Bow	The forward part of a ship.
Breasting Dolphin	A man made structure that extends above the water level that is not connected to shore, against which a ship may berth.
Chart	A nautical map showing the maritime area including depths, navigation marks and selected tidal current flows.
Chart plotter	An electronic device that displays a chart and superimposes the GPS-derived position of a ship. The device can also display data such as ship speed and course.
Conn	To direct the steerage of a ship. An office performing this duty is said to 'have the conn'.
Currency	The extent to which an individual is recently practiced in undertaking an operation and up to date with procedures. Often to be considered 'current' an individual is expected to have carried out the procedure within a specified time period.
Deadweight Tonnage	A measure of how much weight a ship is carrying or can safely carry. It is the sum of the weights of cargo, fuel, fresh water, ballast water, provisions, passengers and crew.
Displacement	A measure of the weight of a ship. The displacement is the weight of the body of water that would otherwise be occupied by a ship.
Fore	Towards the bow, or front, of a ship.
Forepeak	The part of the hold of a ship within the angle of the bow.
Freeboard	The height of a ship's side between the actual waterline and the deck.
Grounding	The act of a ship coming into firm contact with the bed of the sea.
Heading	A direction or bearing.
Headway	The forward progress made by a vessel.
Human Factors	The factors that influence human performance in a given operational environment and situation.

Term	Meaning
Keel	The lengthwise steel structure that runs along the centre of the hull of a ship from the bow to the stern. Typically the lowest part of the hull of a ship.
Knot	A measure of speed. One nautical mile per hour.
Making fast	To attach a line securely.
Making way	Moving through the water.
Lateral mark	A post or buoy marking the side of a navigable channel. Usually accompanied by a 'Port' or 'Starboard' indicating which side of the channel is being marked for a ship entering port.
LOA	Length Overall. The total length of a ship including all fixtures and fittings.
Lead (ing) marks	Navigation marks (usually with lights and/or sight boards) permanently located so that when they align they indicate a defined path or bearing.
Master	The officer in charge (captain) of a commercial vessel.
Nautical Mile (nm)	A nautical unit used for measuring distances at sea, defined in the metric system as 1,852 metres (Historically, defined as one minute of latitude and traditionally approximated to 2,000 yards).
PEL	Port Entry Light. A fixed light has defined sectors. These sectors being coloured to act to indicate to a bridge crew the vessel bearing relative to the light. This to indicate by the colour of light seen, that the vessel is on the correct path, to port or starboard of the path, and unsafe areas so mariners can determine if they are on a defined path or at the correct position.
PIANC	The World Association for Waterborne Transport Infrastructure.
Pilot	A pilot (also referred to as a 'Marine Pilot' or 'Maritime Pilot') is a mariner knowledgeable of a given local area, who is employed to manoeuvre ships through local waters such as harbours or river mouths.
Pilotage	The act of piloting a ship.
Pilotage Plan	A plan of how the pilot will take a ship into, or out of, a port, typically including headings and speeds at a range of points along the way.
Port (side)	Left hand side of a ship (when facing forward on a ship). ALSO Left side of a channel when facing in the direction of the flood tide (usually up a channel), or otherwise as defined by the local maritime authorities.
PPU	Personal Pilotage Unit. A specialist portable chart plotter independent of the ship's own navigation system. Used by pilots.

Term	Meaning
Reach	A defined open or straight portion of water or channel.
Starboard (side)	Right hand side of a ship (when facing forward on a ship). ALSO Right side of a channel when facing in the direction of the flood tide (usually up a channel), or otherwise as defined by the local maritime authorities.
SOPs	Standard Operating Procedures
Stern	Back or rear end of a ship.
Steerage	Effective directional control of the ship by means of the action of water over the rudder.
Suezmax Tanker	A crude oil tanker, which is the maximum size that can transit the Suez Canal. Typical dead weight tonnage is between 120,000 and 200,000.
Waterline	The level of the water on the side of a ship. Or, the designed line that the water will be at with the ship in a known condition.
Way	As in “taking way off”. See Headway and Making way.
Windage	The effect of the wind on the surface of a ship (hull and superstructure) above the water line.

1. Executive Summary

Context

The nature and depth of the approach and channel to the Marsden Point refinery currently limits visiting oil tankers by draught. This allows for fully laden Aframax tankers, but only partly laden Suezmax tankers. It is proposed to dredge and realign the channel to allow for fully laden Suezmax tanker operations. Two possible channel designs labelled 'Option 2' and 'Option 4.2' had been shortlisted for consideration in this risk assessment.

Scope and Process

This risk assessment considers the risks associated with fully laden Suezmax tanker operations (that is vessels in deep draught) to and from the Marsden Point refinery jetty. Given that each harbour and port is unique, and so incident information from one is not directly applicable to another, a quantitative risk assessment would not have been credible. This qualitative risk assessment therefore presents the effect on navigational risk associated with operations given each channel design in qualitative relative terms. The assessment reflects the planning and understanding developed during a specialist navigational risk assessment process undertaken prior to early August 2016 and does not include consideration of any change in operational measures that may have been implemented since.

The threats to safe navigation and the existing controls and mitigations were investigated in detail for each channel 'reach' (part length of the channel) during both arrival and departure, for both current Aframax and part laden Suezmax operations. This work assessed navigational risk for each of the proposed channel designs and made a comparative assessment against the existing channel. The assessment then considered in detail the effect on navigational risk of fully laden Suezmax operations given each channel design.

This assessment of navigational risk formed part of a process of understanding the required operational measures to support the use of the proposed channel as well as the overall change in navigational risk of the proposed operation compared to the current.

The detailed specialist study identified a range of operational measures would be required to support the use of the final channel. Given these measures will be required to achieve the ALARP risk criterion, it is assumed that the measures will be implemented as a pre-requisite prior to use of the revised channel. This risk assessment is based on that being the case.

Separately to the study of the navigational aspects of the channel designs themselves, this report also covers a judgement of the potential navigational impacts of the dredged material after disposal at the designated disposal sites.

Overall conclusions

Having a deeper engineered channel (either design Option) within the natural channel in the outer reaches creates a requirement to navigate vessels within a narrower outer channel than is currently the case. The associated risk can be adequately managed provided the range of operational measures identified in section 5.2 below is implemented.

It is also noted that the Option 4.2 design is closest to full compliance with the applicable international channel design guidelines – a feature that contributes to this design option enabling the lowest navigational risk.

Channel design Option 2 enables significant risk reduction over the current channel for the operations involving vessel types currently handled and enables adequate risk management for operations for the proposed fully laden Suezmax tankers.

Channel design Option 4.2 enables further risk reduction over Option 2 for the operations involving vessel types currently handled. Channel Option 4.2 would, if implemented, also enable operations for the proposed fully laden Suezmax tankers that can be considered to meet the As Low As Reasonably Practicable (ALARP) criterion.

The navigational advantages of Option 4.2 are due to the simplified track with fewer turns as well as fewer and longer straight legs, with each aided by a fixed heading and leading marks. This simplifies the task of navigating large ships through the whole path including the point of highest hazard.

2. Introduction

The approach and channel to the Marsden Point refinery currently limits visiting oil tankers to a maximum draught of 14.7m. This allows for fully laden Aframax tankers, but only partly laden Suezmax tankers.

It is proposed to dredge and realign the channel to allow for fully laden Suezmax tankers to a maximum draught of 16.6m. A series of prior investigations has been carried out that has led to the selection of two possible channel designs labelled ‘Option 2’ and ‘Option 4.2’.

This risk assessment stems from a comprehensive investigation of the navigational risks associated with navigating fully laden Suezmax tankers (that is ships in deep draught) to and from the Marsden Point refinery. The investigation included a two-day expert workshop and analysis and supporting research, including simulation exercises, has enabled the risk to be characterised and described, in relative terms, for each of the two channel options.

Individual ports and harbours, such as the approaches to Whangarei, each have unique features that affect the chance of incidents. It would therefore be incorrect to assume global incident rates can be applied where the features, such as available water, weather and tidal flows, have a significant influence. Therefore, following internationally accepted good practice; this risk assessment uses qualitative methods. It makes a comparison of the navigational risk associated with operations for the existing natural channel and vessel types to the risk associated with the proposed engineered channels and proposed vessel characteristics.

This report provides an overview of the logic, considerations and factors used in the formulation of the risk analysis. It then presents the findings including tabular and graphical representations of the navigational risk expressed relative to ship navigation within the current natural channel.

This risk assessment fits into a larger process to understand, manage and describe navigational and environmental risk as illustrated in Figure 1 below. The channel design process and supporting simulations were precursors to this risk assessment. This risk assessment is designed in part to inform operational developments for use of the revised channel. It will also support the assessment of environmental risk.

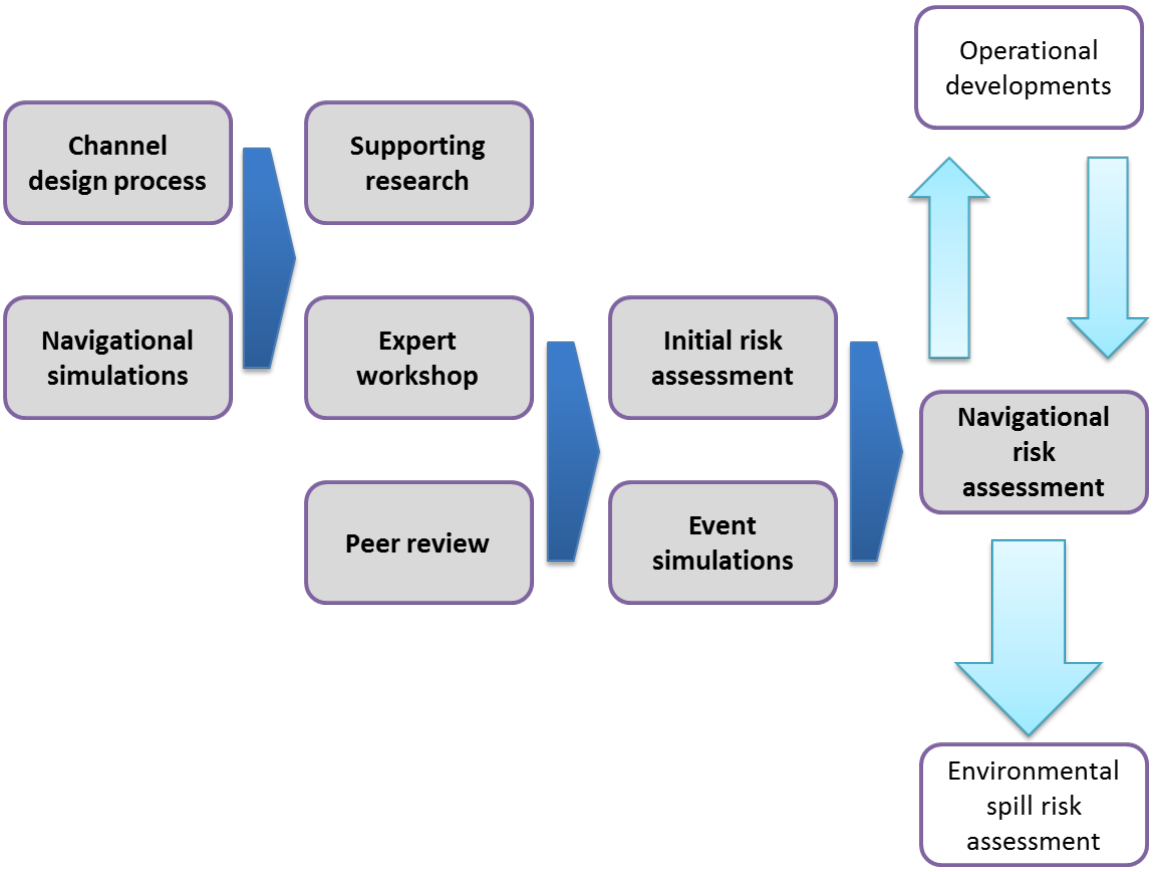


Figure 1 - Overall Process

3. Risk Assessment Process

The risk assessment followed the risk assessment part of the risk management process set out in AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines. The disciplined process was founded on a series of expert workshops supported by additional research and simulator studies.

The workshops were attended by staff from Refining NZ, North Tugz, Northport and the Harbourmaster who bought local expert knowledge in such areas as pilot and tug operation, procedure and practice, jetty management, and local navigation. Specialists from Be Software, Brisbane Marine Pilots, DNV GL and Royal HaskoningDHV who bought external expertise and viewpoints on subjects also supported the work of the workshop group. This included channel design and naval architecture as well as pilotage and general marine practice. Navigatus Consulting, independent specialist risk consultants, facilitated the workshops, carried out the assessment and prepared this report.

The workshop group first considered each reach of the existing channel and operation in detail. The hazards were identified and described, and the existing and potential mitigations to these hazards examined. The workshop group then considered the changes inherent in the two channel options, investigating each for the hazards and mitigations in turn. This process recognised the complexity of risk, including the concept of 'layers of defence' – that being the concept that for each hazard there are multiple and sometimes complementary mitigations as no one mitigation measure can be assumed to be completely effective.

The work of the group was informed by a series of simulation runs and actual approaches and departures that had been held previously. The output from the workshop sessions was then also tested by a further series of simulation runs.

The unique nature of individual harbours and very limited record of ship incidents at Marsden Point means it is unrealistic to attempt to carry out a useful quantitative assessment of the risk associated with piloting large oil tankers at Marsden Point. However, the structured approach of the workshops, use of local and external expertise covering all relevant aspects of the operation and subsequent analysis means a relative qualitative assessment could be completed. This assessment was therefore designed to take into account the changes in the likelihood of an incident and any changes in the consequence, and thus is a measure of changes in risk. The process allowed a conclusion to be made on the overall level of risk associated with the proposed channel designs and therefore their acceptability.

The assessment of the navigational impacts of the dredged material after disposal at the designated disposal sites is also covered. Unlike the complex and in-depth consideration of the engineered designs, given the relatively simple matters involved, the assessment of the effect of the disposed material with regard to navigation is based upon professional judgement of Geraint Bermingham, the lead expert for the overall package of work covered by this report. This work is reported towards the end of each relevant section of this report.

4. Context

4.1. Navigational Area Considered

Whangarei Harbour, close to the northern tip of Bream Bay, stretches some 23km north-west from the entrance at Whangarei Heads to the town basin at Whangarei and is approximately 6km across at its widest. Much of the harbour is shallow with exposed mud banks and sand bars at low tide. The entrance to the harbour is comparatively narrow, less than 0.5 nm at Marsden Point. The expanse of the harbour, a spring tidal range of 2.3m at Marsden Point[1] and the narrow entrance, results in significant tidal currents particularly at the entrance of the harbour. The chart of the harbour area indicates currents of 2.1 knots at Marsden Point and 3.1 knots at Home Point, with local information indicating localised higher rates of flow.

The Marsden Point refinery is located at the low-lying southern shore of the entrance to the Whangarei Harbour. The refinery has three jetties in the deep-water channel close to, and to the north of, Marsden Point. The larger oil tankers berth against both Jetty 1 (the crude oil terminal) and Jetty 2 together. The channel from the Fairway Buoy to the refinery is approximately 5 nm long and is well defined by a series of lit buoys.

The area considered in this risk assessment extends from the Fairway Buoy (S35° 53.25 E174° 33.15) 1.8nm off Busby Head to the Oil Refinery Jetty at Marsden Point (S35° 50.21 E174° 30.05). Specifically it considers the existing and proposed navigation channels defined and designed by Royal HaskoningDHV, and recommended for further consideration in their report[2]. These channels are linked to the dredging required to increase the channel depth to be able to accommodate a fully laden Suezmax tanker with a draught up to 16.6m.

The locations of disposal sites that are also considered in this report are shown at Figure 5[3].

4.1.1. Existing Channel

In terms of navigation the main points of note on the existing channel are:

- The Fairway Buoy is the outermost buoy for ships approaching and departing Marsden Point. In theory ships can pass either side of the buoy. However, the 'wave rider' buoys which feed data to the Dynamic Under Keel Clearance system used to inform ships of safe entry are located 0.3 nm to the north west of the Fairway Buoy and form a prohibited area. The leading marks and Port Entry Light (PEL) at Marsden Point guiding ships into the channel set a line to the west of the Fairway Buoy.
- Buoys #1 and #2 mark the seaward end of the channel. There is a limiting depth of 14.7m between Buoy #1 and the Fairway Buoy.
- Buoys #3 and #6 are close to Busby Head, the outermost land extent. The channel turns to the north at this point.

[1] LINZ Chart NZ5214 Marsden Point, 2014.
[2] Royal Haskoning DHV. Refining NZ Crude Shipping Project. Shipping Channel – Concept Design Report. June 2016.
[3] Tonkin + Taylor. NZ Refining Co Ltd, crude Freight Project, Planning Map Rev 0 dated Aug 16 (pre approval)

- Buoy #7 is close to Home Point. The coast from Busby Head around Home Point has a rocky foreshore and so is considered hazardous. There is a rocky outcrop extending from the Home Point shoreline to the edge of the channel 0.1 nm to the north east of Buoy #7. The outer extent of the rock is charted at 4.8m and so presents a significant hazard to deep draught ships. Although close to the edge of the channel, this rock is currently unmarked. There is a change in the channel alignment at this buoy, which requires that inward ships make a starboard turn at Buoy #3 changing to a port turn to Buoy #14. In effect the channel presents an 'S' bend offshore from Home Point.
- Buoy #14 marks the north-eastern extent of the boundary – the ebb shoal - of the Mair Bank, a large sand bank. It also marks a change in channel alignment as the end of the bend around Home Point.
- Sinclair Leading Lights align to show the channel to the Refinery Jetty.

Royal HaskoningDHV[4] defined the existing channel as 6 reaches with 5 changes of heading shown in Figure 2 below. The reaches are defined as:

1. Fairway Buoy to Buoys #1 and #2;
2. Buoys #1 and #2 to Buoys #3 and #6;
3. Buoys #3 and #6 to Buoy #7;
4. Buoy #7 to Buoy #14;
5. Buoy #14 to Buoy #16;
6. Buoy #16 to Buoy #17 (i.e. off the Oil Refinery Jetty)

[4] Royal Haskoning DHV. Refining NZ Crude Shipping Project. Shipping Channel – Concept Design Report. June 2016.

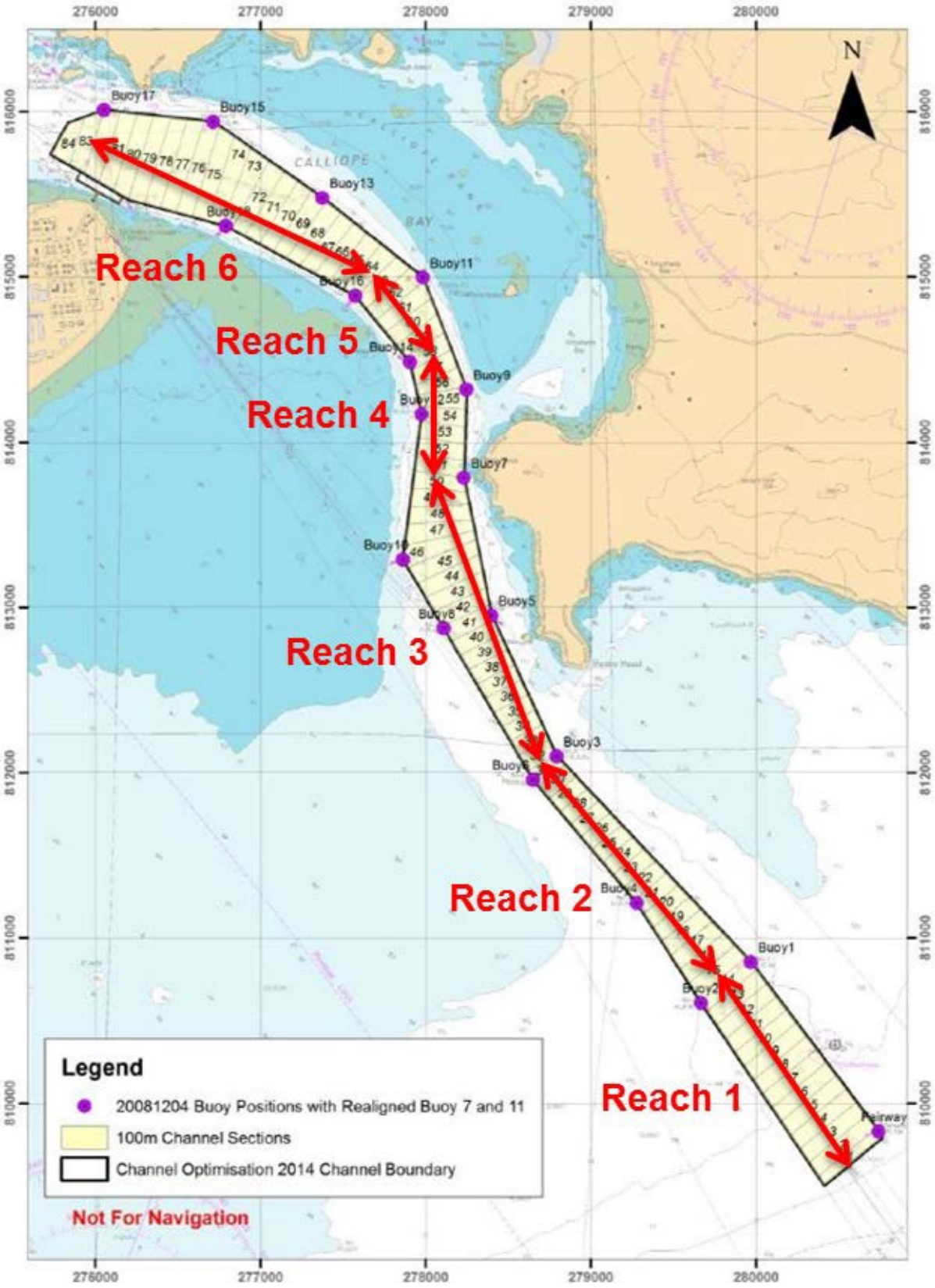


Figure 2 - Existing Channel Design Reaches

4.1.2. Option 2 Channel

The Option 2 channel follows the existing natural channel route and requires the same number of heading changes to navigate as the existing channel. The key change is that dredged depth of the channel is increased to allow for a 16.6m draught ship. The dredging introduces a 'channel within a channel' notably at the shallower entrance to the harbour where the deeper part of the channel is not 'buoy to buoy'. This dredged channel width is to the PIANC[5] guidelines. The minimum width is 220m on reach #3. The channel increases in width at the bends. The Option 2 channel is shown in Figure 3 below.

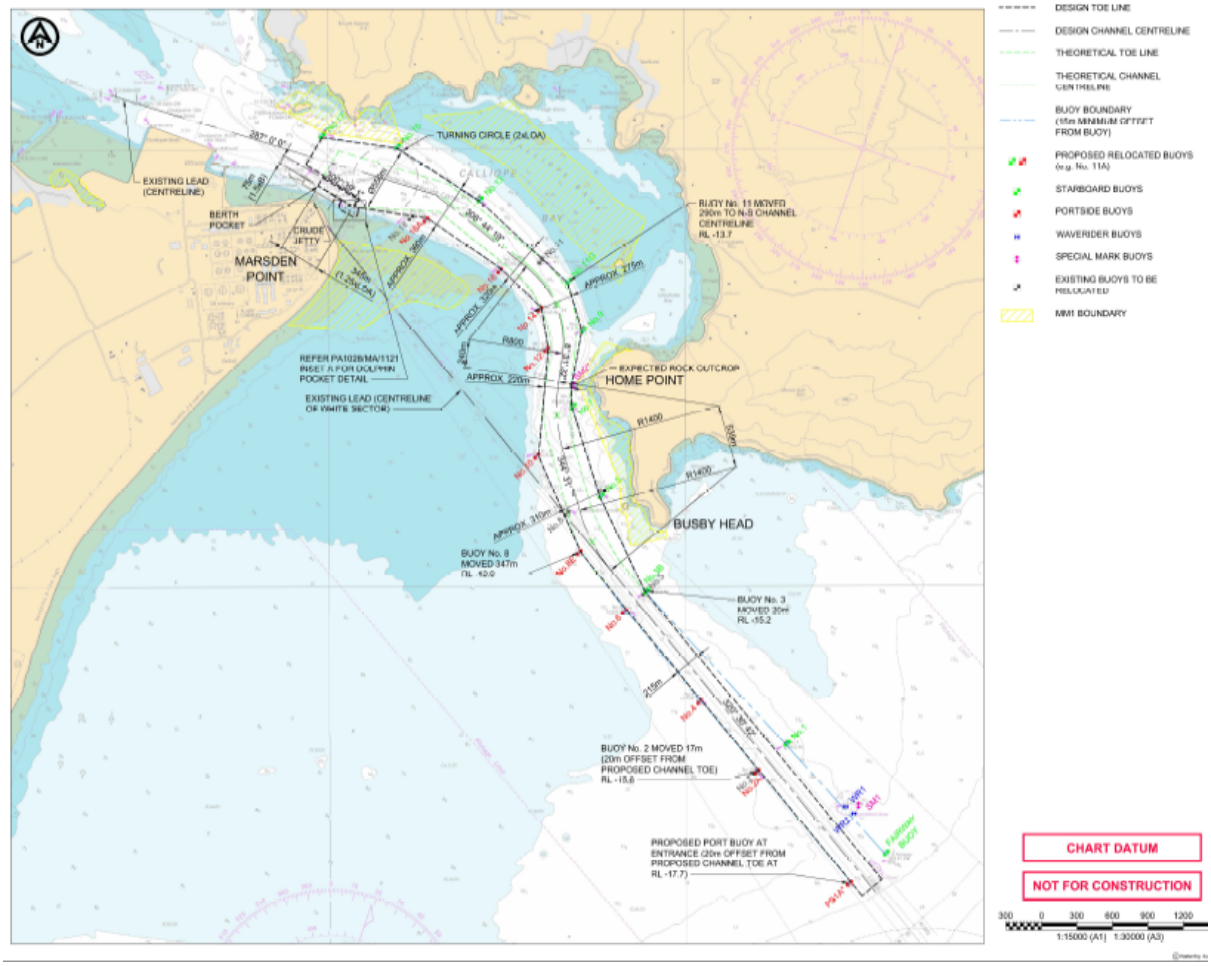


Figure 3 - Option 2 Channel

The PIANC guidelines call for five times the Length Overall (LOA) of the ship as a minimum radius for turns and length of the straights between turns. This figure is 1,380m for a Suezmax tanker with an LOA of 276m. The Option 2 channel improves the existing channel near Home Point as it introduces a straight between the existing two turns. However, the straight is 530m long and so does not achieve the PIANC guidelines, as it is only 40% of that recommended. Whilst the two turns at Home Point have a radius of 1,400m, the radius of the last inbound turn passing Buoy #14 has a radius of 800m[6] which is less than that

[5] PIANC is the World Association for Waterborne Transport Infrastructure. Its mission is to: provide expert guidance, recommendations and technical advice; keep the international waterborne transport community connected; and to support Young Professionals and Countries in Transition.
[6] Royal Haskoning DHV. Refining NZ Crude Shipping Project. Shipping Channel – Concept Design Report. June 2016. . Table 16.

recommended by the PIANC guidelines. This design includes adding a fixed mark to the outer limit of the rocky outcrop at Home Point.

4.1.3. Option 4.2 Channel

The Option 4.2 channel, shown in Figure 4 below, also allows for a 16.6m draught ship and differs from Option 2 in that it only has 2 turns and 3 primary headings. Dredging accordingly, and moving a number of the buoys achieves this. The first turn around Home Point has an extended radius of 1,800m with the second turn remaining at 800m[7]. The straight leg is extended in length to 894m while the channel is widened in places at the bends. Whilst the channel still does not fully achieve the PIANC guidelines it does offer improvements over Option 2. In particular ships will be on a steady, almost North-South, heading when they are passing Home Point and its rocky outcrop. This design is supported by the addition of 2 leading marks on the northern shore of Calliope Bay.

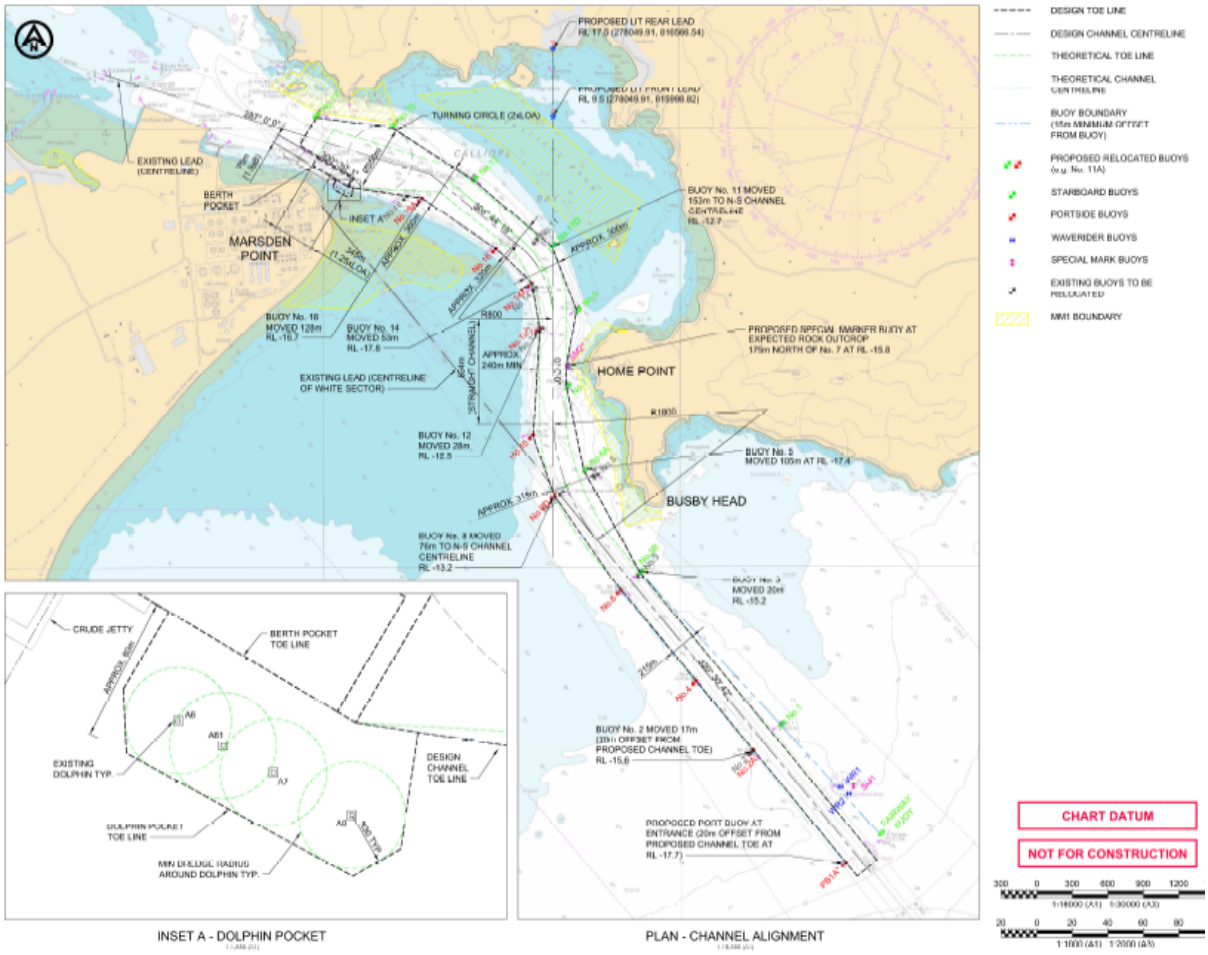


Figure 4 - Option 4.2 Channel

As with Option 2, this design includes adding a fixed mark to the outer limit of the rocky outcrop at Home Point.

[7] Royal Haskoning DHV. Refining NZ Crude Shipping Project. Shipping Channel – Concept Design Report. June 2016. . Table 18.

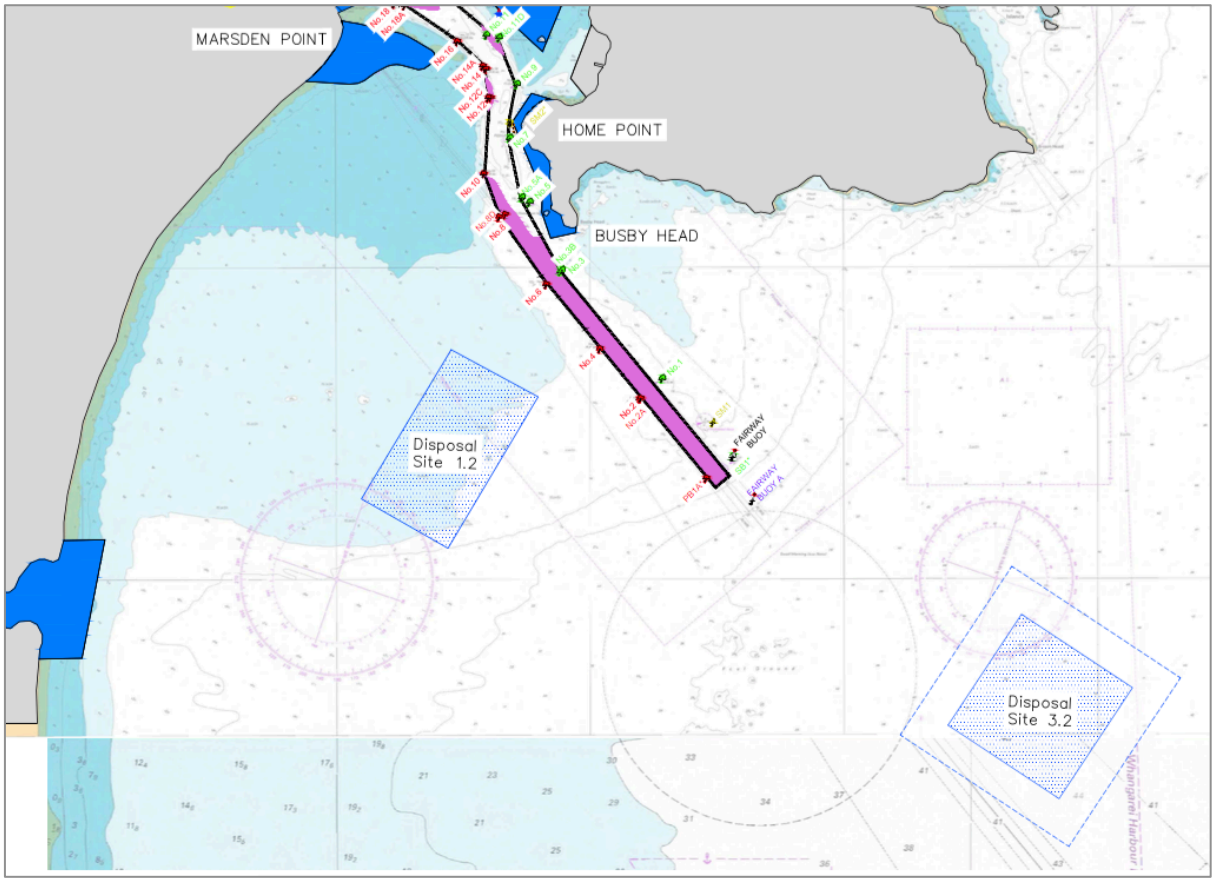


Figure 5 – Dredged material disposal areas

4.2. Port/Pilotage Operation

Whangarei Harbour serves several significant commercial marine operations including:

- Marsden Point Refinery operated by Refining NZ – oil tankers.
- Marsden Point deep-water port operated by Northport – general cargo notably log-ships.
- Portland operated by Golden Bay Cement – cement carrier.

There are also a number of small ship repair facilities and boatyards closer to Whangarei.

4.2.1. Pilotage

Whangarei Harbour is subject to compulsory pilotage for all ships over 500 gross tonnes. North Tugz Limited provides the only pilotage service.

4.2.2. Current Towage Capacity

North Tugz is the provider of towage services in Whangarei Harbour. Currently the company uses a range of tugs[8] to service the Marsden Point refinery:

- *Bream Bay,* Bollard pull: 69 tonne ahead, 68 tonne astern.
- *Takahiwai,* Bollard pull: 50 tonne.
- *Marsden Bay,* Bollard pull: 29 tonne ahead, 23 tonne astern.
- *Kemp,* Bollard pull: 14 tonne ahead, 9.5 tonne astern.
- *Hobson,* capable of Bollard pull: 3.3 tonne.
- *Jack Guy* a rigid hulled inflatable pilot boat (capable of providing a minor push only).

4.3. Ship Navigation Paths

The channel diagrams show a centre line of the channel. However the natural swing of a hull, the effect of wind and tide, and dynamic effects of a large ship making a turn means that this line does not represent the actual path that ships should steer. The optimal paths for a range of scenarios were explored using the series of simulation runs. The results form the basis of the design of the final preferred tracks.

4.4. Types of Ships Considered

Marsden Point Refinery can presently handle fully laden Aframax and partly laden Suezmax tankers with a maximum draught of 14.7m. The proposed dredging of the channel will allow a fully laden Suezmax tanker, with a draught of 16.6m and a greater displacement to enter on any given high tide. It is assumed that a tanker will arrive and discharge most, if not all, of its cargo at the refinery, and that it will not take on petroleum product for onward transit. Therefore the full and part laden tankers were only considered as arriving at the refinery. Tankers leaving the refinery were assumed to be in ballast with a reduced draught. Therefore, the study did not consider the case of a tanker departing fully laden. Whilst laden tankers tend to have a constant draught along their length, ballasted tankers tend to be deep

[8] Plant information supplied by NorthTugz July 2016.

by the stern. It is noted that a ballasted ship will present more windage than a laden one due to greater freeboard.

The assessment also considered a typical log ship (bulk carrier).

It is noted that the only proposed change to current operations is the ability to allow fully laden Suezmax tankers to navigate to the berth.

The ships considered are summarised in Table 1 below.

Type	LOA	Beam	Draught	Indicative Displacement	Comment
Suezmax Part Loaded	276m	50m	14.7m	90,000 to 120,000	Arrival
Suezmax Full Loaded	276m	50m	16.6m	160,000t to 180,000t[9]	Arrival
Aframax Full Loaded	243m	43m	14.7m	80,000t to 120,000t[10]	Arrival
Aframax Ballast	243m	43m	6.0m/8.0m[11]	As required by Master	Departure
Suezmax Ballast	276m	50m	7.0m/ 9.0m[12]	As required by Master	Departure
Bulk Carrier	190m	30m	12m	25,000	Arrival and Departure

Table 1 - Types of ships considered

4.5. Number of Ship Visits

Allowing fully laden Suezmax tankers to visit Marsden Point will reduce the number of large tankers visiting the refinery for a given throughput. The exact change in the number of visits will depend on the existing and proposed loading of the tankers, the mix of tanker types visiting the refinery and the overall oil volumes required to be delivered.

4.6. Probability and Potential Causes of Grounding

DNV GL carried out analysis of the causes of globally reported grounding incidents for the Australian Maritime Safety Authority in 2011[13]. As noted earlier, the unique nature of Whangarei Harbour means application of these global figures to calculate the risk of grounding at Marsden Point would be invalid. However, the report includes a table showing

[9] The actual displacement of a laden Suezmax tanker varies dependent on such factors as cargo size, crude oil density, and ship empty displacement.
[10] The actual displacement of a laden Aframax tanker varies dependent on such factors as cargo size, crude oil density, and ship empty displacement.
[11] Typical draught figures provided by Refining NZ.
[12] Typical draught figures provided by Refining NZ.
[13] Appendix IV (Ship Oil Spill Risk Models) of the DNV Report for the Australian Maritime Safety Authority (AMSA), 2011

the causes of groundings, with 87% of groundings being attributable to 'Human Error' as opposed to ship engineering failures or external factors. This indicates that measures aimed at supporting the human being in the system (e.g. advanced aids, developed and proven procedures, high quality training), will be more effective at reducing risk than measures aimed at responding to potential engineering failures.

4.7. Typical Oil Tanker Operation

All oil tankers entering and leaving Marsden Point Refinery are under the control of a pilot. The chart for Marsden Point[14] shows a pilot boarding position 2 nautical miles to the SE of the Fairway Buoy. In practice the pilot can board anywhere after discussion with the ship's master, aiming to be at least 1½ nautical miles from the Fairway Buoy. Once aboard, the pilot briefs the master on the pilotage plan that will be used to take the ship into the harbour, confirms the ship is in a suitable condition to be taken into harbour, and then takes control.

The ship enters the channel under the pilot's command, typically making way at 6 knots. The aft tug is made fast to a large tanker such as an Aframax or Suezmax close to Buoy #4 (a port lateral mark). For ships greater than 50,000 tons the tugs are made fast before Busby Head. The ship then commences the first turn, to starboard. This is followed by a turn to port approximately to the west of Home Point. It is necessary for the tanker to maintain sufficient speed for the rudder to be effective in turning a large ship whilst not building up such momentum that the ship will be difficult to bring to a stop by the terminal. Its speed is therefore typically 6 to 7 knots through the turns and indeed this is the target exit speed for the ship as it passes Buoy #14, a port lateral mark to the SW of Calliope Island. The rest of the passage is straight so the pilot will concentrate on slowing the ship down using a combination of the ship's main engine and the attached tugs. The target speed alongside Buoy # 18, a port lateral mark, is 3.5 to 4 knots, and the ship aims to be stationary when adjacent to the loading jetty. The tugs then push the ship sideways onto the docking jetty. The pilot will aim to maximise the depth of water under the keel and minimise the tidal current during the pilotage. The pilot therefore aims to arrive at the terminal at high tide, and so typically boards the ship 1¼ hours before high tide.

For departures, the duty pilot boards the ship before cast off, briefs the ship's master on the pilotage plan and confirms the ship is in a suitable condition to proceed. On departure the ship is eased off the dock and then turned around to face out to sea using the tugs. The tugs let go the ship on completion of the swing but stay close to the ship in attendance until they are released by the pilot, typically at Buoy #7, a starboard lateral mark just to the west of Home Point. The ship accelerates using its main engine gaining sufficient speed to ensure the rudder is effective. However, as there is no need to stop at the end of the channel the ship is usually a little faster as it enters the two turns around Home Point, typically making way at 8 knots. Once clear of Busby Head the ship will continue to accelerate to its cruising speed, dropping the pilot off near the pilotage limit.

[14] LINZ Chart NZ5214 Marsden Point, 2014.

5. Risk Analysis

5.1. Undesirable Event

The risk analysis centred on identifying and analysing hazards that could lead to an undesirable event, and then formulating the mitigations that could help prevent this event, or if the event occurred, the responses that could stop the event developing to a full consequence. The undesirable event for this project was defined as:

Unintended departure from the 'Pilotage Plan'

The pilotage plan is the detailed procedure worked out by the pilot before the pilotage is undertaken to ensure that the ship is safely piloted in to, or out of, the refinery jetty. The plan is unique to each pilotage as it takes into account all the relevant factors that could affect the pilotage including ship displacement and handling characteristics, wind direction and strength, tidal height and flow, and visibility. It follows that if the pilotage plan is correct and correctly executed then the ship will arrive safely at its destination. An unintended departure from the pilotage plan will not in itself necessarily lead to an accident, but can be a precursor.

5.2. Operational Considerations

The risk assessment workshops and subsequent simulation runs undertaken showed that a range of operational measures could be implemented and that these measures would have a significant impact on the overall risk assessment. These measures apply to all scenarios and are independent of the channel option selected. The measures were identified as:

- Towage study to identify and implement a capability[15] that can fully mitigate ship failure scenarios as well as build additional performance monitoring and reserve capacity into normal operations.
- Standard common pilotage procedures being consistently applied including optimum capability and use of tugs as risk mitigation measure[16]
- Standard Pilotage Plan issued to ships in advance (with defined waypoints and preferred track.
- Mandatory use of a standard Personal Pilotage Unit (PPU), together with the associated training.
- 2nd pilot on board, at least for the initial fully laden Suezmax tanker operations[17], to allow for redundancy, PPU monitoring and to ensure currency. This includes the adoption of standard procedures to utilise two pilots defining the roles of each.
- Defined pilot/ tug master training and currency requirements.
- Pilots board ships early enough to allow a full and comprehensive briefing.

[15] This capability includes the equipment used (i.e. tugs, lines etc.) as well as the procedures employed and training of the crew in the use of the equipment and procedures.
[16] The study of the optimum use of tugs should also be informed by the simulation sessions.
[17] The value and impact of two-pilot operations will need to be analysed in a separate study.

While some of these operational measures require development and input from a range of stakeholders (and are thus outside the scope of this review), our initial analysis indicated that the risk mitigation due to these measures is significant. This is supported by the DNV GL study showing that the overwhelming majority of ship groundings were caused by 'human factors'. Indeed, given that all these measures are reasonably practical the overall navigational risk post construction of an engineered channel would not meet the ALARP[18] criterion unless these measures were implemented. The following navigational risk assessment of the channel options therefore assumes these measures have been implemented in full as a pre-requisite to the use of the revised channel.

5.3. Channel Considerations

5.3.1. Channel Design

The two options considered were designed by Royal HaskoningDHV based on the PIANC guidelines.

As far as possible the engineered channels were designed to comply with the PIANC guidelines. These guidelines provide recommendations regarding minimum bend radius, channel width and length of straight sections. Meeting these recommendations was not possible throughout the full extent of the channel due to existing site constraints.

The international PIANC guidelines allow the existing and designed channels to be classified according to their ease of operation as follows:

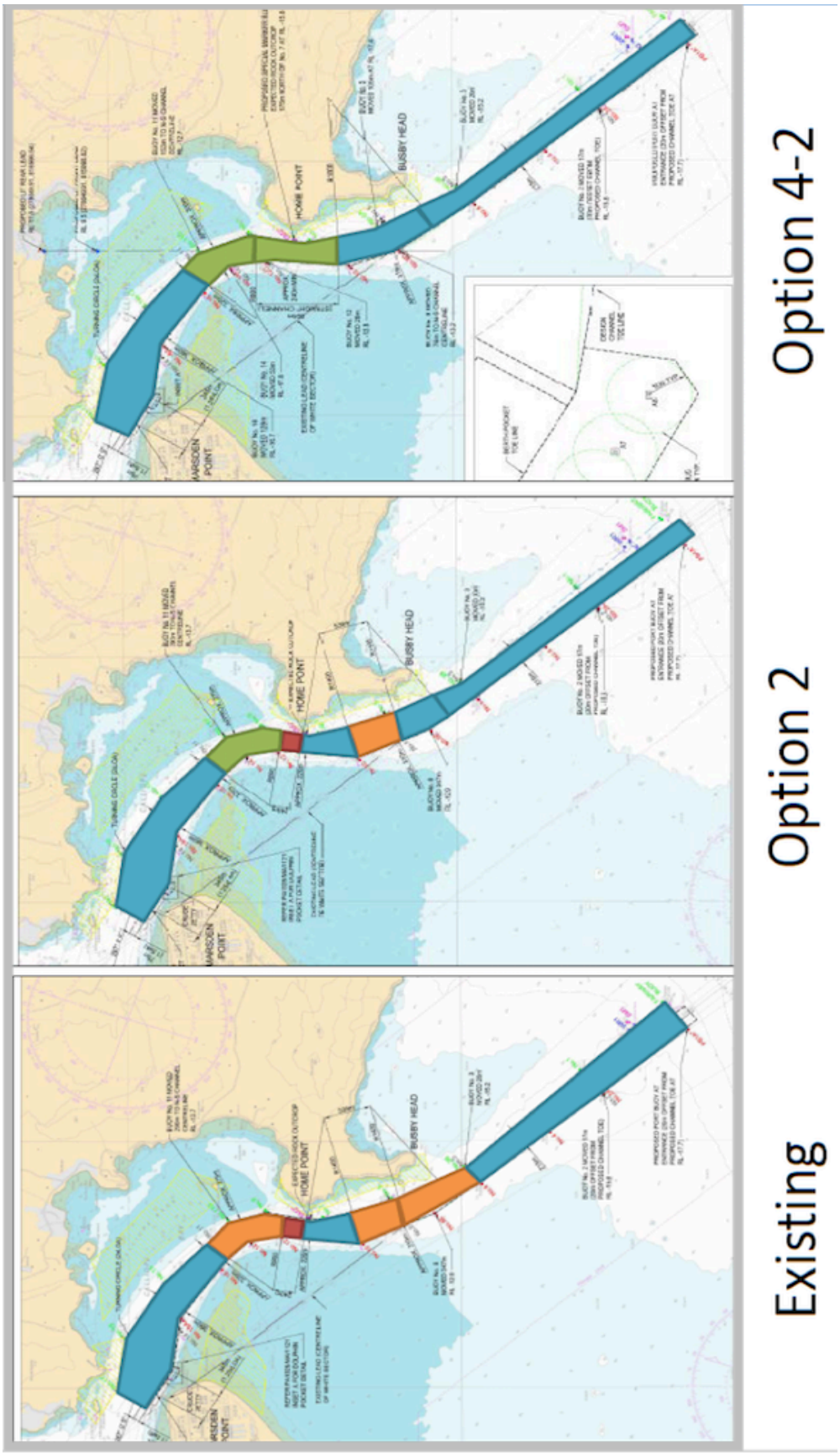
- Optimum – Ideal under both operating and extreme conditions, no issues encountered.
- Adequate – Very good under operating conditions, manageable under extreme conditions.
- Marginal – Adequate under operating conditions but poor under extreme conditions.
- Inadequate – Poor under both operating and extreme conditions, may be considered unacceptable from a navigational risk perspective.

The Royal HaskoningDHV analysis of the channels according to these ratings has been superimposed on the channel option plots in Figure 6. If considered against the PIANC guidelines, the existing channel has a 'Marginal' area to the west and south of Busby Head, and as the channel passes Home Point. The existing channel is 'Inadequate' adjacent to Home Point. Option 2 shows an improvement, with the 'Marginal' area to the west of Busby Head reduced to one segment, and the 'Marginal' area past Home Point improved to 'Adequate'. However, the 'Inadequate' section adjacent to Home Point remains. Option 4.2 is a further improvement on Option 2 with the segments adjacent to and past Home Point rated as 'Adequate'. The bend radius between Busby Head and Home Point is also improved to rate as 'Optimum', while the segment just before Home Point is classed as 'Adequate'.

The channel options were trialled in a portable simulator[19]. The pilots involved showed a clear preference for Option 4.2 over Option 2 as the channel simplified the arrival approach and gave more sea room around the critical area at Buoy #14 (inner curve near the Mair

[19] Subsequent full bridge simulations were carried at the Marine Simulation Centre of New Zealand Maritime School, Auckland.
[19] Subsequent full bridge simulations were carried at the Marine Simulation Centre of New Zealand Maritime School, Auckland.

Bank), improved clearance from, and allowed a straight near North-South aligned section past, the rocky outcrop at Home Point.



	Classification	Definition from Simulation Report	Adopted PIANC Criteria
	Optimum	Ideal under both operating and extreme conditions, no issues encountered.	>5*LOA
	Adequate	Very good under operating conditions, manageable under extreme conditions.	<5*LOA>2.5*LOA
	Marginal	Adequate under operating conditions but poor under extreme conditions.	<2.5*LOA>1.25*LOA
	Inadequate	Poor under both operating and extreme conditions, may be considered unacceptable from a navigational risk perspective.	<1.25*LOA

Figure 6 - Channel classification against PIANC

5.3.2. Dynamic Under Keel Clearance (DUKC) System

The DUKC system uses wave rider buoys and tidal data to calculate the depth of water available for ships in a channel taking into account the effect of tide and waves as well as the dynamic characteristics of ships. Ships and ports can therefore determine whether a ship can safely enter a port. The system has been deployed at many ports around the world and has proved effective.

Marsden Point uses a DUKC system to assist with the decision of whether to allow a ship to proceed into port under the conditions prevailing when the ship is due and on arrival at the Fairway Buoy and on arrival at the Buoy.

5.4. Detailed Reach Analysis – Existing Channel

As noted in section 4.1.1 the existing channel to Marsden Point can be considered as a series of six reaches. This allows a detailed analysis, considering each reach in turn to be effectively carried out. This in turn enables a disciplined and progressive consideration of the threats and associated mitigations of the existing channel to the level of detail required for a comprehensive analysis.

5.4.1. Consistent Threats and Mitigations

Some threats and mitigations are evident throughout the pilotage and are largely irrespective of the reach and whether the ship is arriving or departing. These are:

Threat: Weather. Weather is always a factor for maritime operations, but existing Standard Operating Procedures (SOPs) provide appropriate guidance. A sudden loss of visibility is considered a possibility at Marsden Point but this is mitigated by knowledge of local weather and having good navigation cues such as buoyage and leading lights. The upper extent of the channel does offer protection from wind, waves and swell.

Threat: Engineering. There is the ever-present possibility of an engineering event affecting the ship's ability to manoeuvre. The SOPs, readiness of the bridge team and the general understanding of the local sea conditions, currents and approach channel and the consequent priorities are factors pilots would consider in such circumstances.

Threat: Pilot. Issues with the pilot, either in the case of the pilot becoming incapacitated or, given the relatively limited number of large tankers visiting Marsden Point, pilot currency, are hazards.

A possible mitigation is to take two pilots on a pilotage. One pilot would have the conn with the other monitoring, assisting and being available to step in. Both pilots would gain operational experience. The human factors associated with two qualified pilots working together would have to be considered.

Mitigation: PPU. The PPU is a specialist portable chart plotter available for pilots. It is highly accurate and displays programmed track, current position and a prediction of the ship's path and position. The PPU also enables pre-programmed waypoints and paths to be followed, and can take inputs from the ship's own navigation system. It is thus an effective tool that provides significant assistance to the pilot and can mitigate a range of threats; for example, the pilot's PPU is the most effective mitigation in the event of loss of visibility. At the time of the workshops pilots at Marden Point did not universally use a 'standard' PPU, although at the time of the risk assessment study itself, North Tugz had commenced exploring

formalising its use. In the time since then and the date of this report, PPU use has become a standard requirement for all transits of large vessels.

5.4.2. Arrival - Reach 1

Reach 1 occurs between the Fairway Buoy and the start of the defined channel at Buoys #1 and #2. Whilst this is open water there are still threats and mitigations to consider.

Ship Preparation. The threats in Reach 1 as identified are largely concerned with the ship's preparation for the approach and arrival. Late readiness for harbour entry or not being correctly positioned means the ship may miss the narrow tide 'window' that allows the ship to arrive at the berth at high water slack tide. Lateness for any reason including defects on the ship, will result in the pilot having limited time, and so increased pressure, to decide whether to bring the ship in or not. The mitigations for these are essentially monitoring the ship's state and crew readiness. The IMO[20] requirements that require ships to test and configure steering gear prior to entering a harbour acts as a powerful mitigation.

Pilotage Planning. Inadequate preparation could result in the ship's master and the pilot having differing understandings of the arrival procedure, pilotage plan and planned use of tugs, an undesirable situation that can be prevented by use of common procedures and by planning ahead. Forward planning could be achieved by sending a detailed standard pilotage plan to the ship well in advance. Establishing and applying standard pilotage and towage procedures for large ships could also be an additional and effective mitigation.

5.4.3. Arrival - Reach 2

Reach 2 represents the point at which the ship is within the narrowing channel and where the coast to the north presents a higher level of potential consequence. The relevant threats are largely the same as for Reach 1; however, departure from the planned path is more pertinent. The threat of a late defect notification is not so relevant on this reach as it is taken the pilot has been briefed by the master and has ensured the ship has the required capability to safely complete the approach and berthing.

Departure from Planned Path. A threat of the ship departing the planned path is evident on this reach, as the ship needs to more closely follow the required path in the channel from this point on. Given the ship is closer in, the Port Entry Light (PEL) should be more effective. At the time of the analysis, it was recognised that the formal use of a PPU would provide a very effective method for enabling and ensuring cross track error (relative to the defined preferred path) is monitored and indicating the exact ship positioning relative to hazards. As noted above, since that time routine PPU use has been introduced.

5.4.4. Arrival - Reach 3

Reach 3 includes the first of a series of helm-controlled turns to take the ship past Home Point.

Manoeuvre Hazards. For Reach 3, the threat of departure from planned path can be better expressed as manoeuvre hazards. These include the hazards associated with manoeuvring a ship in a confined channel including allowing for the swing of the stern; these are late helm, early helm, or incorrect rate of turn as any will result in the ship deviating from the

[20] International Maritime Organisation

intended path. This is compounded in the current channel by the lack of a defined or steady heading between the turns to starboard and then the turn to port. There are however a number of mitigations, including that the manoeuvre is well practiced and understood by the pilots as well as effective use of PPUs.

Tugs. Of note, tugs will have taken lines at the start of this reach. However, as large ships need to retain sufficient speed for steerage, typically 6 to 8 knots and as the current tugs are not 'escort tugs', the tugs ability to assist the ship is limited on this reach. In the case of an engineering failure onboard the tanker, or pilot error, tugs need to be in a position to be able to respond in sufficient time to prevent grounding. In addition, tug crews need suitable response procedures and to be trained and current in their use.

5.4.5. Arrival - Reach 4

Reach 4 sees the ship bringing the bow to port; to complete the 'S' turn past Home Point. The ship is thus taken from a starboard turn manoeuvre to a port turn manoeuvre without settling on a steady heading. However the hazards and mitigations remain essentially similar to those for Reach 3 but with the notable rocky outcrop hazard.

Rocky Outcrop. There is a rocky outcrop that extends to the west of Home Point and ends close to the edge of the channel. At this point the rock is charted at 4.6m deep and so is not visible. This rock represents a particular hazard. It is considered essential that this rock is correctly marked with a West Cardinal Marker to provide a clear unambiguous visual indication of its location.

5.4.6. Arrival - Reach 5

Reach 5 represents the completion of the turn to port and the ship being brought on to a steady heading for the final approach to the Marsden Point jetty. The hazards and mitigations are similar to the previous two reaches except the rocky outcrop hazard not being a factor. The key difference is that, with the ship being slowed, the tugs can now take some control of the ship as required by the pilot. The channel also opens up at this point giving more leeway and time to respond to events.

5.4.7. Arrival - Reach 6

The last reach includes the final approach to Marsden Point and the berthing of the ship at the jetty.

Speed Control/ Tugs. The key to this reach is speed control, in firstly taking way off the ship and then preparing to berth the ship; poor speed control is therefore a significant hazard. Although the ship can stop using its own engines, tugs are used to assist. The use of tugs is important in this reach, not least to correctly berth the ship. Tugs feature as a mitigation in holding the ship on course and taking excess speed off. Given the important role of the tugs, tug failure is a hazard. It is noted that the only mitigation for such a hazard is to have sufficient spare towage capacity standing by. The ship is constrained within the channel and so the hazard of incorrect ship positioning also exists.

5.4.8. Departure – Reach 6

For the departure, Reach 6 consists of moving away from the jetty, swinging the ship, and then commencing the departure including bringing the ship to steerage speed.

Ship Preparation. The departure naturally allows more time for preparation as the ship is alongside and the pilot can easily board almost any time. The tidal window is relevant to the start of the passage so departure can be accurately aligned to a favourable tide. Major work on the ship's propulsion and steering is prohibited when alongside so mechanically the ship will be in a known state as it has already been piloted onto the jetty.

Tugs. As with the berthing, tugs are essential to the casting off and turning operation so the threat of tug failure remains until the tugs are let go. Again the only effective mitigation is to have sufficient towage capability standing by.

Departure from Planned Path. The ship is in a channel and so must remain on or close to the planned path. Initially this is achieved using the attendant tugs. However, as the ship gains speed it gains steerage and so is more resilient to the threat of the loss of tug assistance.

5.4.9. Departure – Reach 5

On the departure Reach 5 introduces an easy turn to starboard whilst the ship accelerates. The ship will have gained steerage by the start of Reach 5.

Tugs. The ship has gained steerage and so tugs are not required to direct the direction of the ship's travel. However, the ship may still need assistance in the event of an engineering failure such as a power blackout or steering system failure. Whilst the tugs will have let go, they still need to remain in close attendance to the ship. As with the arrival reaches, the tugs would need to be in a position to be able to respond to a situation in sufficient time. Simulation sessions could provide guidance to the best positions of the tugs and these should then be incorporated into SOPs.

5.4.10. Departure – Reach 4

Reach 4 sees the ship increasing the turn rate to starboard and passing Home Point.

Manoeuvre Hazards. The manoeuvring hazards on departure are similar to those on arrival. The incorrect application of helm will result in the ship deviating from the intended path. Similar mitigations as for arrival are available or in place.

Use of Tugs: The pilots emphasised that they currently 'drive' the ships though the 'S" bend by Home Point. This means that the initial focus is to accelerate the ship to at least manoeuvring speed (over 5 knots) and usually 8 knots. Once up to these speeds, the ship will have sufficient momentum to reach the open sea in the event of an engine failure. The power of the rudder is such at these speeds that specific rudder hard-over failures may not be able to be contained unless the tugs are prepositioned, with suitable response procedures, and with crews trained and current in their use.

5.4.11. Departure – Reach 3

Reach 3 involves the change from a starboard turn to a port turn to complete the 'S' turn after passing Home Point. This is similar to the arrival Reach 4 and so the threats and mitigations are similar, albeit that the ship is well underway which gives greater control.

Ship Momentum. The ship has gained speed and thus momentum by the start of Reach 3. This provides a major mitigation, as a ship would have sufficient momentum to reach the open sea in the event of a propulsion failure. Any tugs in attendance would only be required

to provide support in the event of loss of propulsion or steerage, or a rudder hard-over failure.

5.4.12. Departure – Reach 2

On the departure in Reach 2 the ship lines up on the straight channel heading out to the open sea. The only navigational hazard is the shoaling water north and south of the channel and thus the threat is of the ship failing to maintain the proper path. This is similar to the hazard noted on arrival and, given the tugs are no longer in attendance, has the same range of mitigations; however, it is noted that the expected part-laden, or in-ballast draught of the ship means the 'channel within a channel' should not be a direct threat.

5.4.13. Departure – Reach 1

The departure on Reach 1 is a continuation of Reach 2 and has the similar threats and mitigations.

5.4.14. Responses

It is readily apparent that the responses to an unintended departure from the pilotage plan as planned are the same for arrival or departure.

Responses. The judicious use of the ship's propulsion and rudder may allow the pilot to avoid contact or grounding, and even restore the ship to its planned course; however given the narrowness of the channel combined with the expected headway, a response to a rudder hard over failure may not be possible. The pilot's knowledge and use of the tide and current may help limit the impact on grounding. The tugs could provide towage and so manoeuvre the ship to safety; however, as noted above, this capability is limited by the speed of the ship at any given time, the positioning of the tugs and their capability. Finally, if the ship is making limited headway, typically less than 3 knots, the ship may be able to drop anchor to aid control of positioning.

5.5. Comparative Analysis

Overall the change from the existing channel through to Option 2 and then Option 4.2 results in fewer reaches and turns and so less complexity. This is represented in Figure 7 below.

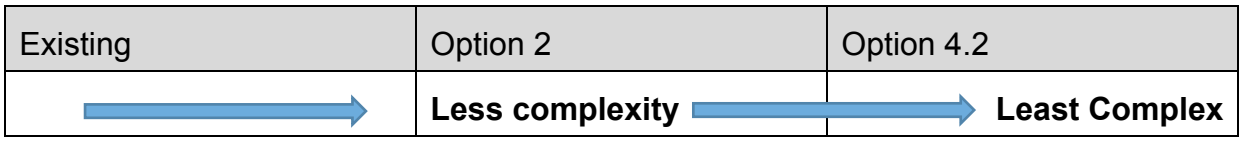


Figure 7 - Channel complexity

5.5.1. General

The differences between a fully laden Suezmax tanker and a part laden Suezmax tanker or fully laden Aframax tanker are essentially:

- A greater tonnage means more inertia that in turn requires more time and sea room to bring a ship to a stop, increase speed through the water, or to change course.
- A deeper draught displaces more water with a greater cross sectional area leading to more interaction with the bottom so the ship may 'suck down', resisting the effect of the rudder.
- A vessel sitting lower in the water will have to less windage, which results in a lower wind induced drift rate.
- The increased load of a fully laden Suezmax tanker compared with the current tankers means that the same amount of crude oil can be delivered by fewer ships. If less entries and exits are undertaken, this could lead to an issue maintaining the pilot's currency handling large tankers.

A number of the hazards identified are independent of the ship type and size or the design of the channel. These are:

- Ship arrives early at the pilot station.
- Ship arrives late at the pilot station.
- Ship is not at the correct position as planned for the pilot transfer.
- Late defect notification, or defect not notified.
- Ship master's understanding of the plan not the same as the pilot's.
- Incorrect 'pilotage plan' on board.
- Poor quality of the ship or crew.
- Pilot incapacity (once onboard and the entry has been commenced).

The mitigations for these threats do not directly relate to the proposed changes to the engineered channel or the proposed increase in ship loading. That noted, the level of risk associated with each hazard may be influenced by the channel design and ship size.

5.5.2. Arrival Reaches 1 and 2

The navigational aspects of Reaches 1 and 2 are essentially the same; therefore the reaches can be considered together.

Channel within a Channel. An important factor of the engineered channel is that the newly dredged channel will not extend across the full width of the existing channel in the first two reaches (that is between the Fairway Buoy and Buoys #3 and #4). Instead the dredged channel will largely be towards the southern side of the existing channel. Whilst the full width

of the natural channel will be available for shallower draught ships including log carriers, the deeper draught oil tankers will be constrained to the narrower channel. The dredged channel meets PIANC recommendations and has been shown to be practical in simulation runs. It thus offers a reasonable balance between operations, environmental impact and cost. The lateral buoys only mark the existing channel; however, the engineered channels would align to the PEL and leading marks.

Navigational Aspects. For this part of the channel, options 2 and 4.2 are identical. The key navigational hazards of both options arise from the 'channel within a channel' caused by the proposed engineered channel dredging being limited to the south side of the marked channel. Factors considered were:

- The existing channel has a PEL to guide ships in and this is aligned to the channel on Reach 1; however there are questions over the effective range of the PEL, in terms of accuracy with distance compounded by visibility during the day. This uncertainty relates to the effectiveness of this mitigation and hence the level of risk. It is considered that the PEL is of only limited use for the outer reaches and is not as effective for determining rate of change as lead marks.
- PPU for pilots are now commonly used globally and are known to be an accurate and effective aid for pilots. At the time of the study, PPU use was not formallised or mandated locally and PPU practice was not common across the pilots. Mandated use of PPUs has since been investigated and introduced by North Tugz. It therefore follows that, use of PPU while navigating the new channel assumed for all tanker passages.
- The existing port channel buoys will mark the southern side of the dredged channel; however, the first starboard channel buoy (Buoy #1) will not mark the edge of the dredged channel. It is noted that the current channel is deep enough for most ships entering Whangarei and that repositioning the starboard channel buoys would unduly constrain all ships.

Sea Room. The larger ships require more sea room to manoeuvre, and thus the 'abort point' that is the latest point at which a ship could come to a complete stop or turnabout before entering the channel, would need to be further out to sea.

5.5.3. Arrival Reaches 3 and 4

As with the previous two reaches, Reaches 3 and 4 are navigationally very similar and so are considered together. These reaches are the most critical part of the pilotage, as this is where the ship executes the turns near Home Point. Home Point is notable due to there being the rocky shore to the north and east and an outcrop 4.6m below Chart Datum close to Buoy #7 at the end of Reach 4 that presents a particular hazard.

Overall Differences Between Options: There are differences between options 2 and 4.2 on Reaches 3 and 4. Option 2 has a short straight section of some 500m between the first, starboard, turn, and the next two port turns. Option 4.2 has a longer straight of approximately 900m between the completion of a starboard turn and the following port turn. In addition, whilst Buoy #11 is repositioned in Option 2, Option 4.2 sees Buoys #12 and #14 repositioned as well – each giving greater sea room. Option 4.2 therefore benefits all ships through a series of complementary benefits.

The workshop group could find no discernible difference in the factors considered between the Suezmax and Aframax ship types.

Navigational Aspects. The existing channel presents a complex compound curved path and clearances that do not meet the PIANC requirements for an engineered channel. Option 2 requires the pilot to steer a continually changing path with complex curves. There is an intermediate straight but it is too short to allow the ship to settle between turns. Therefore neither the existing channel nor Option 2 allow an opportunity to use leads or similar aids to line the ship up mid turn. Moreover on both channels the ship is in the process of changing from starboard turn to port turn near the key hazard (the rock outcrop). Option 2 does have slightly more sea room than the existing channel.

Option 4.2 allows for a longer straight leg between two turns. It is a simpler path allowing the ship to be on a steady bearing as it passes Home Point and the rocky outcrop. This straight leg is very close to a North-South heading and if fitted, leads in Calliope Bay will enable an excellent ability to externally confirm the ship's cross track and positioning ahead of the next turn. The straight leg also allows for time to correct any cross track error or excess speed. Option 4.2 offers an increase in sea room over Option 2 and is also better aligned to the natural current flow in the channel. In particular Option 4.2 will also give improved clearance from Home Point on departure.

5.5.4. Arrival Reaches 5 and 6

Navigationally Reaches 5 and 6 are similar and so can be considered together.

Differences Between Options: Reaches 5 and 6 are the same for Options 2 and 4.2. Both options require a repositioning of Buoys #16 and #18 to minimise dredging along the channel edge.

Navigational Aspects. The engineered channels, Options 2 and 4.2, both offer a slight increase in sea room over the existing channel. However, the resultant advantage is only considered marginal.

Taking Way off the Ship: The pilots stated that at speeds of 3 knots an Aframax tanker's engines can be expected to be able to bring a ship to a stop in its own length without the aid of tugs. It was noted that the greater tonnage and increased draught of the fully laden Suezmax ship means it will take more sea room to take way off the ship and more time to complete the berthing. This means that manoeuvres will have to be started earlier than for the part laden Suezmax or fully laden Aframax tankers; however, it is considered that at slow speeds the additional sea room required was slight. It is therefore considered there will be reserve power available in the ship's main engine and the use of tugs to slow the ship is desirable, but not essential. This manoeuvre has been demonstrated in simulation runs.

Berthing: There are very tight limits on speeds and docking angles when berthing ships. Whilst a fully laden Suezmax tanker has more mass than the existing tankers, the manoeuvre is undertaken at very low speed. Significant expertise has been built up over the years and it is considered that this expertise could be transferred to ships carrying larger cargo without any issues.

5.5.5. Departure Reaches 6 to 3

Differences in Ships: It was noted that ships will almost always depart part laden or in ballast, and thus draw no more than 13m. There will therefore be no difference in the ships compared to those currently used.

Differences between Options. As with the arrival the additional sea room available in Option 2 over the existing channel is of benefit, and the further increased sea room in Option 4.2 is of further benefit. In particular, the repositioning of Buoy #14 in Option 4.2 significantly opens out the first turn of the series taking the ship around Home Point. Likewise the straight section between the turns and passing the submerged rock at Home Point is a significant benefit and reduces the risk in this area.

5.5.6. Departure Reaches 2 and 1

The only change to navigation for Reaches 2 and 1 is the ‘channel within a channel’. However, it was noted that the whole of the buoyed channel would have sufficient depth to accommodate a ship of 13m draught. Therefore this change is not relevant and thus the risks associated with Reaches 2 and 1 will be unchanged.

5.6. Consequences

Risk is a combination of likelihood and consequence. To this point of the report the analysis has concentrated on the likelihood of an incident and the mitigations necessary to reduce that likelihood to an acceptable level. Indeed, given that all threats have been identified and analysed, it could be argued that implementing all the mitigations would reduce the likelihood but have no effect on consequence which, given the larger ships, may be higher. The responses to the defined undesirable event, also discussed earlier, would further reduce the likelihood of a consequence. A complete risk analysis calls for the consideration of all levels of consequence.

Possible Consequences. There are six potentially significant consequences as follows:

- Contact with buoy
- Heavy contact with jetty (Reach 6 only)
- Grounding on sand
- Contact with sand
- Grounding on rock (Reaches 3 and 4 only)
- Contact with rock (Reaches 3 and 4 only)

5.6.1. Contact with Buoy

Contact with a buoy would almost certainly be a glancing blow with the buoy sliding down the side of the ship's hull for some distance. The buoys are secured by a chain and bottom tackle and so able to move with the impact and lessen the force transmitted between the ship and buoy. The damage would be limited to scrapes, at worst no more than some minor denting of the platting of the outer hull. Overall the consequence would be very minor.

5.6.2. Heavy Contact with Jetty

The limiting lateral speed for berthing is 0.15 m/s. Higher closing speeds would result in a heavy contact on berthing. In the past some ships have made heavy contact with the breasting dolphin; however, buffers on the dolphins limited any damage to the ships to cosmetic marks. In one case a dolphin, was knocked out of alignment while the ship remained undamaged. This would suggest that, as is the design intent, even given heavy contact with a fully laden Suezmax tanker, penetration of the outer hull plating would not be expected.

5.6.3. Grounding on Sand

A ship that was well off-track would contact the edge of the channel and could ground. In the case of an impact at a shallow angle a firm grounding is unlikely. In the case of a steeper frontal impact, it is almost certain the propulsion and steering systems would be undamaged. The bow sections are likely to suffer buckling to the outer plates and damage to the intervening structure. It is possible this damage to the structure could cause limited damage to the inner hull and tanks; however the collision bulkhead design of all tankers in designed to protect the watertight integrity of the main hull and so makes this unlikely. A minor oil leak from the bilges of the void spaces is possible. The key factors after grounding would be the subsequent sea state and weather. It was noted by the naval architect that tankers' forward and lower hull plates tend to be heavy and so resistant to rupture. However, the movement

caused by swells would be expected to increase the damage to the ship and over time may cause plate failure.

5.6.4. Contact with Sand

Contact with the bottom sand without grounding would almost certainly be the case after a glancing blow with the side of the channel. It is likely the tanker would suffer some deformation of the outer hull plates and buckling of these plates is a possibility. There is a chance of damage to the structure between the outer and inner hulls. However, damage to the inner hull and oil tanks is considered highly unlikely. The glancing or sliding nature of the blow means that it is likely that the propulsion and steering systems would be unaffected. Cracking associated with heavy buckling of the outer plates could lead to slow flooding of the void sections of the hull and an increase in the ship's draught. However, it is considered likely the ship would still be able to continue to the berth and to be brought alongside safely.

5.6.5. Grounding on Rock

Given the high pressures and potential cutting action, grounding on rock would be expected to cause considerably more damage than grounding on sand. This damage would be to the fore part of the ship, causing major damage to the forward hull plates and structure leading to flooding of the ship's forepeak. Given the ship would likely continue to move after initial contact, it is possible that this damage would extend down the strakes and potentially damage the inner hull leading to more extensive flooding and leakage of oil. Clearly the extent of the damage would depend on the impact speed and extent of collision, and time in contact. Given the tonnage involved and the limited size of the nearby rocks it is unlikely the ship would not ride up over the rock – rather it would sustain damage to the hull plating and associated structure as it was being deflected laterally. However, as the impact would be to the side parts, the naval architect considered it extremely unlikely that the ship would become fast on the rock; a situation that could rapidly damage a ship beyond recovery (as per the MV Rena). As with grounding on sand, the full extent of the damage would depend on the speed and angle at which the ship grounded. The consequences of grounding on a rock will almost certainly be severe. It is of note that should a tank be ruptured, considerable oil leakage would be expected.

5.6.6. Contact with Rock

A glancing or passing contact with a rock would have notably greater consequences than a similar contact with sand. It is highly likely that hull plates would be buckled and quite possibly torn leading to relatively fast flooding of the void spaces. The structure between the hulls would also most likely suffer damage. It is quite possible that the inner hull and tanks would be breached which would lead to significant oil spillage. The extent of the damage would depend on the speed and angle of the ship at contact. Given a speed of 6 to 8 knots around Home Point, the damage could extend for a significant distance along the hull. It was noted that the end of the rocky outcrop off Home Point is some 5m below the sea surface and so would cause damage to a ship from about 7m and below. A particular consequence of note would be if the glancing contact included the stern. Given the double hull, spaces may also have taken on water (and so vessel displacement increased), an effect that could be significant. The consequences of glancing contact with a rock would therefore be severe.

5.6.7. Consequence Plot

A graphical representation of the severity and locations of the consequences is at Figure 8 below:

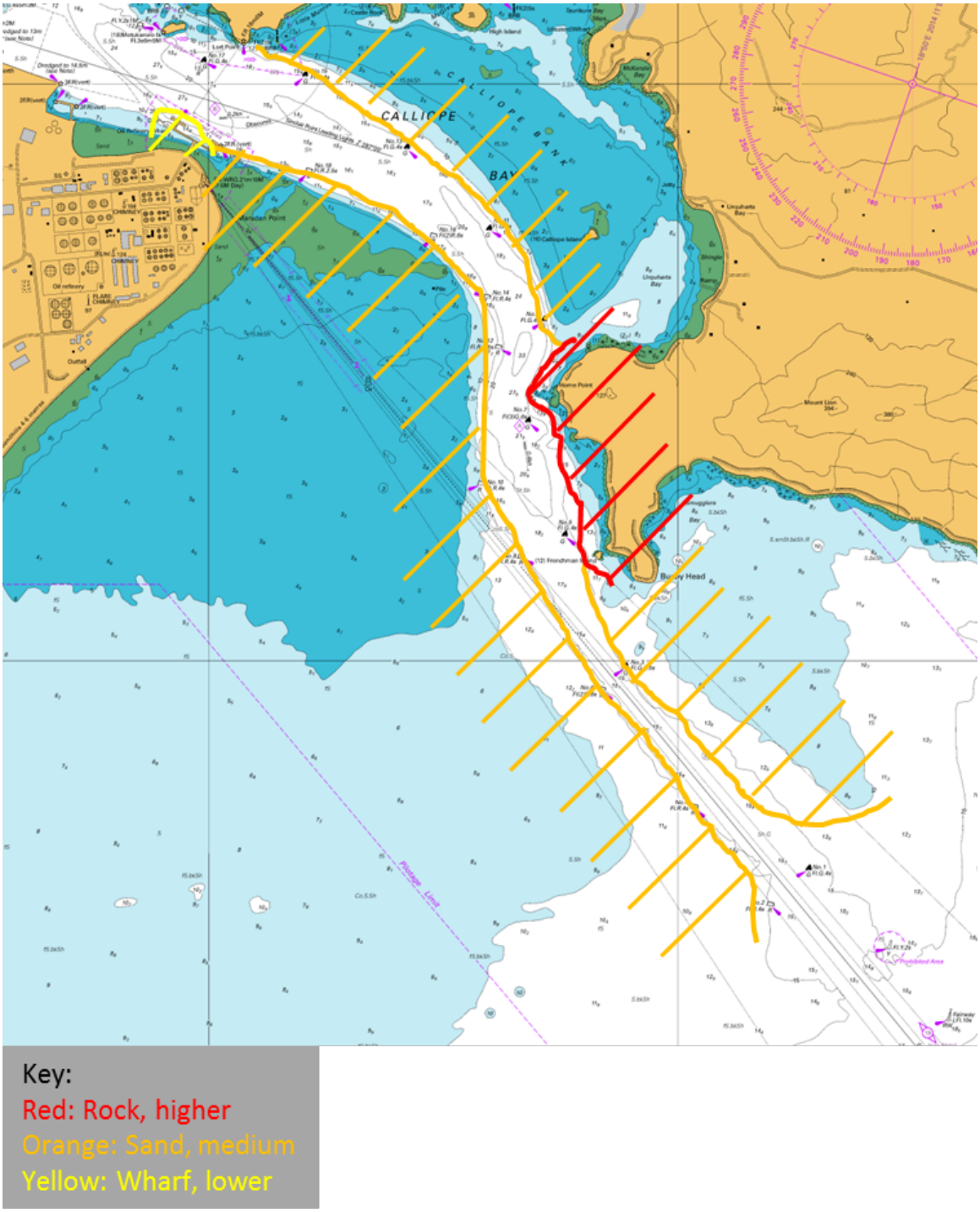


Figure 8 - Consequence Severity and Locations

5.7. Impact of dredged material disposal sites.

The consideration of the effect on navigation of the disposed dredged material is based on information reported in Section 2.2 of the Dredging and Disposal Options - Synthesis Report[21]. Other information considered came from the Tonkin and Taylor[22], and the MetOcean modelling report[23].

The key features that underpin this assessment are noted to be:

- Area 3-2 is situated 45 m below Chart Datum.
    - The average height of the placement mound will be not more than 4 m, which equates to < 9% of the natural water depth.
    - The effect on the surface will be imperceptible.
- Area 1-2 is an area of seabed situated on the southern end of the ebb tidal delta in water depth of between 7 and 15 m Chart Datum.
    - The average placement depths of around 0.6 m (<9% of the natural water depth) covering an area of around 10% of the total placement area),
    - A maximum temporary mound height of 1m (15% to 6% of natural water depth) – which is expected to quickly smooth out.
    - The modeled effect on the surface is incidental.
- Both marine disposal areas comprise sand of a similar composition to the channel area to be dredged.

Given the above, it is self-evident that the effect on safe navigation of surface vessels of any kind while simply transiting the area will be nil.

It is reasonable to assume that the operation of the dredger and spoil barges will be undertaken following proper professional maritime practice. Given this, the operations themselves will not materially effect the safe navigation of other vessels.

Modelling predicts that the effect on wave height will be extremely small – in the order of no more than a few centimetres even under extreme conditions and assuming high spoil mound heights.

[21] Tonkin & Taylor Ltd Crude Shipping Project, Dredging and Disposal Options - Synthesis Report, Date February 2017
[22] Richard Reinen-Hamill, Geraint Bermingham personal communication 3 Aug 17
[23] Predicted physical environmental effects from channel deepening and offshore disposal, MetOcean report PO297-02 July 17

6. Findings

6.1. Risk Factors

A series of factors have been identified as necessary to enable safe navigation of tankers to and from the jetty.

The following factors drive the risk profile:

Primary Existing Channel Related Risk Factors.

- Complex curved track required passing Home Point.
- Constriction in channel near Home Point.
- Tidal effects (current).
- Channel depth (constraint on ship draught).
- Consequence of deviation from planned pilotage and failure of responses.

Primary Channel Option Related Factors (relative to existing channel).

- Shape of the channel
    - Level of alignment to PIANC guidelines.
- For Reaches 1 and 2
    - For Option 2 and 4.2
        - Channel within a channel in reaches 1 and 2.
        - Buoyage marking port side of deep channel only.
        - Use of leads/PEL located at Marsden Point.
- For Reaches 3 and 4
    - For Option 2
        - Slight increase in sea room at Buoy #11.
    - For Option 4.2
        - Straight track section in Reach 3-4.
        - Leads in Calliope Bay.
        - Increased sea room at Buoys #11, #12 and #14.

Primary Ship Related Risk Factors.

- Greater length and displacement corresponds to reduced manoeuvrability (larger turning circle, less sea room).
- Deep draught corresponds to lessor manoeuvrability (increases drag and forces due to current and less navigable water).
- Greater displacement / cross-section relative to channel cross section creates greater hydrodynamic interactions.
- Windage effects will be lower for fully laden vessels of the same type due to less above water cross section.

6.2. Risk Profile - Channels

As this risk assessment is qualitative and aims to identify the relative change of risk profile between channel options the overall risk profile is described visually in a series of tables and charts formatted to describe risk in relative terms. As noted earlier in section 5.2, a range of operational measures has been assumed to have been implemented as pre-requisites to the use of the revised channel.

6.2.1. Graphical Risk Profile

The graphical risk profiles below use the following key:

For PIANC (as used in Figure 6)

- Blue: Optimum – Ideal under both operating and extreme conditions, no issues encountered.
- Green: Adequate – Very good under operating conditions, manageable under extreme conditions.
- Orange: Marginal – Adequate under operating conditions but poor under extreme conditions.
- Red: Inadequate – Poor under both operating and extreme conditions, may be considered unacceptable from a navigational risk perspective.

For Consequence (as used in Figure 8):

- Red: Rock, Higher
- Orange: Sand, Medium
- Yellow: Jetty, Lower

The coloured arrows indicate the change in threat risk. Red arrows (↑) indicate an increased level while green arrows (↓) indicate a decreased risk. A dash (-) indicates the current level or no effect on the current level of risk. The degree of change in risk is indicated by the number of arrows; with the ratio of the number of arrows approximating to the relative change. It is emphasised that these are 'ordinal' scales and so do not have a strict arithmetic relationship. However, in general terms, a risk change indicated by two arrows can be considered to be indicatively twice the change indicated by one arrow.

Throughout these risk profiles 'Existing Tankers' are defined as the Aframax tankers and part laden Suezmax tankers with a maximum draught of 14.7m currently visiting Marsden Point. "Proposed Tankers' are fully laden Suezmax tankers with a maximum draught 16.6m. N/A indicates that fully laden Suezmax tankers cannot transit the existing channel.

The risk profiles are shown in Table 2 and Table 4 below:

Table 2 - Arrival Risk Profile - Existing Tankers

Arrivals – Existing Tankers							
Reach	1	2	3	4	5	6	Overall Channel
Consequence	Orange	Orange	Red	Red	Orange	Yellow	Orange
Existing Channel							
Risk Factors	-	-	-	-	-	-	-
PIANC	Blue	Blue	Orange	Red	Green	Blue	Green
Overall Risk	-	-	-	-	-	-	-
Option 2							
Risk Factors	-	-	↓↓	↓↓	↓	-	↓
PIANC	-	-	-	-	↓	-	-
Operational Measures	↓	↓	↓↓	↓↓	↓	↓	↓
Overall Risk	↓	↓	↓↓↓↓	↓↓↓↓	↓↓↓	↓	↓↓
Option 4.2							
	-	-	↓↓↓	↓↓↓	↓	-	↓
PIANC	-	-	↓	↓↓	↓	-	↓
Operational Measures	↓	↓	↓↓	↓↓	↓	↓	↓
Overall Risk	↓	↓	↓↓↓↓↓↓	↓↓↓↓↓↓	↓↓↓	↓	↓↓↓

Table 3 - Arrival Risk Profile - Proposed Tankers

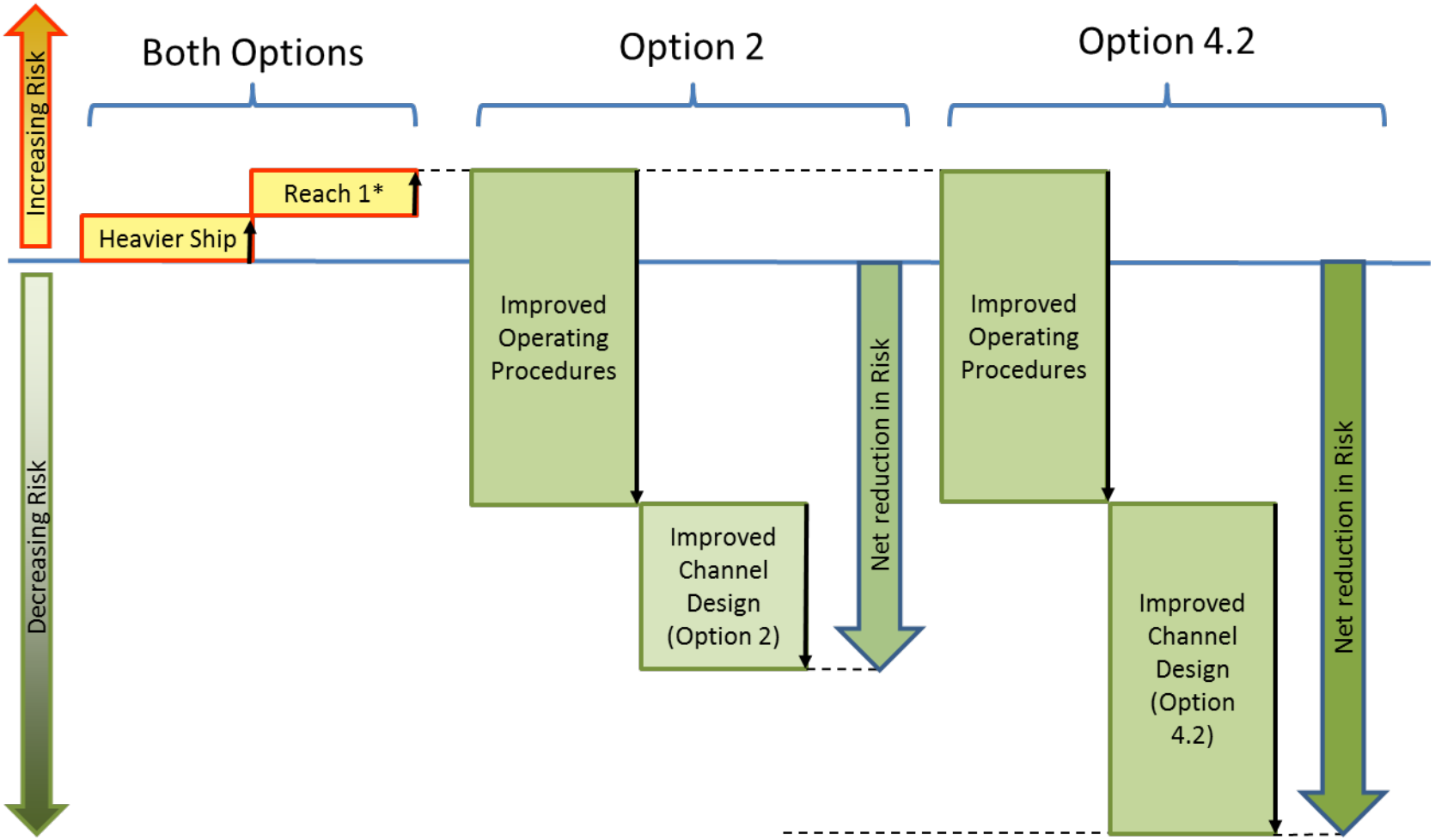
Arrivals – Proposed Tankers							
Reach	1	2	3	4	5	6	Overall Channel
Consequence	Orange	Orange	Red	Red	Orange	Yellow	Orange
Existing Channel							
Risk Factors	N/A						
PIANC	Blue	Blue	Orange	Red	Green	Blue	Green
Overall Risk	N/A						
Option 2							
Risk Factors	↑	↑	↓	↓	-	-	-
PIANC	-	-	-	-	↓	-	-
Operational Measures	↓	↓	↓↓	↓↓	↓	↓	↓
Overall Risk	-	-	↓↓↓	↓↓↓	↓↓	↓	↓
Option 4.2							
Risk Factors	↑	↑	↓↓	↓↓	-	-	-
PIANC	-	-	↓	↓↓	↓	-	-
Operational Measures	↓	↓	↓↓	↓↓	↓	↓	↓
Overall Risk	-	-	↓↓↓↓↓	↓↓↓↓↓	↓↓	↓	↓

Table 4 - Departure Risk Profile

Departures – Existing Tankers							
Reach	1	2	3	4	5	6	Overall Channel
Consequence	Orange	Orange	Red	Red	Orange	Yellow	Orange
Existing Channel							
Risk Factors	-	-	-	-	-	-	-
PIANC	Blue	Blue	Orange	Red	Green	Blue	Orange
Overall Risk	-	-	-	-	-	-	-
Option 2							
Risk Factors	-	-	↓↓	↓↓	↓	-	↓
PIANC	-	-	-	-	↓	-	-
Operational Measures	↓	↓	↓	↓	↓	↓	↓
Overall Risk	↓	↓	↓↓↓	↓↓↓	↓↓↓	↓	↓↓
Option 4.2							
Risk Factors	-	-	↓↓↓	↓↓↓	↓	-	↓
PIANC	-	-	↓	↓↓	↓	-	↓
Operational Measures	↓	↓	↓	↓	↓	↓	↓
Overall Risk	↓	↓	↓↓↓↓↓	↓↓↓↓↓↓	↓↓↓	↓	↓↓↓

6.2.2. *Visual Risk Profiles*

The case of the proposed fully laden Suezmax tankers arrival is of particular interest as this is the focus of the Assessment of Effects on the Environment (AEE) appraisal. The increased displacement and draught of the fully laden Suezmax tankers and the 'channel within a channel' in Reach 1 do act to increase risk compared to the current situation. However, the overall reduction in risk due to the simpler navigational passage made possible by the channel design itself and improved operating procedures, is notably greater. This combination is illustrated in Figure 9 below. It can be seen that, enables greatly reduced risk and, given the use of the required operational procedures, the overall risk is lower than that for the existing channel and procedures, with the channel design of Option 4.2 resulting in a lower level of risk than that possible given channel design Option 2.



** = Effect of narrower deep channel than natural channel in Reach 1*

Figure 9 - Overall Change in Risk - Full laden Suezmax Tankers

6.3. Overall Risk Assessment - Channels

The overall risk assessment assumes the operational measures detailed in Section 5.2 have been implemented. It shows the relative risk of utilisation of the engineered channels against use of the existing channel (noting that fully laden Suezmax tankers are unable to use the existing channel due to their draught). The overall risk assessment is shown in Table 5 below.

Table 5 – Overall Risk Assessment

Reach	Channel	Existing	Option 2	Option 4.2
Arrival				
1-2	Existing Tankers	-	↓	↓
	Proposed Tankers	N/A	-	-
3-4	Existing Tankers	-	↓↓↓↓	↓↓↓↓↓↓
	Proposed Tankers	N/A	↓↓↓	↓↓↓↓↓
5-6	Existing Tankers	-	↓↓	↓↓↓
	Proposed Tankers	N/A	↓	↓
Departure				
5-6	All Tankers	-	↓↓	↓↓
3-4	All Tankers	-	↓↓↓	↓↓↓↓↓
1-2	All Tankers	-	↓	↓
All	Existing Tankers	0	-13	-18
	Proposed Tankers[24]	N/A	-10	-14

The coloured arrows indicate the change-in-risk. Red arrows (↑) indicate increased risk while green arrows (↓) indicate a similar decreased risk. The number of arrows indicates the degree of change-of-risk; more arrows indicate a greater degree of change. A dash (-) indicates no change from present. To aid clarity, the final tally is indicated numerically (e.g.-6). It is important to note that this figure forms an 'interval' scale[25] and so are only indicative of relative risk and where a value of zero represents the current level of risk.

[24] It is noted that there are no plans to depart with fully laden Suezmax tankers. Therefore the proposed tankers are counted as if existing tankers for departure.
[25] Interval scale is described in SA/SNZ HB 436:2013 Risk Management Guidelines. Table 4.

6.4. Risk Assessment – Disposal Sites

As noted before, given the very limited change in depth and bottom profile from disposal activity, and that the effect on wave height is predicted to be less than 10cm under the most pessimistic conditions, it is self-evident that the effect on safe navigation of surface vessels of any kind while simply transiting the area will be nil.

It is conceivable that vessels involved in bottom trawling could be affected. However, given the natural behaviour of sand and that trawls are designed and operated to handle the inevitable natural undulations of the sea floor, it is difficult to conceive of an issue. This aspect can be expected to be further mitigated by the correct chart amendments to show the disposal sites.

Given it is also assumed that the operation of the dredger and spoil barges will be undertaken following proper professional maritime practice, the operations themselves will not materially effect the safe navigation of other vessels.

It is therefore assessed that the risk to the navigation of other vessels from the disposal sites and the associated activity is less than incidental.

7. Conclusions

7.1. Channel Design – Relative Risk

The findings of the risk assessment are given in Table 5 above and summarised below in Table 6. This assumes that the previously described package of operational measures has been implemented.

Table 6 - Risk Summary – Indicative change in overall risk

Channel	Existing	Option 2	Option 4.2
Existing Tankers	0	-13	-18
Proposed Tankers	N/A	-10	-14

Having a deeper engineered channel (either design Option) within the natural channel in the outer reaches creates a requirement to navigate vessels within a narrower outer channel than is currently the case. However, the associated risk with this design is not unique and can be adequately managed provided the range of operational measures identified, are implemented.

Channel design Option 2 offers significant risk reduction for the operations involving vessel types currently handled and enables adequate risk management for operations for the proposed fully laden Suezmax tankers.

Channel design Option 4.2 offers further risk reduction over Option 2 for the operations involving vessel types currently handled. Option 4.2 design is closest to full compliance with the applicable international channel design guidelines – a feature that contributes to this design enabling the lowest navigational risk. Channel Option 4.2 would, if implemented, enable operations for the proposed fully laden Suezmax tankers that can be considered to meet the ALARP criterion.

The risk-advantages of Option 4.2 are due to the notably simplified navigational path with fewer turns as well as fewer and longer periods of fixed-bearing-paths for the pilots, with each aided by leading marks. This greatly simplifies the task of navigating large ships through the point of highest hazard, namely Home Point.

7.2. Disposal Sites – Absolute Risk

It is concluded by professional review of the maximum physical changes that spoil disposal will have on the sea floor at each of the two disposal grounds, and assuming that the dredging and disposal operation is conducted to normal good maritime practice, then there is no discernable risk to safe navigation of vessels transiting the channel of nearby coastal areas.

Annexure Two: Technical Reports

g) **Environmental Spill Risk Assessment for Proposed Tanker Operations Associated with Engineered Channel. Navigatus. Kevin Oldham, Matt Bilderbeck and Geraint Bermingham. Dated 14 August 2017**

Environmental Spill Risk Assessment for Proposed Tanker Operations Associated with Engineered Channel

Prepared for Refining NZ

by

Navigatus Consulting

14 August 2017

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Environmental Spill Risk Assessment for Proposed Tanker Operations Associated with Engineered Channel

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Revision	Description	Date	Authorised By	
			Name	Signature
Rev 0	Draft for Review (Stage 1)	19 August 2016	Kevin Oldham	
Rev 1	Draft for Review (Stage 2)	4 October 2016	Kevin Oldham	
Rev 2	Final Draft for Client Review	7 November 2016	Kevin Oldham	
Rev 3	Consultation Draft	7 February 2017	Kevin Oldham	
Rev 4	Post Consultation Final Report	14 August 2017	Kevin Oldham	

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Table of Contents

Executive Summary 1

1. Introduction 4

2. Scope 4

3. Process 5

4. Context 6

4.1. Background 6
4.2. Base Information 9
4.3. Recent Local Spills 12
4.4. Response Capability 13

5. Inputs from Work Stream Specialists 14

6. Environmental Consequences 16

6.1. Relevant Factors 16
6.2. Measures of Consequences 16
6.3. Summary of Environmental Consequences 17

7. Risk Analysis 19

7.1. Methodology 19
7.2. Difference in Event Likelihood per Transit 20
7.3. Difference in Number of Vessel Transits 20
7.4. Difference in Amount Spilled per Event 21
7.5. Resulting Difference in Environmental Consequences 25

8. Risk Evaluation 32

9. Conclusion 35

10. References 36

Appendix A: Economic Cost of Damages 38

Appendix B: Selected Case Studies 40

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Executive Summary

Refining NZ (RNZ) proposes to deepen and realign the approach channel to Whangarei Harbour in order to enable Suezmax tankers to carry larger crude oil cargoes to Marsden Point.

This environmental risk assessment explores the effect of the proposed tanker operations associated with an engineered channel on the environmental risk profile of Whangarei Harbour and surrounding areas arising from potential oil spills. The objective is to determine whether there would be a positive or negative net impact on environmental risk given the proposed operational changes as compared to current operations.

This report draws on a navigational risk assessment undertaken for Refining NZ by Navigatus Consulting Ltd (Navigatus).

Oil tanker access to Marsden Point is currently limited to vessels with a maximum draft of 14.7m due to the constraints of the current natural channel and approach. This allows access by fully laden Aframax tankers, but only partly laden Suezmax tankers.

It is proposed to dredge and realign the channel to allow Suezmax tankers with a maximum draft of 16.6m to access Marsden Point. Refining NZ advise that this change will result in fewer tanker visits per year as Suezmax tankers will generally be carrying roughly a quarter more oil on each visit on average. Suezmax tanker visits will also make up a significantly larger proportion of foreign tanker visits than current, although Aframax tankers will continue to visit Marsden Point from Far East ports due to loading constraints at the port of origin.

Refining NZ commissioned a study that considered several channel design options and led to a shortlist of two designs labelled Option 2 and Option 4-2. The navigational risk assessment of channel designs undertaken by Navigatus considered both of these options (Navigatus Consulting, July 2017).

It was concluded that channel design Option 2 offers significant risk reduction for the operations involving vessel types currently handled while channel design Option 4.2 offers further risk reduction over Option 2.

It was further concluded that Option 4.2 would, if implemented offer notably simplified navigational path and hence enable operations for the proposed fully laden Suezmax tankers that, when combined with operational improvements, can be considered to be as low as is reasonably practicable.

Use Cases

Two use cases were evaluated against the Baseline:

- **Baseline:** Existing mix of tankers and cargo sizes operating in the existing channel with existing operational procedures.
- **Use Case A**: Existing mix of tankers and cargo sizes operating with channel design Option 4-2 implemented. Same count and mix of tanker visits as baseline.

- **Use Case B:** Mix of tankers and cargos includes fully laden Suezmax tankers along with implementation of the package of operational measures identified in the navigational risk assessment. Fewer tanker visits overall.

Evaluation of Use Case A: Existing Tanker Cargoes with the Option 4.2 Channel

Given the findings from the navigational risk assessment, it is self-evident that, if the existing mix of tankers and the cargoes remains unchanged, then overall environmental risk will also be significantly reduced compared to the Baseline.

Evaluation of Use Case B: Fully Laden Suezmax with the Option 4.2 Channel

The purpose of the improved channel is to enable fully laden Suezmax tankers to safely navigate to Marsden Point. The oil spill environmental risks of this future use case B are summarised below.

A series of discussions were held with a range of expert consultants engaged by Refining NZ. These discussions covered features present in the surrounding environment, effects of spilled oil on these features and, in particular, discussion of the marginal effects of larger volumes of oil spilled in the environment (including potential tipping points).

This information, combined with research on oil spill case studies, informed the analysis of the difference in environmental consequence and the evaluation of the expected net difference in the environmental risk profile.

The countervailing components that contribute to and change environmental risk are summarised in the following table.

Summary of Environmental Components

ID	Factor	Comment
A	Difference in event likelihood per transit.	The implementation of Option 4.2 and operational measures will significantly reduce the likelihood of an event for each transit compared to current operations.
B	Difference in number of transits.	The potential for Suezmax tankers carrying larger cargoes to access Marsden Point means fewer transits are needed to deliver the same volume of oil. This is expected to have a roughly linear effect on reducing risk.
C	Difference in amount spilled per event.	There are many uncertainties regarding the amount of oil spilled in a given event. But ultimately a greater volume of oil carried means the potential for a larger spill. We assume volume spilled increases linearly with increase in amount carried.
D	Resulting difference in environmental consequences	A larger spill volume would result in further oil spread and longer persistence in the environment. However, these factors would most likely increase to a lesser degree than the increase in cargo carried, e.g. a 25% increase in spill volume would likely result in less than a 25% increase in area covered. Some areas are more ecologically and socially sensitive to others although there are many variables which determine whether they are affected. It is not expected that there would be disproportionately more harm resulting from the proposed increase in cargo size.

The most significant factor is the reduced likelihood of a spill per tanker transit, which is the result of adopting channel design Option 4-2 and implementing the package of operational measures. The engineered channel enables access and navigation of fully laden Suezmax tankers that is simpler than is currently the case for tankers, and, when combined with implementation of the operational improvements, will reduce the likelihood of a spill. Likelihood is further reduced, although to a lesser extent, as a result of the reduced number of tanker transits needed to bring in the same amount of oil.

Environmental consequences are somewhat increased as larger crude oil cargo sizes means that there is the potential for more oil to be released in a given spill event. However, attempting to isolate the marginal effect of increased cargo sizes is problematic as there are many complex factors at play.

It is unlikely that a tipping point would be reached that would cause disproportionate damage to ecological and social features. This is because the potential amount of oil spilled and the additional oil spreading would likely increase to a lesser extent than the increase in the crude oil cargo size.

Whilst any large scale spill would have profound effects on the environment over the short to medium term, the proposed crude oil cargo size increase would not make environmental consequences disproportionately worse. When balanced against reduced event likelihood this results in a net reduction in risk.

We conclude that the benefits of simplified navigational path and enhanced operational measures and the anticipated fewer tanker visits would significantly outweigh the countervailing risks due to larger crude oil cargo sizes. Overall environmental risk for Use Case B (fully laden Suezmax tankers together with implementation of the package of operational measures) will be significantly lower than the baseline of existing tanker operations with the existing channel and meet the ALARP criterion.

1. Introduction

Refining NZ (RNZ) proposes to deepen and realign the approach channel to Whangarei Harbour in order to enable Suezmax tankers to carry larger crude oil cargoes to Marsden Point.

This environmental risk assessment explores the effect of the proposed tanker operations associated with an engineered channel on the environmental risk profile of Whangarei Harbour and surrounding areas. The objective is to determine whether there would be a positive or negative net impact on environmental risk given the proposed operations associated with an engineered channel as compared to operations in the existing natural channel.

This report draws on a navigational risk assessment undertaken for Refining NZ by Navigatus Consulting Ltd (Navigatus).

2. Scope

While much of the focus of this resource consent application is on the effects of construction works associated with the proposed engineered channel, this risk assessment is concerned with the operational phase and with the possibility and potential consequences of oil spills in particular. This is as opposed to risks associated with channel construction where the effects would be relatively minor and more certain.

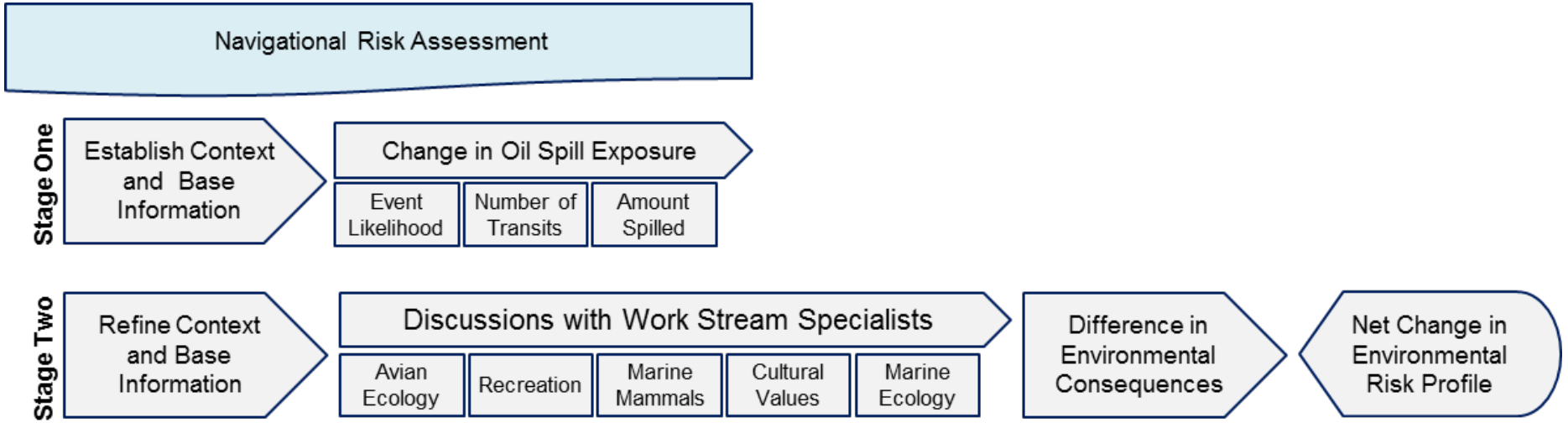
This study employs a differential assessment approach comparing two scenarios: essentially being operations with and without the engineered channel. The assessment addresses operating risk when the channel works are complete and is based on an assumption that any associated operational regime changes are implemented. As such it is comparing two fully developed alternative operating regimes.

This risk assessment does not attempt to cover ‘change risk’ associated with implementation of construction works or with the introduction of a new operating regime. An implicit assumption is that the operational change process will be well-managed.

3. Process

The overall process of Stage One and Stage Two of this environmental risk assessment is outlined in Figure 3.1.

Figure 3.1 - Process



A series of discussions were held with experts engaged by Refining NZ in respect of numerous work streams. These discussions covered features present in the surrounding environment, potential effects of spilled oil on these features and, in particular, discussion of the marginal effects of larger volumes of oil spilled in the environment (including potential tipping points).

This information, combined with research on oil spill case studies from elsewhere, informed the analysis of the difference in environmental consequence and the evaluation of the expected net difference in the environmental risk profile.

4. Context

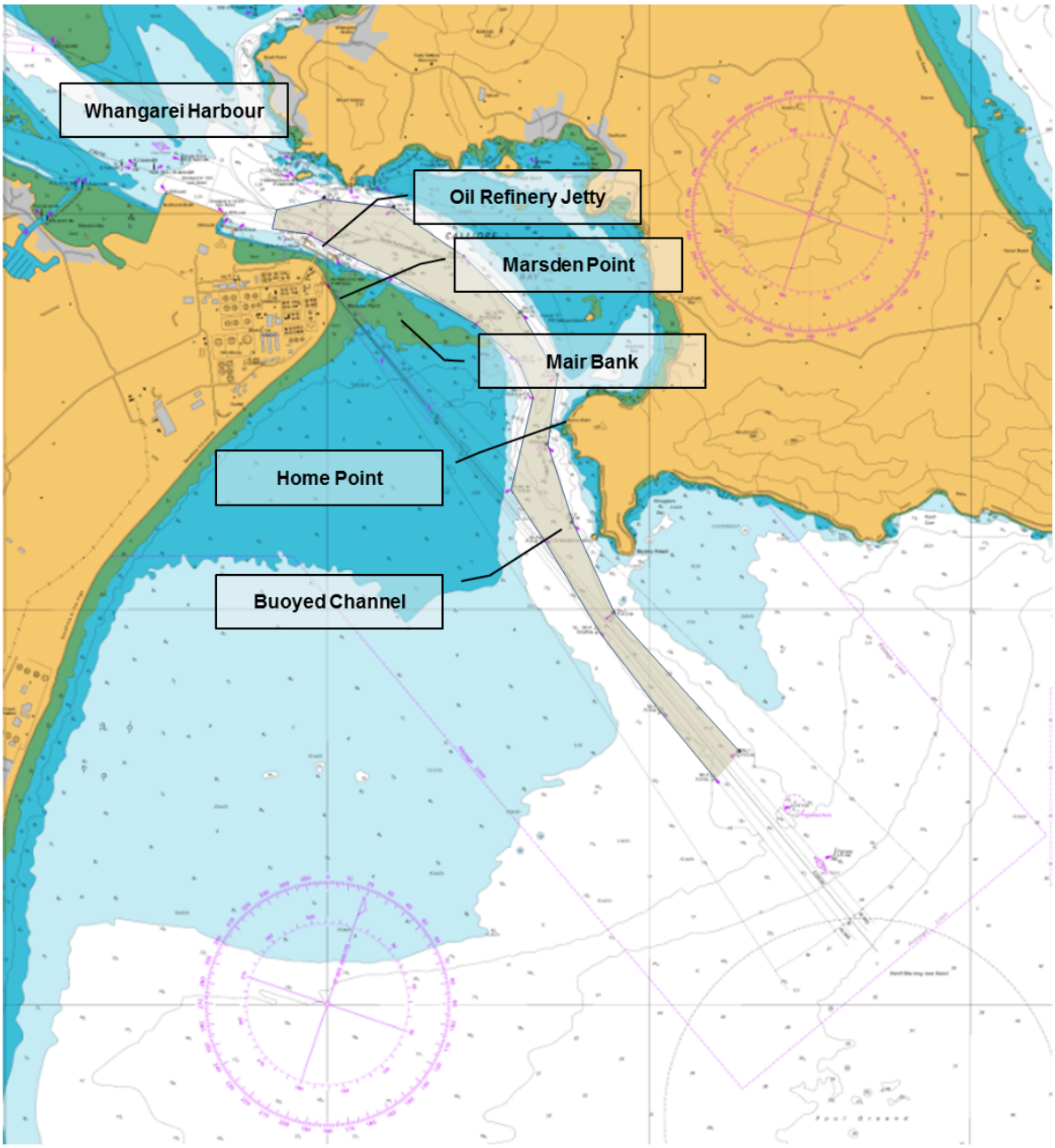
4.1. Background

Current Operations

Oil tanker access to Marsden Point is currently limited to vessels with a maximum draft of 14.7m due to the constraints of the current natural channel and approach. This allows access by fully laden Aframax tankers, but only partly laden Suezmax tankers.

The existing natural channel is shown in Figure 4.1.

Figure 4.1 - Existing Natural Channel



The business environment in which Refining NZ is operating has become challenging in recent times. Factors such as increased competition from other refineries in the Asia Pacific region, a general overcapacity in global refining have increased pressure on refining margins.

Refining NZ has commenced a number of initiatives to reduce costs and create efficiencies on site. This includes construction of the Continuous Catalyst Regeneration Platformer (CCR) or “Te Mahi Hou” project which will increase production while improving energy efficiency and significantly reducing emissions. It is also envisaged that bringing in bigger crude oil parcels would lift margins and improve competitiveness for the refinery.

Crude cargo arrivals to the Marsden Point Jetty are typically brought in by Aframax class tankers for crude oil of both Middle East and Far East origin. In addition, larger Suezmax tankers have also occasionally visited from the Middle East although not fully loaded due to current port draught constraints. Suezmax tanker usage and cargo size fell away following two near grounding incidents that occurred in 2003 in close succession at Fairway Shoal, prompting the Harbour Master to reduce the port operating draught and limit more fully loaded Suezmax ships from entering the harbour. A Dynamic Under Keel Clearance (DUKC) system was installed and has been in operation since 2004 to ensure safe under keel clearance of ships can be maintained when entering the harbour. Studies in 2005 and 2008 by oil companies indicated that deepening at Fairway Shoal would be required to restore previous port operating draught and potentially widening Home Point to improve safety and navigability for shipping.

All tankers using Marsden Point are double-hulled. In a double-hulled tanker there is a void space between the vessel’s hull in contact with the sea and the tanks that contain the cargo oil. The oil carried to Marsden Point is typically light to medium crude and would float in the marine environment.

Vessels arrive from sea, take a pilot and proceed up the channel prior to taking tugs and continuing to the jetty.

Proposed Alternatives

Following discussion with its customers Refining NZ is exploring the options to deepen the channel to enable Suezmax tankers to bring larger crude cargoes from the Middle East and West Africa. They propose going deeper than looked at by the oil companies back in 2005 to more fully load Suezmax and ensure they are capable of taking crude in larger parcel sizes. This would improve overall crude freight economics and improve RNZ’s competitiveness compared to alternative overseas suppliers.

It is proposed to dredge and realign the channel to allow Suezmax tankers with a maximum draft of 16.6m to access Marsden Point. This change will result in fewer tanker visits per year as Suezmax tankers will be carrying roughly a quarter more oil on each visit on average. Suezmax tanker visits are also expected to make up a significantly larger proportion of foreign tanker visits than current, although Aframax tankers will continue to visit Marsden Point from Far East ports due to loading constraints at the port of origin. Expected operational differences are summarised in Section 4.4.

Proposed Channel Design Options

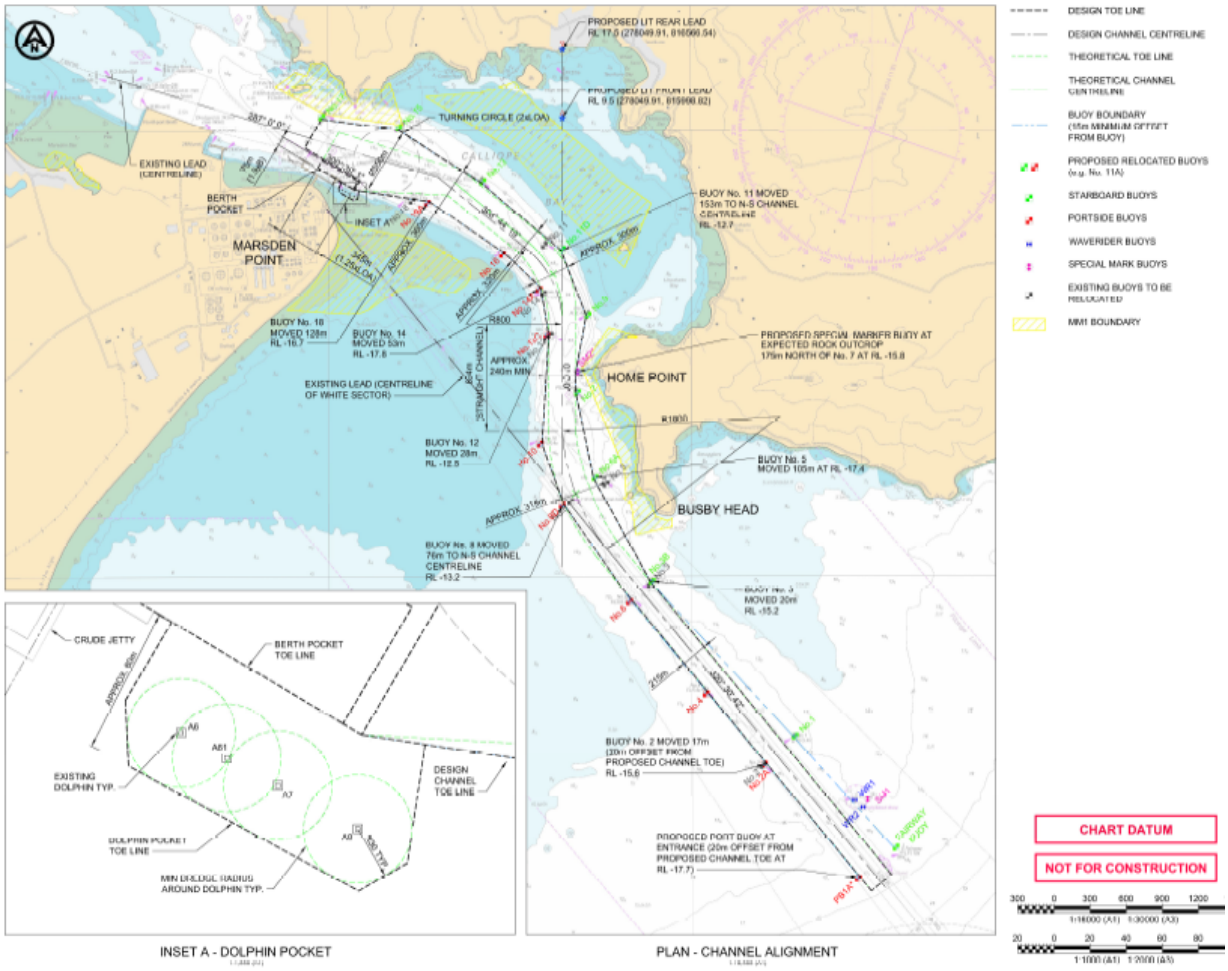
Refining NZ commissioned studies (Royal HaskoningDHV, 2016; Tonkin + Taylor, 2016) that considered several channel design options and led to a shortlist of two designs labelled Option 2 and Option 4-2. The navigational risk assessment undertaken by Navigatus considered the navigational risk profiles of both of these options (refer *Navigational Risk Assessment of Proposed Channel Designs*).

It was concluded that Channel design Option 2 enables significant risk reduction over the current channel for the operations involving vessel types currently handled and enables adequate risk management for operations for the proposed fully laden Suezmax tankers.

Channel design Option 4.2 enables further risk reduction over Option 2 for the operations involving vessel types currently handled. Channel Option 4.2 would, if implemented, also enable operations for the proposed fully laden Suezmax tankers that can be considered to meet the As Low As Reasonably Practicable (ALARP) criterion.

Refining NZ has selected Option 4-2 as the preferred option based on an options assessment which was informed by the navigational risk assessment among other information.

Figure 4.2 - Channel Design Option 4-2



Anticipated Operational Measures

The navigational risk assessment identified a package of operational measures required to enable safe operations given either design option. This report proceeds on the basis that , prior to fully laden Suezmax operations, these operational measures will be fully implemented along with the Option 4-2 channel design[1].

4.2. Base Information

This analysis compares the proposed future scenario given Channel Option 4-2 with an alternative future scenario in which usage of the existing channel is continued. The alternative scenario is based on historical averages for the period 2006-2015, although adjustments have been made to account for the increased processing capacity resulting from the Te Mahi Hou unit introduced in 2016.

This 2005–2016 period was chosen as the basis to inform the alternative future scenario so as to exclude operations prior to the 2003 incidents and the introduction of the Dynamic under Keel Clearance system, following which there was a notable reduction in the size of cargo parcels carried. The last complete year of data is 2015. Figure 4.3 shows the number of tanker visits to Marsden Point and Figure 4.4 shows the yearly average cargoes of tankers visiting Marsden Point (each for the period 2006 to 2015).

Figure 4.3 - Tanker Visits 2006-2015

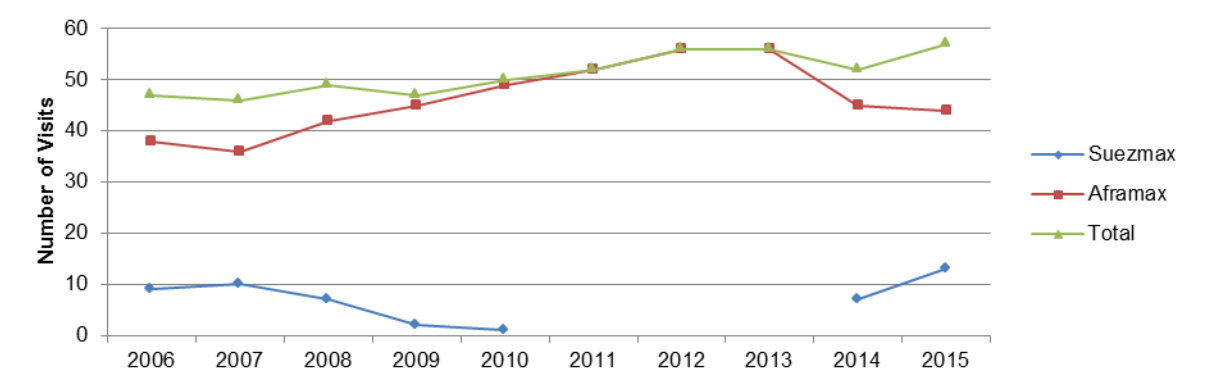
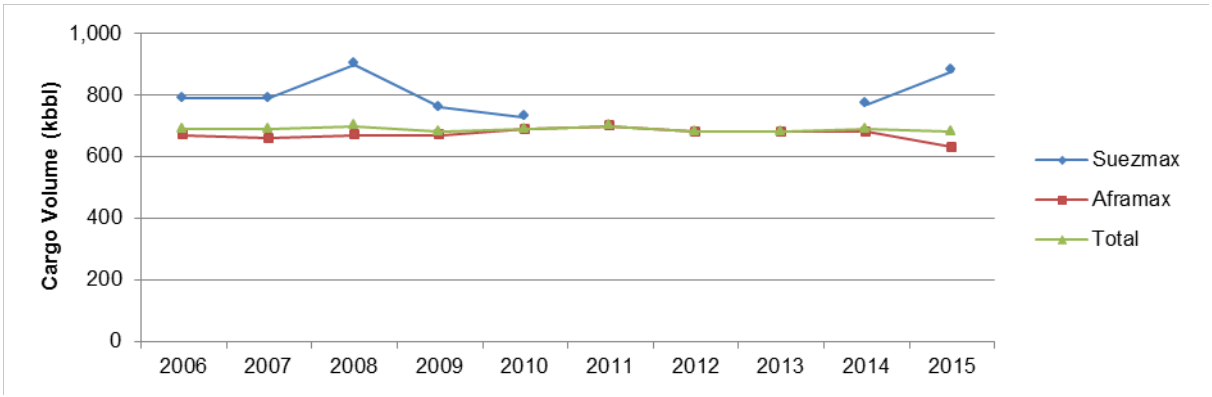


Figure 4.4 – Yearly Average Tanker Cargoes 2006-2015



[1] Refer to the navigational risk assessment for an outline of the operational measures (Navigatus 2016).

Table 4.1 summarises historical averages and the base information used for the comparison of future operations under the existing channel versus under Channel Option 4-2.

Table 4.1 – Summary of Base Information

Item	Historical (Average 2006-2015)	Future (Existing Channel)	Future (Channel Option 4-2)	Difference (4-2 vs. Existing)	Comment / Source
Refinery (kbbl)					Te Mahi Hou CCR unit on stream in 2016 increasing capacity. Excludes natural gas and blendstock processing.
Crude Oil Throughput	37,700	40,700	40,700	0%	
Tanker Visits					Historical numbers are averages taken from RNZ-supplied data. Future numbers take into account increased refinery capacity post CCR and are based on the assumption that approximately 37% of oil will continue coming from the Far East in Aframax tankers and the rest will arrive in Suezmax tankers.
Number of Suezmax tanker visits	4	4	25	460%	
Number of Aframax tanker visits	51	55	23	-58%	
Total Tanker Visits	**55**	**59**	**48**	**-19%**	
Tanker Cargoes (kbbl)					Historical numbers are averages taken from RNZ-supplied data. The future Suezmax cargo of 1,050 is the basis for the channel design although about 30% expected at 1,000. Aframax cargoes from Far East slightly smaller on average. The overall average large tanker cargo is the result of increased Suezmax cargo sizes and also the increase in number of visits by Suezmax tankers.
Average Suezmax Cargo	828	828	1,035[2]	25%	
Average Aframax Cargo	673	673	647	-4%	
Average Tanker Cargo	**685**	**685**	**862**	**26%**	

As shown above, it is expected that implementing Channel Option 4-2 would see a significant increase in the number of Suezmax tanker visits and a reduction in Aframax tanker visits (although, Aframax would continue visiting from the Far East due to constraints at ports of origin). Overall (Suezmax and Aframax combined) there would be approximately 19% fewer tanker visits to Marsden Point with Channel Option 4-2.

Average Suezmax cargo sizes are expected to be 25% larger for the improved channel. Aframax cargoes are not expected to change significantly, although historically cargoes from the Far East have been slightly smaller on average. Overall, taking into account the difference in tanker mix, the average tanker cargo is anticipated to be 26% larger with the engineered channel.

[2] Channel Option 4-2 is designed on the basis of 1,050 kbbl Suezmax cargoes which is an increase of 27%. The average Suezmax cargo is based on a 70:30 split of 1,050 kbbl cargoes to 1,000 kbbl cargos.

There has historically been some variation in the tanker cargoes arriving at Marsden Point. This is illustrated by Figure 4.5 which shows the yearly average Suezmax cargoes. Error bars denote the maximum and minimum cargoes in each year.

Figure 4.5 - Average and Range of Suezmax Tanker Cargoes 2006-2015

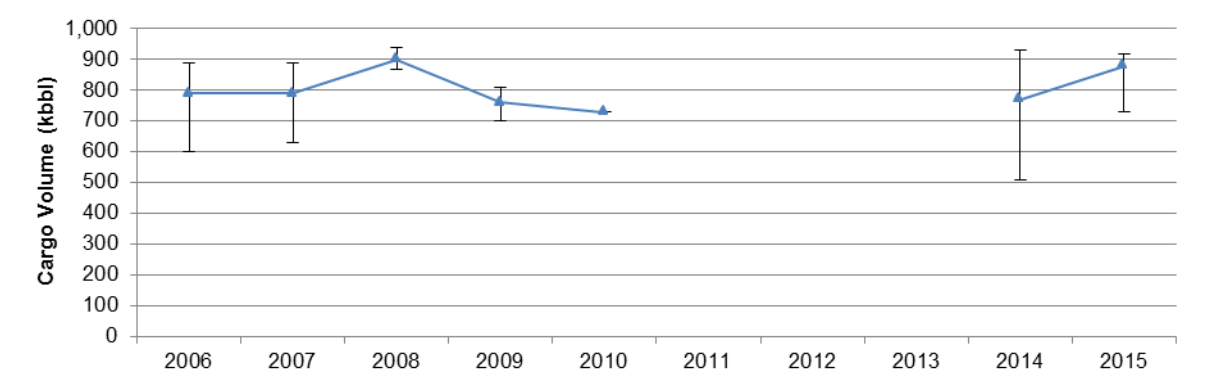
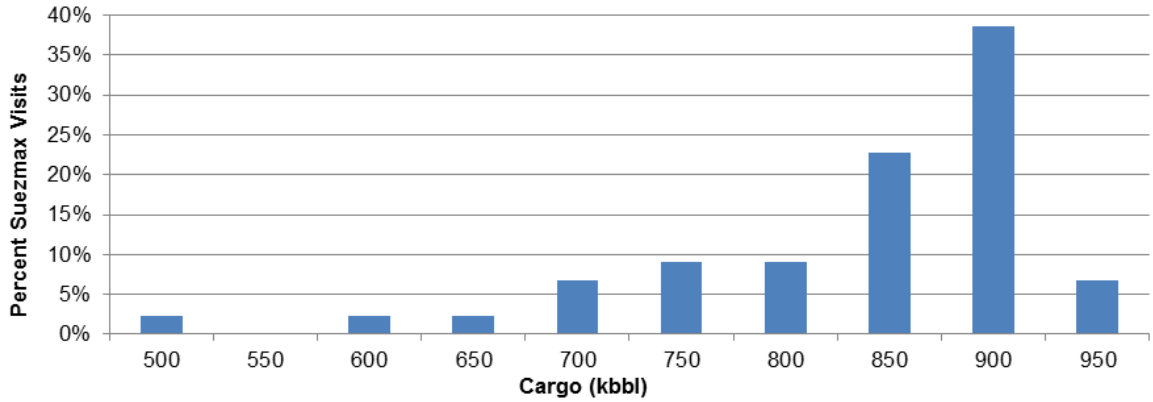


Figure 4.6 shows the distribution of historical Suezmax cargo size from 2006-2015.

Figure 4.6 - Distribution of Suezmax Tanker Cargoes 2006-2015



Variation can be due to such factors as:

- Different crude densities relative to ship dimensions meaning more or less loaded to keep within harbour draft constraint.
- Risk appetite of individual oil companies (e.g. risk of being held out due to weather given current harbour draft limitations and resulting demurrage)
- Access to available oil parcel sizes (with smaller parcels potentially being more difficult to purchase)

It is expected that the engineered 98% access channel[3] and 1 Mbbl +/-5% common parcel sizes will reduce variability of cargo sizes under the future scenario.

[3] The channel is designed to accommodate 75% of Suezmax fleet with a 98% likelihood of gaining channel access and not being held out for reasons such as bad weather.

4.3. Recent Local Spills

There has not been a major incident/spill associated with crude tankers traversing the channel to Marsden Point. However, there have been some minor spills resulting from leaks, not groundings or collisions.

2014 Spill at Marsden Point

In December 2014 several hundred litres of oil escaped from foreign tanker vessel, HS Alcina, over several hours, resulting in a roughly 20-metre by one-metre oil slick. The tanker was discharging a load of crude oil at the refinery jetty at the time, although the leak came from one of the vessel's bunker fuel tanks.

Oil from the suspect tank was pumped into another tank. The oil spill response team consisted of refinery staff and regional council workers. Most of the oil was contained by sorbent booms, which prevented it from coming ashore at the public beach between the refinery and Northport. The oil skimming barge 'Taranui' was used to capture oil outside the boomed area. The small amount of oil that was not able to be recovered on the day of the spill was spread very thinly and appeared to have been broken up by subsequent wind and tide movements with little or no impact on the environment (NZ Herald, 2014; Refining NZ, 2014).

2015 Spill at Northport

In December 2015 approximately 7,000 litres of fuel oil leaked into Whangarei Harbour from the mixed container and cargo vessel the 'Ningpo' while visiting Northport.

The response involved workers from Northport, Refining NZ and the Northland Regional Council. The majority of the oil was collected by containment booms placed around the vessel. Disposable booms were also placed around oil sludge that the incoming tide had carried onto the shore.. Oil slicks were removed from the surface with skimming equipment.

There were no confirmed reports of wildlife being affected by the spill although bird recovery experts were part of the response, as a precaution. A black streak was left at the high-tide mark along several hundreds of metres of white sand beach. Workers used blotting equipment, diggers and spades to scrape up contaminated sand and hand wash rocks at the marina entry. The clean-up was practically complete by late afternoon. *Source: NZ Herald (2015).*

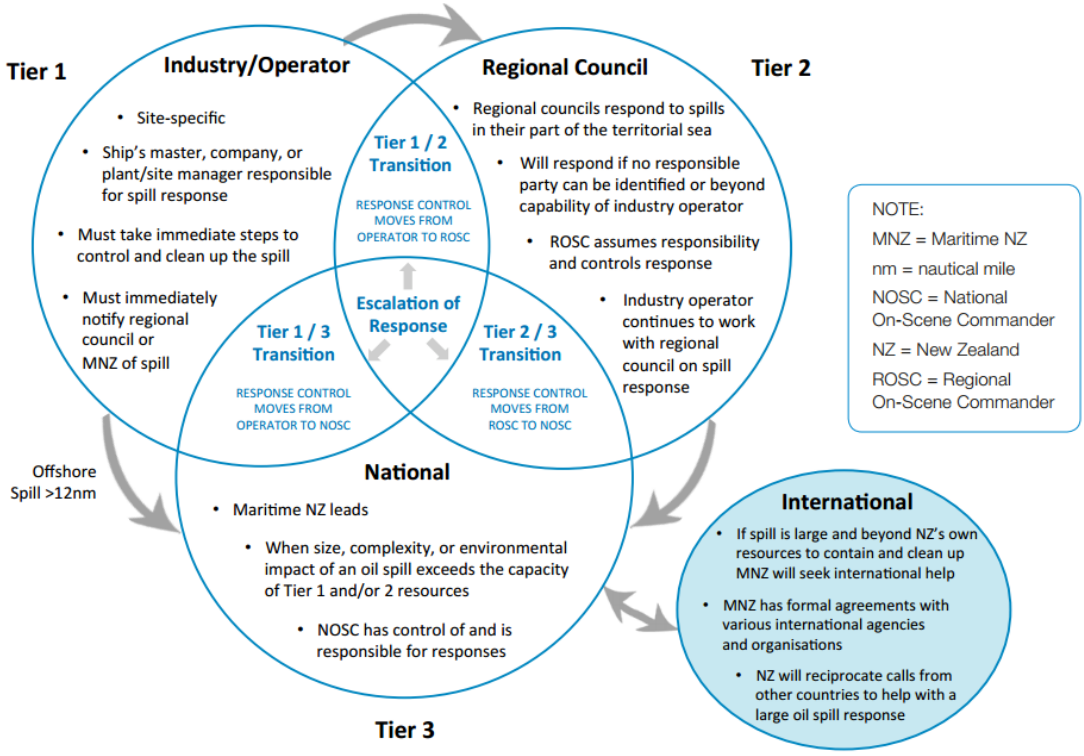
4.4. Response Capability

Oil spill response capability exists at multiple levels:

- RNZ and Northport
- Northland Regional Council
- Maritime New Zealand
- International Capability

The national three-tiered marine oil spill response system as set out in the National Oil Spill Contingency Plan (Maritime New Zealand, 2017) is outlined in Figure 4.7.

Figure 4.7 - New Zealand's Three-Tiered Marine Oil Spill Response System



The recent minor spills described in Section 4.3 have seen responses from Refining NZ, Northport and the Northland Regional Council. Equipment available locally includes containment booms and skimmer vessels. Refining NZ has trained spill response personnel and stockpiles including: booms, skimmers, a spill response trailer and oil spill recovery barge (Taranui). This allows response to a Tier 1 spill in accordance with the Refining NZ marine oil spill contingency plan that is approved by Maritime NZ. In addition to the equipment held onsite, oil spill responders have access to the Northland regional stockpile of oil spill response equipment at Marsden Point. This includes booms, skimmers, pumps, dispersant and storage tanks.

Given the crude oil cargo sizes being transported to Marsden Point this analysis assumes that a spill due to a grounding or collision would immediately result in escalation to a Tier 3 response. Depending on the nature and scale of an incident, we expect international assistance would also be sought. This assumption applies to both current operations and future scenarios.

5. Inputs from Work Stream Specialists

Refining NZ implemented multiple work streams related to the proposed channel project. Navigatus engaged with relevant specialists from these work streams to better understand the potential marginal impact resulting from additional spill volumes. Table 5.1 contains an outline of discussions held.

Table 5.1 - Outline of Discussions with Specialists

Person (Date)	Organisation	Work Stream	Comments	References
Graham Don	Bioresearches	Avian Ecology	Discussed species types, and hotspots (e.g. feeding, breeding) both within the Bioresearches study area and beyond (i.e. to areas that may reasonably be affected by a large spill). Discussed marginal impact of larger spills and whether there were any obvious tipping points.	*A Review of Literature on the Marine Natural Environment of Whangarei Heads, Bream Bay and its Adjacent Coastline* (Bioresearches, 2016)
Rob Greenaway	Rob Greenaway and Associates	Recreation	Identified and located recreation activities. Many activities ecologically based (e.g. food harvesting). Discussed marginal impact of larger spills and whether there were any obvious tipping points. Noted release rate could result in different scales of effect.	*Recreation and Tourism: Literature Review and Recommendations for further Research and Consultation* (Greenaway, 2015)
Deanna Elvines	Cawthron Institute	Marine Mammals	Discussed species types, hotspots and impacts of oil. Uncertainty around marine mammals ability to detect oil, and would not necessarily avoid it. As such will potentially be affected as they come to the surface to breathe. Noted impact more dependent on spill extent than spill volume. Individual species risk can be ranked according to their 1) range 2) habitat 3) prey diversity 4) behavioural flexibility 5) population size.	*Phase 1: Preliminary Review of Potential Dredging Effects on Marine Mammals in the Whangarei Harbour Region* (Cawthron Institute, 2016)
Juliane Chetham	Patuharakeke Te Iwi Trust Board Inc	Cultural Values Assessment	Discussed oil spill effects on cultural values, areas of cultural and ecological importance, e.g. shellfish beds and potential tipping points. In addition to harvested species, spill would affect *mauri* of water and iconic species, i.e. whales. Noted Trust objection to use of dispersant for clean-up.	*Cultural Values Assessment Report: Of Refining NZ Limited's Proposal to make Modifications to the Whangarei Harbour to allow Larger Freight Parcels/Oil Tankers to enter the Harbour* (Juliane Chetham, 2016)

Person (Date)	Organisation	Work Stream	Comments	References
Brian Coffey	Brian T Coffey and Associates	Marine Ecology	Discussed marine ecology, protection areas and marginal impacts of additional spill volume. Discussed the surrounding environment's regenerative capacity and recolonization dynamics post spill (including potential threat of invasive species).	*Complementary Literature Review to Inform Survey Work and Reporting Requirements to Assess the Environmental Effects of Proposed Dredging and Spoil Disposal Activities in the Approaches to Marsden Point* (Coffey, 2016)

6. Environmental Consequences

6.1. Relevant Factors

The impacts of an oil spill depend on a range of factors including:

- Event type, e.g. collision, grounding or contact with rock, impact force and extent of hull and tank damage. This will significantly affect the spill amount, event response and spill release rate.
- Event response, i.e. actions taken to save human life, the vessel and to reduce the volume spilled. Responses could have a positive or negative effect on the spill volume and spill release rate.
- Cargo size - larger crude oil cargoes mean there is potential for a larger spill (although this does not mean a larger spill will necessarily result). Cargo size may also affect spill size indirectly through hydrostatic forces.
- Release rate – the rate of oil release from the vessel into the sea depends on the above factors as well as the sea conditions. Oil release over a longer period of time means tides will change and there is potential for wind and sea conditions to change thus affecting the spill extent.
- Amount of oil spilled – this depends on the above factors and influences the spill extent.
- Sea conditions, wind conditions and oil degradation – these all directly affect the spill extent.
- Spill extent – depends on the above factors. This determines what ecological and social features will be impacted.
- Ecological features affected by the spill. This depends on the location of this spill and the tide and weather conditions affecting spill extent. Consequences include direct mortality and reduction in species diversity.
- Social features affected by the spill. Many social features are ecologically based. Resulting social damages include cultural, amenity and economic impacts.
- Spill response – driven primarily by the ecological and social features exposed and will aim to reduce the impacts on these.
- Recovery dynamics, e.g. post spill recolonisation of damaged area and restoration to pre-spill conditions. Includes potential imbalances between species which could be short or long lasting.

6.2. Measures of Consequences

The term ‘environmental consequences’ is broad and encompasses a range of short and long-term effects on ecology and society.

Ecological effects include:

- Direct mortality, i.e. destruction of habitat and decline in populations.
- Reduction in species diversity, i.e. the number of different species in the area.
- Duration of effects, i.e. time to restoration to pre-spill conditions, including potential short or long term imbalances between communities due to recovery dynamics.

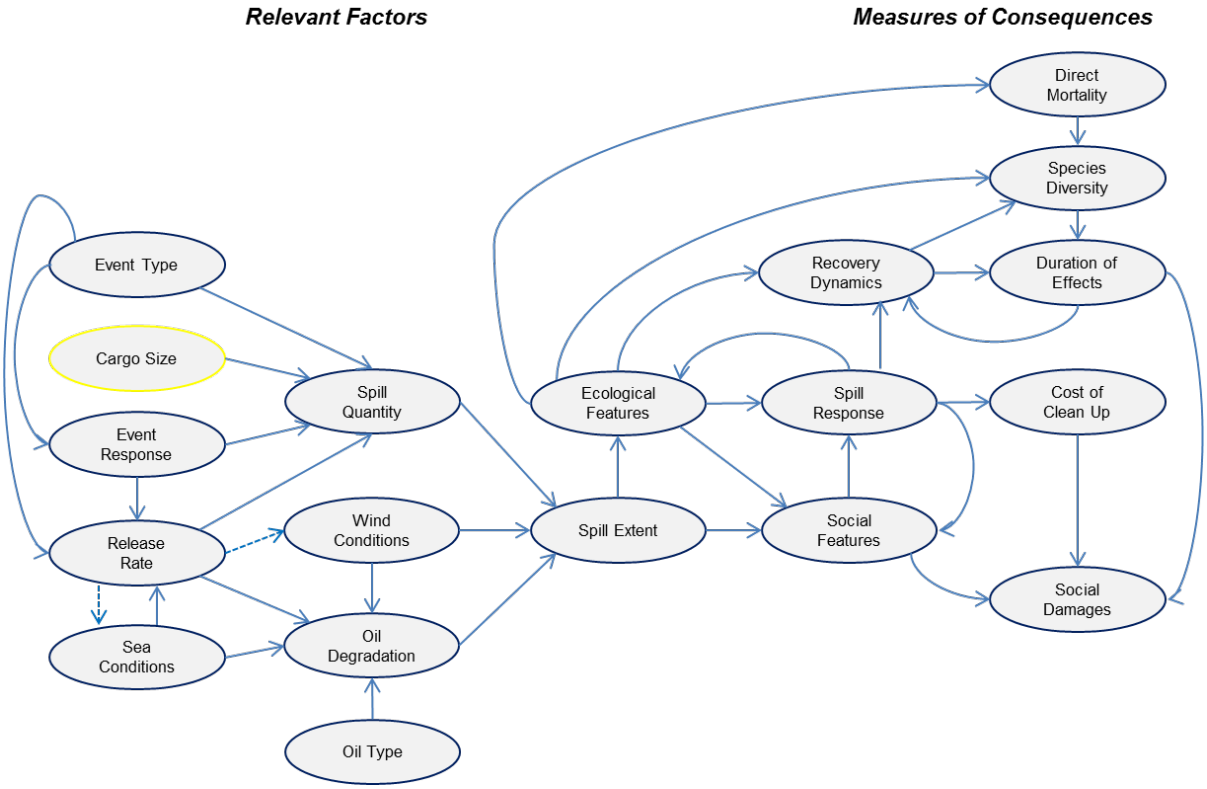
Social damages include:

- Cultural impacts.
- Amenity and recreation impacts.
- Clean up costs (Appendix A).
- Economic impacts (Appendix A).

6.3. Summary of Environmental Consequences

The number of variables that determine the outcome of a spill is potentially vast, although some factors are more important than others. Figure 6.1 shows many of the important factors and interactions which should be considered when evaluating the environmental consequences of a spill.

Figure 6.1 – Summary of Environmental Consequences



Note: while spill location is typically considered to be of critical importance, this analysis effectively assumes the spill location to be fixed (i.e. within the general vicinity of the approach to Marsden Point) so this is not shown in the above.

The purpose of this report is not to evaluate the absolute impact on these factors but to better understand the difference in effects that could be caused by larger vessel cargoes arriving less frequently with an improved channel and package of operational measures.

7. Risk Analysis

7.1. Methodology

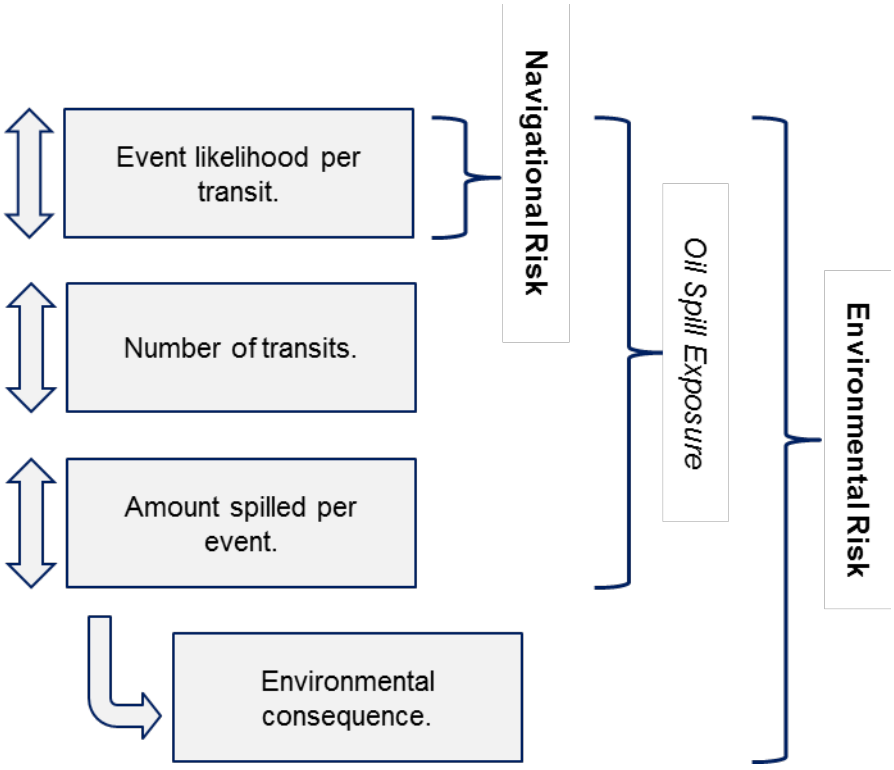
Risk is defined as the combination of likelihood and consequence. In the case of oil spills these elements can be further broken down to improve understanding.

The analysis in the following sections considers the following factors:

- Difference in the spill event likelihood per transit (likelihood).
- Difference in the number of transits (likelihood).
- Difference in the amount spilled per event as a result of greater volumes carried (initial consequence).
- Resulting difference in the environmental consequence of a spill (subsequent consequence).

This analysis draws on the navigational risk findings and further considers differences in the number of transits, differences in the expected amount of oil spilled for a given event and differences in the subsequent effects on environmental features. The relationship between navigational and environmental risk is shown in Figure 7.1.

Figure 7.1 - Relationship between Navigational and Environmental Risk



This analysis considers differences in the above factors that would result if a shift to the engineered channel was implemented. Given that some components of environmental risk may increase and others may reduce, assessments are made as to how the differences in scales of those exposures affect the overall risk profile.

7.2. Difference in Event Likelihood per Transit

The findings of the navigational risk assessment found that Option 4-2 offers a significant reduction in risk compared to current operations and would be a notable improvement for more fully loaded Suezmax tankers when compared to Option 2.

The navigational risk assessment also found that a package of operational measures is required to achieve risk reduction of a similar magnitude to that achieved by the proposed channel design.

Channel design Option 4.2 enables significant reduction in likelihood of an adverse event over the current channel for operations involving vessel types and cargo sizes currently handled. If implemented with improved operational measures, Option 4.2 would also enable operations for the proposed fully laden Suezmax tankers that can be considered to meet the As Low As Reasonably Practicable (ALARP) criterion.

7.3. Difference in Number of Vessel Transits

There are three types of tanker vessels visiting Marsden Point:

- Coastal tankers (distributing refined products to New Zealand ports)
- Aframax tankers (bringing in crude oil)
- Suezmax tankers (bringing in crude oil)

Coastal Tankers

The proposed changes are not expected to significantly affect coastal tanker operations and so this analysis focuses on Aframax and Suezmax tanker visits only.

Current Mix of Tankers and Cargos

For operations with the current mix of tankers and cargoes, there would, by definition, be no change in the vessel frequency and cargo sizes. That is, other than changes over time arising from fluctuations in demand for crude oil imports to the refinery. The existing mix of tankers and cargo sizes can apply to either the existing channel or to the improved channel.

Future Use with Fully Laden Suezmax Tankers

Enabling Suezmax tankers with larger cargoes to visit Marsden Point is expected to reduce the overall number of tankers visiting the refinery, assuming national petroleum demand remains constant. Historically, there has been an average of 55 tanker visits per year (2006-2015), expected to increase to around 59 visits following the successful commissioning of the Te Mahi Hou CCR unit in late 2015. There are expected to be around 48 visits on average given Channel Option 4-2. This is 19% fewer tanker visits than the alternative future scenario with the existing channel (which takes into account increased processing capacity resulting from the Te Mahi Hou unit introduced in 2016).

The overall chance of an event in any given year is a function of the event likelihood per transit and the number of transits. It is considered that this relationship is linear and proportionate, so a 19% reduction in transits would equate to a 19% reduction in the overall chance of an event in any given year. This assumes that pilot currency is maintained and the package of operational measures is implemented. It is noted that fewer transits would also

result in a lower overall likelihood of smaller transfer spills, e.g. from cargo transfers at the jetty.

7.4. Difference in Amount Spilled per Event

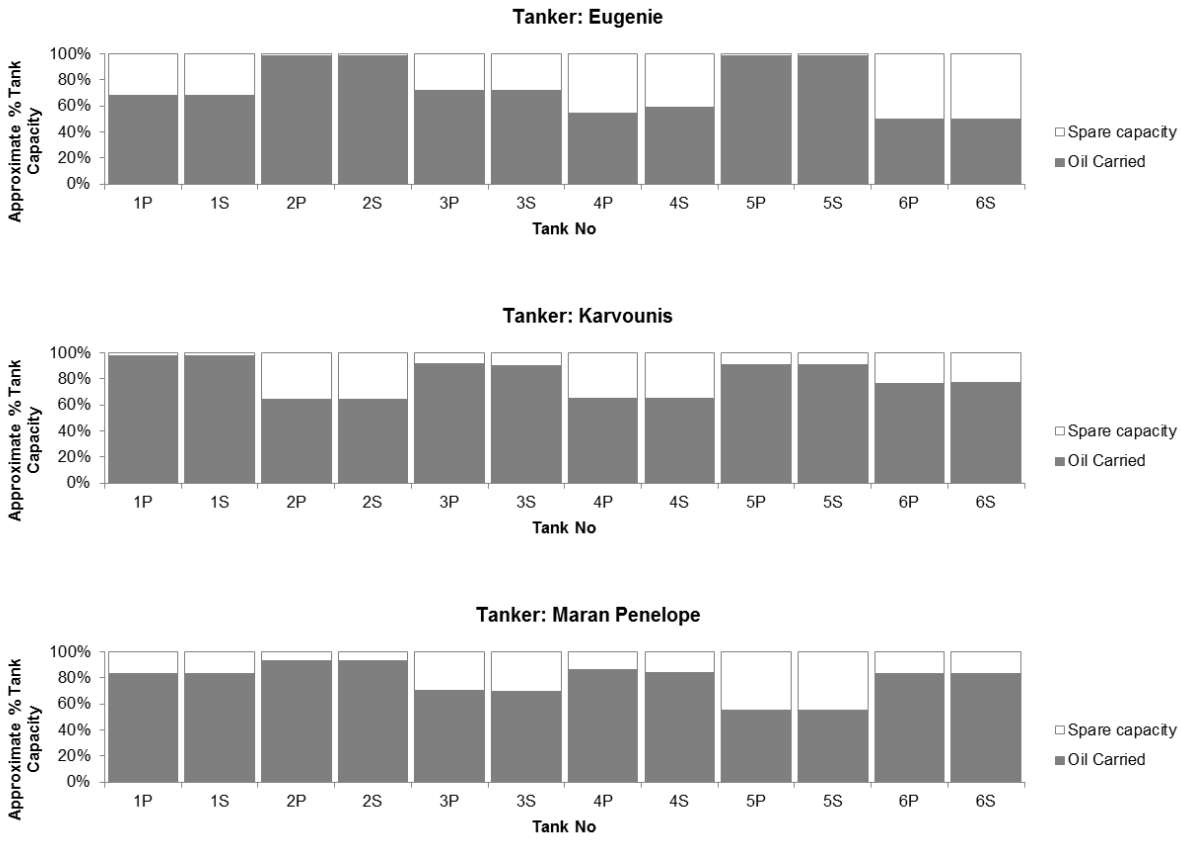
Overview

There are several factors that may influence the volume of oil spilled in a tank rupture event. As noted in Section 6, these include event type, event response, cargo size and spill release rate. These factors are discussed in the following subsections.

Tanker Cargo Sizes

Suezmax tankers typically have 12 main oil cargo tanks. A single tanker may carry several types of crude oil, separated in different tanks. Sample ullage reports from recent operations are summarised in the following graphs.

Figure 7.2 – Sample Reports of Oil Carried as Approximate Percent of Tank Capacity



Source: Refining NZ

Note: Oil carried is shown as an estimated percentage of capacity based on the recently recorded Ullage Dip.

The charts show that every tank is not filled to the same level: the pattern of partial loading varies. Some tanks are filled to near capacity even though the vessel is only partially laden overall. This means that the volume of oil in a single ruptured tank could potentially be the

same for a partially laden vessel as for a more fully laden vessel. However the likelihood of a particular tank being full would be greater for a more fully laden Suezmax vessel.

Hydrostatic Pressure

Hydrostatic pressure refers to the driving force that would act to push oil out of the tank due to the height of oil in the tank above sea level. In essence the higher the oil level the greater the outward flow rate for a given size of hole.

It could be contended that a more heavily laden vessel would spill less oil under a given tank rupture event. The argument is that a more fully laden vessel sits lower in the water so less oil would be exchanged due to hydrostatic pressure.

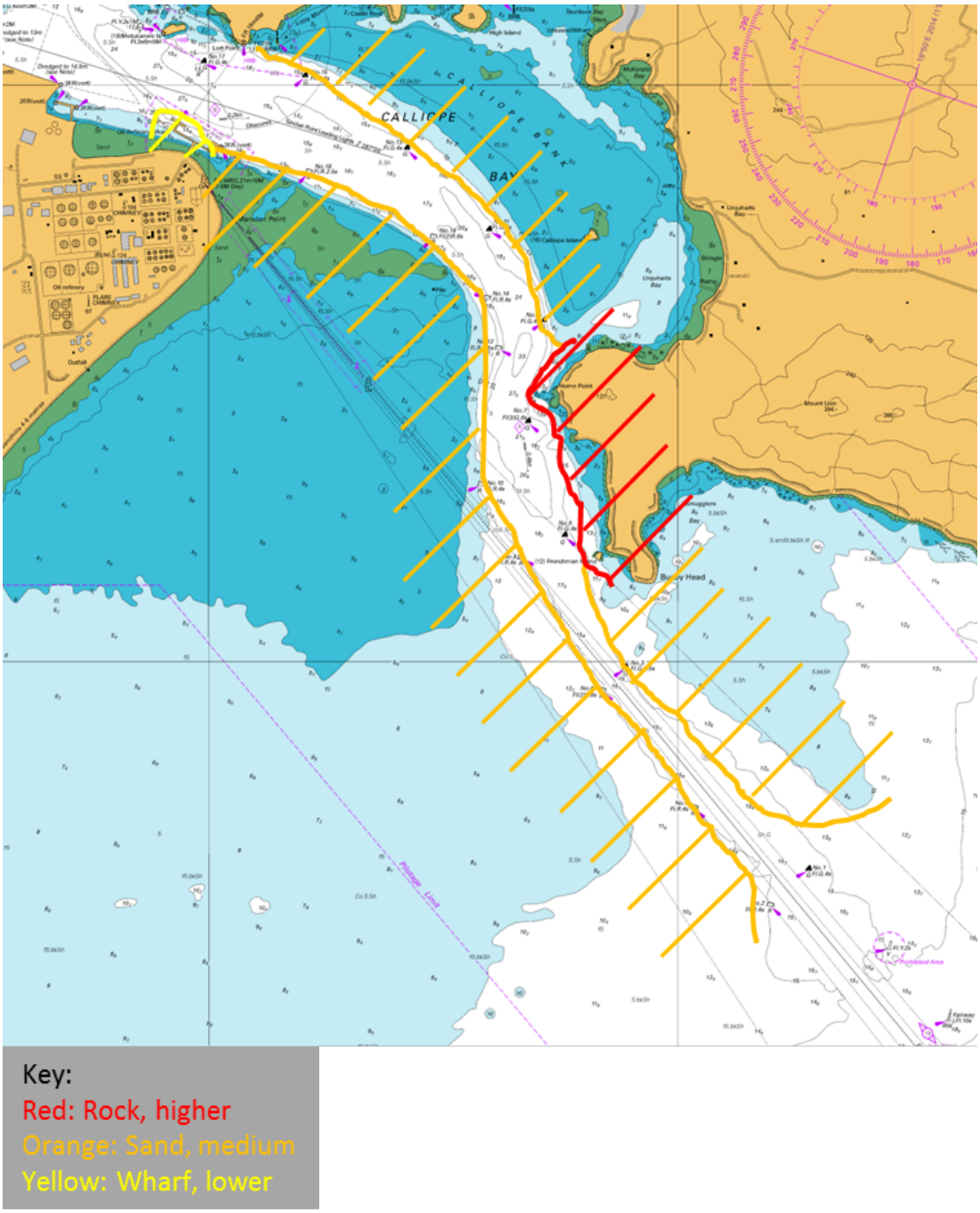
Although this contention has some validity, there are other significant factors to consider such as tides, oil being trapped in the double hull space, the effects of “pumping” due to wave action and the exact nature and location of the event.

Perhaps most important are the likely actions of the crew and incident responders. In the event of a ruptured tank (or tanks), actions to save the vessel (and therefore prevent damage to other tanks) would take priority over those to immediately reduce oil exchange from the ruptured tanks. In some cases, these actions could increase the hydrostatic effects, for example by deballasting the ship or offloading oil in other tanks.

Potential Event Types

The navigational risk assessment considered a range of potential collision and grounding scenarios. Figure 7.3 shows a graphical representation of the severity consequences resulting from a contact or grounding incident and various locations along the channel. The colours yellow, orange and red represent increasing severity in that order. The navigational risk assessment considered the upper half of the area marked in red (Home Point) to be the highest risk segment of the channel.

Figure 7.3 - Consequence Severity and Locations



This environmental risk assessment focuses on the consequences from grounding on or contact with rocky features as this would cause considerably more immediate damage to a vessel than contact or grounding with a sand bottom. Spills from other events such as grounding on sand bottom are less likely (although they remain credible).

It was noted in the navigational risk report that, given the draught of the vessels involved and levels of rocky outcrops (i.e. near Home Point), it is highly unlikely the vessel could ride up over the rock (as per the MV Rena). Rather, it would most likely sustain damage to the hull plating and associated structures as the vessel was deflected or ground and come to a stop.

The extent of the damage would depend on the speed and angle of the ship at contact. Given a speed of 6 to 8 knots around Home Point, the damage could extend for a significant

distance along the hull. The end of the rocky outcrop off Home Point is some 5m below the sea surface at chart datum and so would cause damage to a vessel from about 7m below the waterline (assuming a 2m tide). If the outer hull is ruptured the vessel would likely take on water and settle somewhat (draught would increase). It is considered that damage to more than one tank is a credible scenario. This analysis has been conceptually based on rupture of two tanks.

The proposed increase in cargo sizes for Suezmax tankers is not envisioned to influence the most likely types of spill events.

Event Response Actions

Following a significant incident, it is reasonable to expect that response actions would be implemented according to the following priority order:

1. Saving life.
2. Recovering the vessel.
3. Reducing amount of oil spilled.

These priorities can have countervailing effects, for example, actions to save the vessel, e.g. by refloating and transport to the jetty, could increase the proportion of oil spilled from the ruptured tanks (although may reduce further tank ruptures). (Note the proportion of oil spilled from ruptured tanks can also be affected by a range of other circumstances such as wind direction and sea state.)

The proposed larger cargo sizes for Suezmax tankers would not be likely to result in any change in event response actions.

Spill Release Rate

The type of event and the event response will influence the spill release rate. As noted above, it is unlikely the vessel could ride up over rock. It is therefore more likely the vessel could be towed to the jetty. If a damaged tanker is moved to the jetty at Marsden Point then further leakage during both incoming and outgoing tides can be expected over a number of days.

A constant for the oil spill scenario considered in this analysis is that any large scale spill will most likely start on an outgoing tide as tankers are brought in Marsden Point just before high tide. However the duration of a spill may vary with potential for ongoing discharge of oil on an incoming tide.

International Spill Statistics

DNV (2011) analysed international spill statistics and published cumulative probability distributions of tanker spill volumes. Spill volumes are standardised based on vessel deadweight tonnage. This means different cargo volumes can be applied to the distributions to calculate the difference in expected oil spilled in a given tanker event. Applying a shift of 25% from the long term average Suezmax cargo size of 828 kbbl to 1035 kbbl results in a 30% increase in expected oil spilled. Note that this includes spill sizes from 50 kbbl through to 1,035 kbbl.

Summary of Difference in Amount Spilled Per Event

There are significant uncertainties given that it is not possible to predict the exact nature of an event or the responses. It is considered that the expected volume of oil spilled for a given event at Marsden Point increases in an approximately linear relationship with the volume of oil carried in a given vessel. That is to say, an overall cargo increase of 25% roughly equates to a 25% (+-5%) increase in the likely volume of oil spilled for a given event. While a counter argument relating to hydrostatic pressure may have some validity, this would likely be offset by response actions. This assumption is roughly in line with the increase suggested by applying the cumulative probability distribution reported by DNV.

7.5. Resulting Difference in Environmental Consequences

Overview

As noted previously, the proposed engineered channel will result in fewer tanker visits, with Suezmax tankers generally carrying a greater volume of oil on each visit. This creates the potential for larger spill volumes. A key question is therefore, in the unlikely event of a spill, how would the environment be affected differently by larger spill volumes?

As mentioned in Section 6 there are many relevant factors. Some of the main factors are discussed below.

Spill Extent

Spill extent is mainly determined by spill amount, wind and sea conditions and oil degradation. The way these factors influence the transport and fate dynamics of spilled oil plays a role in how greater volumes of spilled oil could affect ecological and social features.

On the one hand, if a 25% larger spill mainly results in oil spreading over a wider area and into further reaches of the harbour then this will increase the extent of environmental damage (assuming a significant concentration of oil is maintained with spreading). On the other hand, if a greater spill volume primarily results in more oil accumulating in the same places rather than dispersing more widely, then the extent of the spill will not increase directly with larger spill sizes.

In particular these dynamics are likely to influence the effect of a greater volume of oil spilled on local social and cultural features. These features are typically always seen as highly sensitive and important and the effect of any spill volume is likely to have a severe impact. The social impacts are therefore largely a function of the extent of oil ashore and the duration to completion of clean-up and recovery. The following description of oil spreading is provided by ITOPF (2014):

> *As soon as oil is spilled, it starts to spread over the sea surface. The speed at which this takes place depends to a great extent on the viscosity of the oil and the volume spilled. Fluid, low viscosity oils spread more quickly than those with a high viscosity. Liquid oils initially spread as a coherent slick but quickly begin to break up. Solid or highly viscous oils fragment rather than spreading to thin layers. At temperatures below their pour point, oils rapidly solidify and hardly spread at all and may remain many centimetres thick. Winds, wave action and water turbulence tend to cause oil to form narrow bands or 'windrows' parallel to the wind direction. At this stage the properties of the oil become less important in determining slick movement.*

The rate at which oil spreads or fragments is also affected by tidal streams and currents - the stronger the combined forces, the faster the process. There are many examples of spills spreading over several square kilometres in just a few hours and over several hundreds of square kilometres within a few days, thus seriously limiting the possibility of effective clean-up at sea. It should also be appreciated that, except in the case of small spills of low viscosity oils, spreading is not uniform and large variations of oil thickness from less than a micrometre to several millimetres can occur (ITOPF, 2014).

Typically an increase in the volume of oil spilled by say 25% would increase the area affected due to the effect of sea turbulence on oil spread. A reasonable upper bound estimate for the additional area covered would be roughly equivalent to the increase in oil spilled, e.g. a 25% increase in spill volume could result in *up to* 25% more area covered. However, the actual area covered would likely be less than this, with some of the additional oil being pushed by wind and currents to areas that would already be oiled, thereby increasing the oil concentration. Oil that is washed ashore to an already oiled area of shoreline may re-float on the next tide and be transported to another location if not collected in time.

Sea Conditions

Large tankers accessing Marsden Point enter on high tide to ensure maximum channel depth. This means that immediately following any event, there will be six hours of outgoing tidal current moving oil out to sea and away from the harbour. According to nautical charts, the outgoing tidal current at Whangarei has an average speed of to 1.2 knots on a neap tide and 1.8 knots on a spring tide.

Table 7.1 - Tidal Velocities

Stage of Tide		**Tidal Velocity (knots) from NZ5214**	
		Site A (in channel off Home Point)	
		Springs	**Neap**
Hours Before	-6	0.3	0.2
	-5	2.0	1.4
	-4	2.3	1.5
	-3	2.2	1.5
	-2	2.0	1.4
	-1	1.7	1.1
High Water		0.6	0.4
Hours After	1	0.8	0.5
	2	2.2	1.5
	3	3.1	2.1
	4	2.8	1.9
	5	1.9	1.3
	6	0.4	0.3

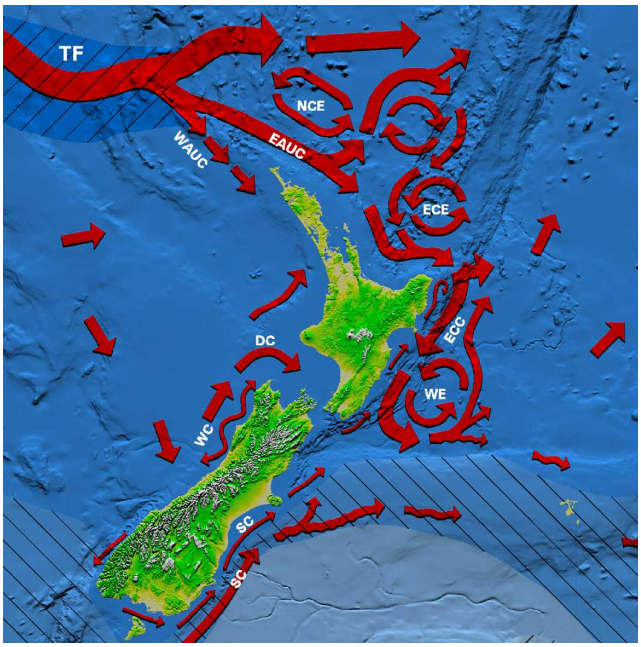
If oil is released at a rapid rate immediately following the spill then much of the oil spilled will travel out to sea on the ebb tide. This provides more time to mobilise oil spill response resources and will result in less oil arriving in the more sensitive inner harbour areas than would be the case for a spill occurring on an incoming flood tide. Oil subsequently arriving on shore from any initial release will also be partially degraded through weathering processes. Offshore tidal flows are north-south so would spread oil along the coast.

On the other hand, if oil is released more slowly, with significant volumes still being released over six hours later, then more oil will be moved into the Whangarei Harbour on the flood tide. A longer duration of oil release also means there is a greater chance that wind conditions may change, pushing the oil into more disparate areas.

However, even if most of the bulk of oil spill occurs initially on an outgoing tide, if a damaged tanker is moved to the jetty at Marsden Point then further leakage over both incoming and outgoing tides can be expected over a number of days until full control over the leakage is established.

Due to the strength of currents in the vicinity of Marsden Point jetty it is assumed that containment booms would be only partially effective. Accordingly there is the potential for an oil spill to impact both the inner Whangarei Harbour and coastal areas in the vicinity of the harbour entrance. Once out of the harbour the oil would be subject to predominant currents and wind conditions. A high level overview of major currents is shown in **Figure 7.4**.

Figure 7.4 - Major New Zealand Currents



Source: http://calib.qub.ac.uk/marine/currents/NewZealand.html

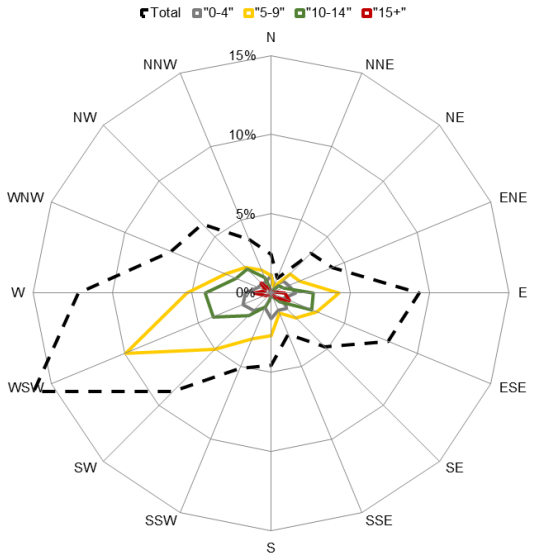
Wind Conditions

Wind typically acts to push oil at approximately 3% of the wind speed and oil slick direction can be generally predicted from simple vector calculation of wind and surface current direction (ITOPF, 2014).

A wind rose for the period 2000-2012 inclusive is shown below. It is generated from NIWA data from the Mokohinau Automated Weather Station. The rose shows a distribution of both

speed and frequency for the wind in 16 directions. The bearing represents the direction the wind comes from.

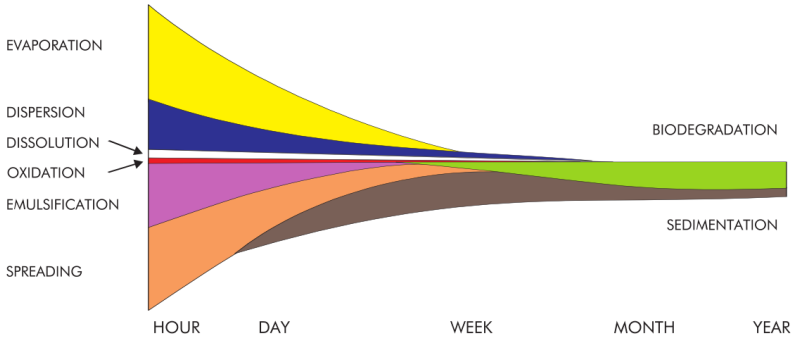
Figure 7.5 - Mokohinau AWS Wind Rose 2000-2012 Inclusive



Oil Degradation

As oil is transported by sea and wind conditions, it also undergoes different forms of degradation. This breakdown is also influenced by sea conditions, so oil at sea is more exposed and is likely to break down faster than oil in harbour. Figure 7.6 shows the relative effects of crude oil weathering processes over time.

Figure 7.6 – Generic Crude Oil Weathering Processes with Time (Galvez-Cloutier, 2014)



Ecological and Social Features

The focus of this analysis is on the difference in effects caused by larger tanker cargoes in the unlikely event of a spill. Therefore it conceptually compares a spill in one location with a larger spill in the same location. The Whangarei Harbour and surrounding area is highly sensitive for both the ecological and social features present.

Figure 7.7 shows a section of Whangarei Harbour taken from the Northland Regional Coastal Plan (Northland Regional Council, 2003). Green areas represent Marine 1 (Protection) Management Areas. Figure 7.8 shows sensitive marine ecological and bird areas as proposed in the Draft Regional Plan (Northland Regional Council, 2016). These

identified areas may be subject to change through the plan consultation and approval process.

Figure 7.7 – Regional Coastal Plan – Whangarei Harbour

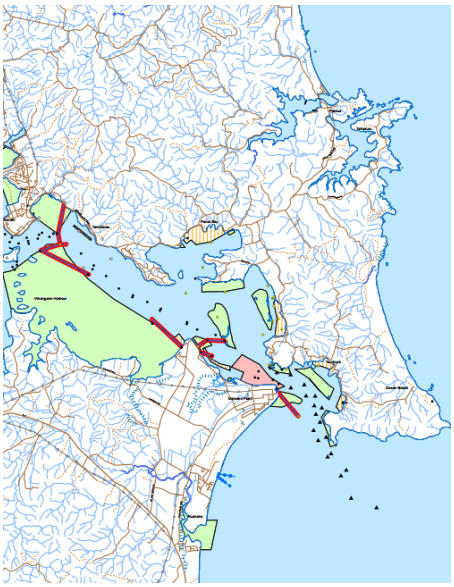
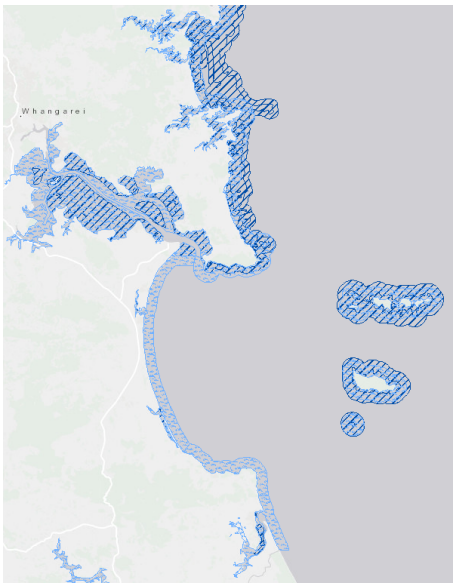


Figure **7.8 – Draft Sensitive Marine Ecological Areas**



Source: Northland Regional Council (2016).

Mair Bank is a delta bar on the southern side of the Whangarei Harbour entrance. The presence of pipi and mussel beds on Mair Bank provides a degree of armouring, protecting Mair Bank from erosion. If the shellfish were to be depleted then accelerated erosion of Mair Bank could be expected as remnant shells are worn away. The long term existence of Mair Bank is therefore dependant on biological processes.

In the event of the area being affected by a large oil spill we would expect significant depletion of pipi and mussel populations at Mair Bank lasting over the short to medium term, particularly in shallow waters. Over the longer term repopulation of Mair Bank would be expected from shellfish larvae arriving on the East Auckland Current and from local sources.

The primary effect of increased cargo size in the unlikely event of a spill would be due to a somewhat larger spill extent. A particular threat would be if oil spread to some sort of 'hotspot', e.g. a feeding or breeding area that would otherwise not be affected by a marginally smaller spill. This point was raised with each of the specialists in discussions related to this report.

However, attempting to isolate the marginal effect of increased cargo carried is problematic as there are many complex factors at play. It is highly unlikely that a tipping point would be reached that would cause disproportionate damage to the ecological and social features due an increased spill size. This is because the amount of oil spilled and the additional oil spreading would not be disproportionate to the increased amount of cargo carried.

Spill Response Actions

The extent of spill response actions would be driven by the perceived threats to social and ecological features.

It is likely that critically endangered species in the wider locality would be pre-emptively captured in response to a moderate – large spill.[4] The difference in cargo carried would not affect this response.

Clean up actions would involve the use of skimming vessels and removal of oil from shoreline. Due to the strength of currents in the vicinity of Marsden Point jetty it is assumed that containment booms would be only partially effective.

It is noted that the Patuharakeke Te Iwi Trust object to the use of dispersant.

Clean-up costs are discussed in Appendix B.

Duration of Effects

The duration of effects of an oil spill depends on factors such as the type of oil, nature of the receiving environment, effectiveness of clean-up processes and the effects concerned.

In our assessment we assume that shoreline will be affected, both within the harbour and outside of the harbour. We also assume that an effective clean-up response will be mobilised. This would be undertaken in accordance with the National Oil Spill Contingency Plan (Maritime New Zealand, 2017) and would be similar to the Rena response, but on a larger scale. We would expect international resources to be involved in the clean-up, as happened in the Rena clean-up where staff from the Australian Maritime Safety Agency participated in the response.

Traces of oil in the environment will naturally degrade through microbial activity. An objective of the clean-up activity is to continue cleaning up where there is a net environmental benefit. Recognising that too much clean-up activity can be damaging in itself, clean-up proceeds to a level where ecological processes are best left to do the final remediation steps. While the initial clean-up approach to a more heavily oiled area may differ from a more lightly oiled, we expect the clean-up endpoints to be determined mainly by the shoreline type, sensitivity and ecological sensitivity, and less by the initial level of oiling.

For these reasons we assess that the levels of residual hydrocarbons at the substantial completion of clean-up efforts would be similar between the two scenarios. A larger spill may take slightly longer to clean up if there are some equipment limitations, but a larger spill would also likely prompt the mobilisation of more resources. In both cases we would expect a clean-up to be substantially completed in a time period of months. At that time all bulk clean-up operations would be completed and many areas released back to public use. Residual monitoring and clean-up of patches would continue (e.g. recovery of buried oil residues uncovered by storm action on beaches). Some pre-emptively captured animals may be held in captivity or re-located until there is a higher degree of confidence in likely outcomes.

We would expect shellfish to be lost for a period from some areas due to the toxicity of hydrocarbons, until levels of hydrocarbons subside to a level where the areas can be recolonised by shellfish larvae. Even where shellfish survive, gathering prohibitions can be expected to last for several years due to concerns for human health impacts of consumption.

[4] An example of this was the pre-emptive capturing of New Zealand Dotterel following the Rena spill.

In summary recovery from a major spill of the scale envisaged, is expected to take some years. We would expect that timescale to be very similar, if not identical, between the existing situation and for a potentially larger spill with the improved channel.

Recovery Dynamics

In the short to medium term all of the marine flora and fauna in the most heavily affected areas would be expected to be killed. This would effectively create a 'blank slate' which would be recolonised over time as hydrocarbon levels drop through restoration activities and through natural degradation.

The best case recovery scenario would be for native species to recolonise the affected area, restoring balance to pre-spill conditions. This is enabled by the daily flow of tides which creates connectivity between the harbour and the marine biodiversity of surrounding waters. In particular, the East Auckland current carries subtropical species larvae from warmer regions to the north and east of New Zealand.

However, species have different levels of sensitivity to oil and some would re-establish themselves before others. This could cause imbalances and the ecology would be expected to transition through a series of stages before reaching pre-spill conditions. An alternative scenario is that ecology could settle in a new steady state permanently. In case studies of a range of spills, the environment has returned to the previous conditions, albeit with detectable levels of hydrocarbons buried in sediment in some locations (Appendix B). We have not identified any instances where the ecology has settled into a new stable state after a spill.

A particular threat associated with a 'blank slate' environment would be potential recolonization by invasive species which could be brought into the environment by vessels travelling internationally. This could plausibly create a situation whereby native species could not gain sufficient traction to re-establish themselves in the area.

The likelihood of such a threat eventuating would be determined principally by the presence or absence of invasive species rather than the area affected, and so would not be affected by the potential increase in spill volume.

Summary of Resulting Difference in Environmental Consequences

A larger spill volume would result in further oil spread in the environment. However, these factors would most likely increase to a lesser degree than the increase in cargo carried, e.g. a 25% increase in spill volume would result in less than a 25% increase in area covered.

Some areas are more ecologically and socially sensitive to others although there are many variables which determine whether they are affected. The effects of any large spill are therefore likely to be profound over the short - medium term. It is not expected that there would be disproportionately more harm resulting from the proposed increase in cargo size.

8. Risk Evaluation

This environmental risk assessment explores the effect of proposed tanker operations associated with the Option 4.2 engineered channel on the environmental spill risk profile of Whangarei Harbour and surrounding areas. Three use cases are considered:

- **Baseline:** Existing mix of tankers and cargo sizes operating in the existing channel with existing operational procedures.
- **Use Case A**: Existing mix of tankers and cargo sizes operating with channel design Option 4-2 implemented. Same count and mix of tanker visits as baseline.
- **Use Case B:** Mix of tankers and cargos includes fully laden Suezmax tankers toegther with implementation of the package of operational measures identified in the navigational risk assessment. Fewer tanker visits overall.

The objective is to determine whether there would be a positive or negative overall impact on environmental risk for Use Cases A & B.

This assessment draws on the navigational risk findings and further considers differences in the number of transits, differences in the expected amount of oil spilled for a given event, and differences in the subsequent environmental consequences. These factors are discussed in the previous sections and summarised in Table 8.1. In all cases the comparison is made against the Baseline use case.

Some components increase risk and others reduce risk, so judgements have been made as to their relative effects on the overall environmental risk profile.

Table 8.1 - Summary of Environmental Risk Components Compared to Baseline

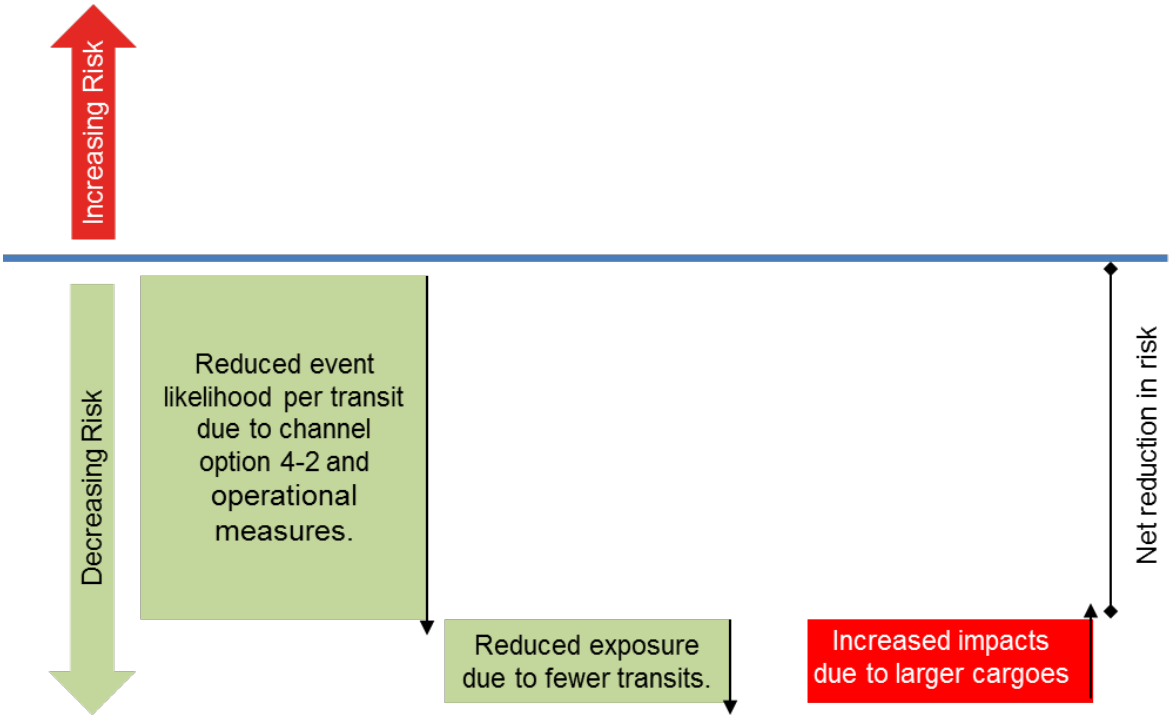
ID	Factor	Comment
A	Difference in event likelihood per transit.	Appendix A.1. Use Case A: Significant reduction in event likelihood. Use Case B: The implementation of Option 4.2 and operational measures will significantly reduce the likelihood of an event for each transit compared to current operations.
B	Difference in number of transits.	Use Case A: No change from Baseline. Use Case B: The potential for Suezmax tankers carrying larger cargoes to access Marsden Point means fewer transits are needed to deliver the same volume of oil. This is expected to have a roughly linear effect on reducing risk.
C	Difference in amount spilled per event.	Use Case A: No change from Baseline. Use Case B: There are many uncertainties regarding the amount of oil spilled in a given event. But ultimately a greater volume of oil carried means the potential for a larger spill. We assume volume spilled increases linearly with increase in amount carried.

D	Resulting difference in environmental consequences	Use Case A: No change from Baseline. Use Case B: A larger spill volume would result in further oil spread and longer persistence in the environment. However, these factors would most likely increase to a lesser degree than the increase in cargo carried, e.g. a 25% increase in spill volume would likely result in less than a 25% increase in area covered. Some areas are more ecologically and socially sensitive to others although there are many variables which determine whether they are affected. It is not expected that there would be disproportionately more harm resulting from the proposed increase in cargo size.

For Use Case A it is self evident that risk is significantly reduced: the improved channel significantly reduces navigational risk, and all of the components of consequence are unchanged.

For Use Case B, Figure 8.1 illustrates our evaluation of the components in Table 8.1. The blue line represents the baseline level of risk, i.e. baseline scenario in which usage of the existing channel is continued. A green block represents a risk-reducing effect of an operational change and a red block represents a risk-increasing effect. The relative sizes of the blocks indicate the relative extent of the reduction or increase.

Figure 8.1 - Evaluation of Environmental Risk Components for Use Case B



The first green block in Figure 8.1 shows that the most significant factor is the reduced event likelihood per transit for Use Case B is due to implementing channel design Option 4-2 and the package of operational measures.[5]

[5] Note: this reduction is significantly stronger for Option 4-2 than it would for Option 2.

The next green block in shows that risk is further reduced, although to a lesser extent, as a result of the reduced number of transits needed to bring in the same amount of oil.

The red block on the right of shows that there is a countervailing increase in risk due to the greater consequences arising from larger crude oil cargo sizes per transit. However, this is outweighed by the first two blocks. The cumulative effect is that there is a significant net risk reduction resulting from the proposed tanker operations associated with engineered channel Option 4-2.

9. Conclusion

The proposed tanker operations associated with an engineered channel to Marsden Point would affect both the likelihood and potential consequences of a large-scale spill event.

The most important factor is the reduced likelihood of a spill per tanker transit, which is the result of adopting channel design Option 4-2 and implementing the package of operational measures. Likelihood is further reduced, although to a lesser extent, as a result of the reduced number of tanker transits needed to bring in the same amount of oil.

For Use Case A (existing mix of tankers and cargo sizes operating with channel design Option 4-2 implemented) the net result is a significant reduction in environmental risk compared to the Baseline of existing tanker operations in the existing channel. This is self-evident, once the navigational effects of the improved channel on existing tanker operations are known (being a significant reduction in navigational risk) as all else is unchanged from Baseline.

For Use Case B environmental consequences are somewhat increased as larger crude oil cargo sizes means that there is the potential for more oil to be released in a given spill event. However, attempting to isolate the marginal effect of increased cargo sizes is problematic as there are many complex factors at play.

It is unlikely that a tipping point would be reached that would cause disproportionate damage to ecological and social features. This is because the potential amount of oil spilled and the additional oil spreading would likely increase to a lesser extent than the increase in the crude oil cargo size.

Whilst any large scale spill would have profound effects on the environment over the short to medium term, the proposed crude oil cargo size increase would not make environmental consequences disproportionately worse. When balanced against reduced event likelihood this results in a net reduction in risk.

We conclude that, for Use Case B, the benefits of improved navigational safety and fewer tanker visits would significantly outweigh the countervailing risks due to larger crude oil cargo sizes. The overall environmental risk for Use Case B will be significantly lower than the Baseline of existing tanker operations in the existing channel.

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Appendix A: Economic Cost of Damages

It is self-evident that the damages arising from any particular spill event will depend on local circumstances, such as the type of oil, the direction of current movement and winds at the time of the spill, the sensitivity of the local environment, and the effects of spill response actions and clean-up. In that respect every spill is unique.

However, researchers have sought to determine whether patterns emerge when a wide range of spills are considered in aggregate. In particular, researchers have looked at relationships between spill size and cost of clean-up or the economic cost of damages resulting from spills. Intuitively such a relationship can be expected: the bigger the spill the more it will cost to clean up and the greater the damages. But the question of "by how much?" has received attention from researchers.

Studies of clean-up costs versus volume of spilled oil have been undertaken by a number of researchers such as Kontovas et al. (2010), Montewka et al. (2013), Ventikos & Sotiropoulos (2014), Kontovas et al. (2011). Due to methodological limitations the results should be treated as broadly indicative only. However, the authors generally agree that an overall trend is observed where the costs of clean-up are proportional to spilled volume in the form of:

$$\text{Cost} \propto (\text{Volume})^{\text{Exponent}}$$

Where the exponent is less than 1

Recent estimates of the value of the exponent in this formula for total economic cost of damages, including compensation, range from 0.65 (Psarros, Skjong, & Vanem, 2011) through to 0.85 (Ventikos & Sotiropoulos, 2014). The significance of this observation is that increases in volume of oil spilled have a decreasing marginal effect on the total economic cost of damages.

As an example, the figure below uses a mid-range exponent value of 0.75 to illustrate how clean-up costs begin to level off as the volume of oil spilled increases. This is further illustrated in the table over.

Illustration of Damages vs. Volume Relationship, Exponent = 0.75

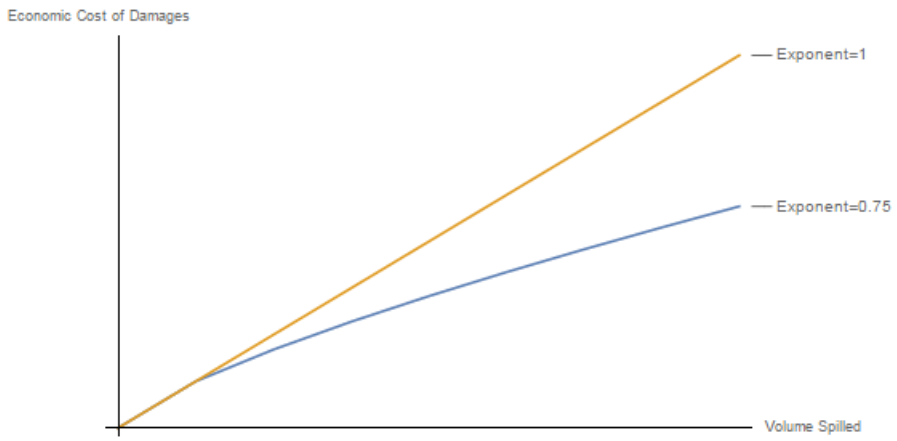


Table 10.1 – Example of Damages vs. Volume Relationship, Exponent = 0.65, 0.75, 0.85

Spill Size (Tonnes)	Estimated Economic Cost of Damages (Base 6,000 Tonnes = 100)				% Increase from Previous			
	0.65	0.75	0.85	1.0	0.65	0.75	0.85	1.0
6,000	100	100	100	100	N/A	N/A	N/A	N/A
8,000	121	124	128	133	21%	24%	28%	33%
10,000	139	147	154	166	16%	18%	21%	25%
12,000	157	168	180	200	13%	15%	17%	20%
14,000	174	189	206	233	11%	12%	14%	16%

Appendix B: Selected Case Studies

Sea Empress Spill

Overview

The 1996 Sea Empress spill is a useful case study for considering the potential outcomes of a large tanker incident and spill scenario. It has similarities to a type of incident that is conceivable at Marsden Point. In particular it highlights the effects of potentially compounding factors such as weather and response actions. The spill occurred in a nationally important and sensitive wildlife and marine conservation area.

Spill Incident

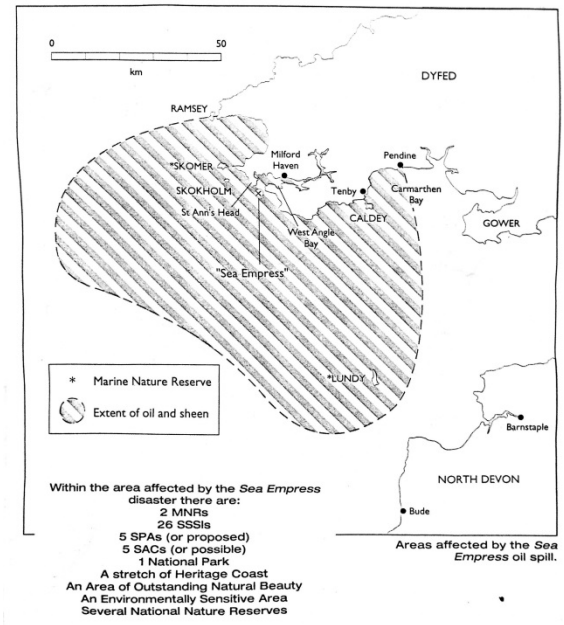
On 15 February 1996, the single hulled oil tanker Sea Empress, carrying 130,000 tonnes of Forties Blend North Sea crude oil, ran aground in the channel to Milford Haven refinery in South-West Wales.

The tanker was initially refloated within a couple of hours; however, it sustained serious damage to its starboard and centre tanks, resulting in a major release of oil. Attempts to bring the vessel under control and to undertake a ship-to-ship transfer operation were thwarted by severe weather and the tanker grounded and was refloated several more times over a period of five days resulting in further release of oil.

In all, some 72,000 tonnes of crude oil and 370 tonnes of heavy fuel oil were released into the sea between the initial grounding and the final refloating operation (ITOPF 2015).

Fortunately, most of the fresh crude oil was released during ebb tides and carried into deep water in the Bristol Channel, which helped the extensive dispersant spraying operation (Law & Kelly, 2004).

Figure 10.1 Extent of oil and sheen



Source: Pembrokeshire Archives

Oil Ashore

It was estimated that between 3,700 to 5,300 tonnes of oil reached around 200km of shoreline (Edwards & White, 1999). Another estimate (found during a physical search of archival records by Navigatus at Pembrokeshire archive) reports that approximately 40% of the oil was estimated to have evaporated soon after the spill, 50% dispersed in the water and broken down by microorganisms, 1-2% collected at sea with the remaining 5-7% arriving on shore (3,600 to 5,040 tonnes) ("Sea Empress - impact less than feared," 1998).

Clean-up Costs

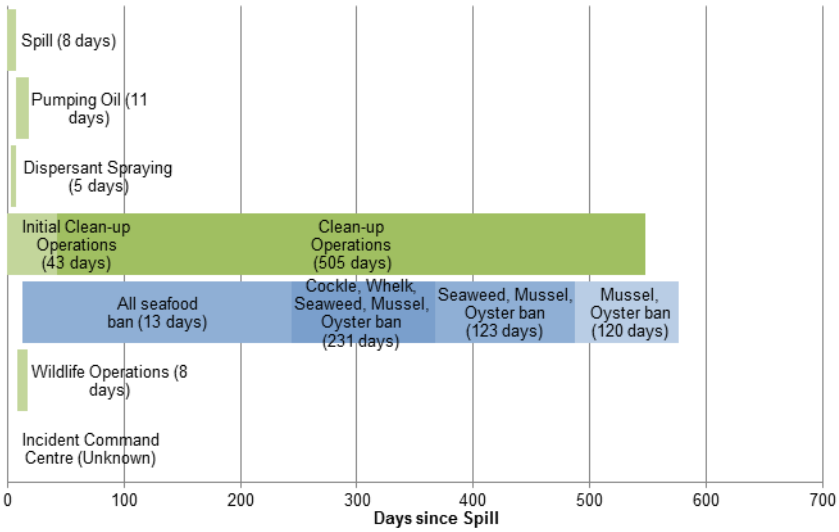
At that time, the site was the only coastal national park in the UK, with 35 Sites of Special Scientific Interest and one of only 3 UK marine nature reserves. It was also a site of special European status to conserve rare and vulnerable birds. Initial operations with 1,000 workers cleaned all amenity beaches in six weeks. Overall clean-up, including re-released oil from storm movement of sediments, took place over 18.3 months (Edwards & White, 1999). The total cost was put at approximately £23 million (GeoResources, n.d.-a).

Another article found by Navigatus at Pembrokeshire archive reported that during the first three weeks more than 500 people worked on cleaning the beaches, half local authority employees and the rest employed by contractors. By the end of April this resource had been reduced by half. Expenditure on the clean-up at sea and on the beaches totalled over £5.5 million by the middle of September 1996, with nearly £400,000 spent on dispersants. The aerial clean-up operations cost more than £500,000 pounds ("Clean-up bill tops £11 million mark," 1996).

Marine Flora

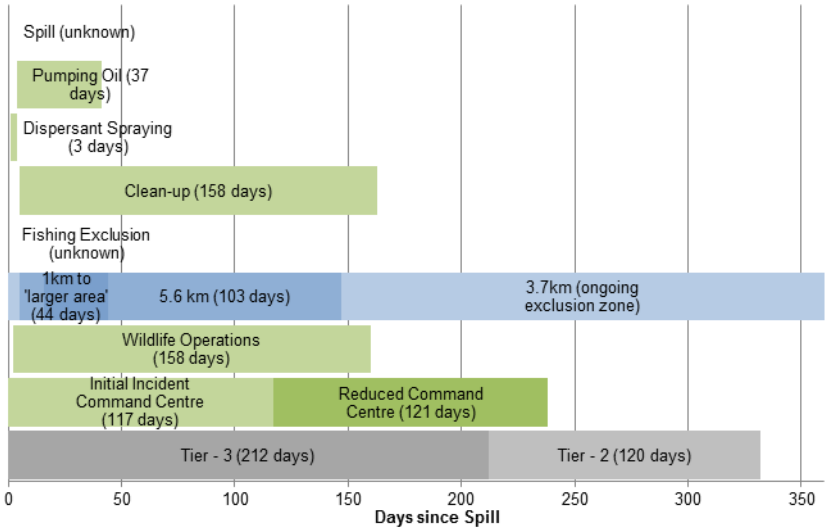
Flora	Short Term Effect	Recovery
Subtidal seagrass (*Zostera marina*)	No discernible effects.	Hydrocarbon analysis of sediment samples from the bed, found that concentrations were low and concluded that the growth of *Z. marina* was not adversely affected.
Intertidal seagrass (*Zostera angustifolia*)	Considerably oiled and then affected to some extent by vehicles driving across during the clean-up.	Surveys in 1996 found no discernible overall change in the extent of the beds compared to pre-spill conditions, but showed that ruts from vehicles had caused some lasting physical damage. Annual monitoring continued to show no discernible impact of the oil, but the vehicle tracks were detectable up to 1999/2000.
Fucoid algae (particularly *Fucus vesiculosus* var. *linearis*).	Massive growth, reaching blanket cover in spring 1997, maintained this cover into 1999, but then reduced rapidly on wave exposed areas. Much longer survival in sheltered areas, with some plants still present in 2005.	By February 2006 populations of these algae are essentially the same as they were before the spill, i.e. very sparse.

Flora	Short Term Effect	Recovery
Splash zone lichens *Caloplaca* spp.; *Xanthoria parietina* *Ochrolechia parella*	Very high tides and strong wind conditions during the first few days of the spill resulted in the oiling of many splash zone lichens, causing necrosis and bleaching in various species. In addition, high pressure washing and some other clean-up methods (eg wiping with sorbent rags) caused damage to lichen colonies in some locations.	No traces of oil could be seen on any of the sites after 2 years and recovery of the lichens was reported as well underway. Differential rates of growth have also been observed between different encrusting species. Where experimental trial plots with high pressure washing were established, it is clear that the colonisation and growth of *Caloplaca* spp. has been much faster on the areas that were left alone, than on the areas that were pressure washed.
Saltmarsh *(Atriplex portulacoides*, *Juncus gerardii*, *Puccinellia maritima*, *Triglochin maritimum* and *Carex extensa*	Some dieback of the vegetation where oiling had been substantial. Trampling damage during the clean-up response also noted. A re-survey in autumn 1997 found good recovery of most species in most locations, but continued reduction of *T. maritimum* and *A. Portulacoides.*	A comprehensive resurvey of all the saltmarsh in the waterway was carried out in 2002. No obvious differences found between sites affected by the spill and those either protected from its effects or situated beyond its zone of impact. Concluded that the saltmarsh vegetation of the Haven is no longer influenced by the effects of the oil spillage.
Coastal Plants	All studies concluded that there were no discernible impacts.	No *Sea Empress* related damage noted in various surveys and studies since the spill.

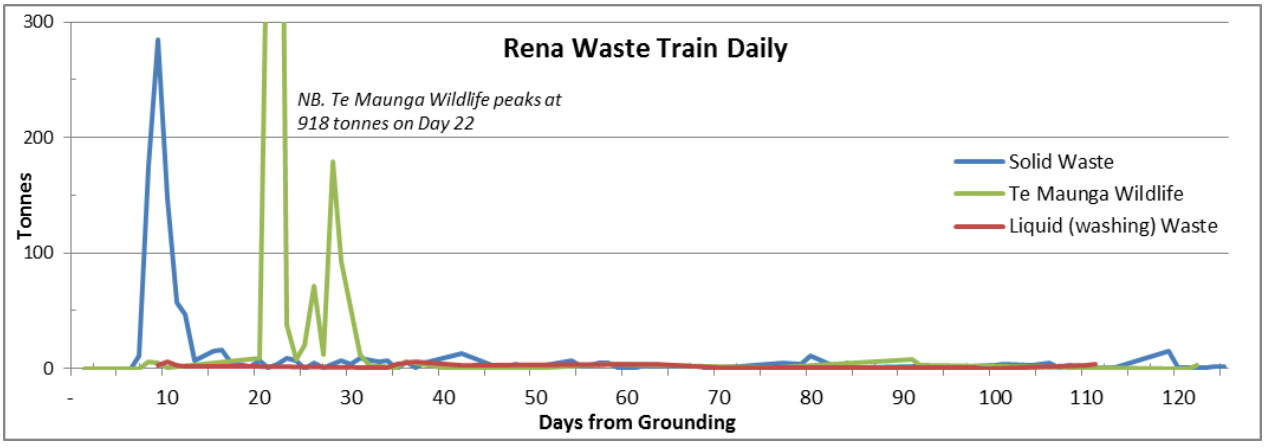
Ship/Installation	Sea Empress	**Location**	Milford Haven, South-west Wales	
Relevance	Large volume oil spill in temperate waters.			
Date	15 February 1996			
Timeline				
Spilled Oil	72,000 tonnes of light crude oil was released over a period of 7 days of which 3,700 to 5,300 tonnes reached 200 km of shore (Edwards & White, 1999).			
Duration of Clean –up operations	Initial operations with 1,000 workers cleaned all amenity beaches in six weeks. Overall clean-up including re-released oil from storm movement of sediments took place over 18.3 months (Edwards & White, 1999). The total cost was approximately £23million (GeoResources, n.d.-b).			
Environmental Sensitivity	The only coastal national park in the UK, with 35 Sites of Special Scientific Interest, and one of only 3 UK marine nature reserves. Also a site of special European status to conserve rare and vulnerable birds (Edwards & White, 1999).			
Environmental Impacts	No evidence of mass mortalities of commercial fin-fish or crustaceans. Significant mortality of mussels, star fish and heart-urchins. Amphipods, polycheate worms and brittlestars decimated in heavily contaminated areas but returned to pre-spill levels within five years. Known cushion starfish population reduced from 150 to 13 (Edwards & White, 1999). Intertidal communities on some severely impacted rocky, muddy and sandy shores, recovered rapidly. Impacts on subtidal seabed communities were limited geographically and to a few groups of sensitive species. Densities of tube dwelling amphipods (Ampelisca spp.) returned to pre-spill levels within five years. Some populations of burrowing echinoderms (Echinocardium cordatum) and spiny cockle (Acanthocardia echinata) have not recovered, although factors other than the oil spill may also be involved (Moore, 2006). Lichen communities in the splash zone of rocky shores reported as recovering; but some species are particularly slow growing and have not yet returned to pre-spill levels. Oiled saltmarsh areas showed very limited impacts beyond two years, and no effects could be detected in 2002. There was no evidence of significant spill-effects to coastal plants and terrestrial lichens (Moore, 2006).			
Impact on Birds	7,000 oiled birds were collected on shore, with an unknown number dying at sea. Of these birds, half were cleaned. However a study commissioned by the Sea Empress Environmental Evaluation Committee (SEEEC) to analyse previous data on guillemots (the most common species oiled around the UK, 23% of those collected after the Sea Empress (Edwards & White, 1999) showed that more than 70% of the cleaned birds died within 14 days of release and only 3% survived for two months or more (GeoResources, n.d.-b). Peak visiting population of a species of migratory sea duck, the scoter (Melanitta nigra) reduced from 15,000 to 4,300 in year following spill, representing 66% of those collected after the Sea Empress. Overall numbers of guillemots and razorbills reduced by 13% and 7% in 1996 (Edwards & White, 1999). The numbers of the majority of affected breeding seabird			

	colonies (primarily guillemots and razorbills) recovered to pre-spill values within two or three years. Slow recovery of two specific colonies of guillemots and razorbills. Subtle effects of large spills on guillemot populations suggested, but the long-term effects are unclear (Moore, 2006). Numbers of common scoter migrating through Carmarthen Bay rapidly returned to a level comparable with that present immediately before the spill. Total numbers of migratory wetland birds using the Milford Haven waterway were not apparently affected by the spill; and localised effects on their distribution within the waterway were not evident after two years (Moore, 2006).
Impact on Marine Mammals	No impacts were observed on grey-seals or cetaceans (harbour porpoises, otters, grey seals and bottleneck dolphins), and none have been reported in the following years (Moore, 2006).
Commercial Fishing and Shellfish Harvesting	Elevated levels of hydrocarbons were detected in crustaceans, fin fish, and especially molluscs. Fishing bans were implemented on 2,100 km^2 of coast for: finfish (3 months), crustaceans, cockles and whelks (8 months), and mussels and oysters (19 months). Hydrocarbon contamination of fish and shellfish returned to background levels in less than one year; and there was no evidence of any impacts to fish stocks after two or three years (Moore, 2006). Changes in the volume of harvests was not detectably attributable to the oil spill (Edwards & White, 1999).
Tourism	An estimate of the direct effects of the Sea Empress spill on the tourism spending in Pembrokeshire in 1996 was an average reduction of 12.9%, and slightly less for Wales overall. This equates to £20.64 million (Hill & Bryan, 1997).
Social Impacts	Profound attitudinal change to community perception of risks associated with transport of oil (Edwards & White, 1999).
References	Edwards, R. & White, I., 1999. The Sea Empress oil spill: environmental impact and recovery. International Oil Spill Conference. Available at: http://www.ioscproceedings.org/doi/abs/10.7901/2169-3358-1999-1-97. GeoResources, The Sea Empress Clean-Up Operation. Available at: http://www.georesources.co.uk/seclean.htm [Accessed January 12, 2015]. Hill, S. & Bryan, J., 1997. The Economic Impact of the Sea Empress spillage. International Oil Spill Conference. Moore, J., 2006. State of the marine environment in SW Wales, 10 years after the Sea Empress oil spill. Countryside council for Wales, pp.1–33.

Rena Spill

Ship/Installation	MV Rena	**Location**	Astrolabe Reef, Tauranga
Relevance	Largest oil spill in New Zealand waters.		
Date	5 October 2011		
Timeline			
Spilled Oil	1,772 cubic metres of heavy oil was on board when Rena grounded. Approximately 467 cubic metres is thought to have been lost to sea and 109 cubic metres of heavy fuel oil likely remains on board (Murdoch, 2013).		
Duration of Clean –up operations	Overall, 2,584 tonnes of waste was recovered between 12 October 2011 and 1 February 2012 (this includes solid and liquid waste, wildlife, sea lettuce and other waste) (Maritime New Zealand, n.d.-b). 1,053 of the 1,368 containers on board were also recovered (Office of the Attorney General, 2014). The cost to the Crown at March 2013 was approximately $47 million (Murdoch, 2013). In addition to this, more than USD $300 million had been spent on salvage operations and up to a further USD $759 million is estimated for complete removal of the wreck taking up to 7 years (Office of the Attorney General, 2014).		
Environmental Sensitivity	At the end of February 2012 4,500 tonnes of waste was processed, approximately 3,800 tonnes of this went to landfills with the remainder being recycled (Murdoch, 2013). There are no known threatened species in the Bay of Plenty at depths shallower than 300 metres (the lowest part of the wreck is at 65 metres) (The Rena Project, 2013a).		
Environmental Impacts	The grounding has had little long-term effect on the environment, likely due to the volunteers and contractors working quickly to clean up debris. Whilst some contaminants remain in the environment there has been no evidence of catastrophic die-off or physiological stress of wildlife (Rena Recovery, n.d.). In November 2012, scientists found PAH and metal contamination though this was restricted to 100m either side of the wreck (Rena Recovery, n.d.). The environmental impacts on the reef itself may vary dependent on whether the complete Rena wreck is removed.		
Impact on Birds	2,062 dead coastal and marine birds from 46 different species were collected during the Rena wildlife response. Of these 1,376 (66.7%) were oiled, though it is not known the proportion of birds which became oiled after death (Maritime New Zealand, n.d.-a). Between 7 October 2011 and 17 January 2012, an additional 420 live oiled birds were recovered, of these 45 were euthanized or died in care, with the remaining 375 (89.3%) released back to the wild (Maritime New Zealand, n.d.-a). In addition to the recovery of oiled birds, 63 threatened New Zealand Dotterels were pre-emptively captured to protect them from becoming oiled. These birds were held in captivity for approximately 3 months, during which time 6 died of fungal pneumonia. The remaining birds were released once the risk of oiling had passed (Maritime New Zealand, n.d.-a).		

Impact on Marine Mammals	At least 26 marine mammal species are known to be present in the greater Bay of Plenty Region (Cawthron Institute, 2014). During the Rena wildlife response, the bodies of 17 Fur seals, 3 of which were oiled and 4 Whales of 3 different species (none oiled) were collected (Maritime New Zealand, n.d.-a). As of October 2012, marine mammal activity surrounding the Rena and other Bay of Plenty areas has returned to normal and marine mammal populations appear unaffected by the presence of the wreck (The Rena Project, 2013b).
Commercial Fishing and Shellfish Harvesting	Ongoing testing in areas where oil has been found, identified low levels of Polycyclic Aromatic Hydrocarbons (PAH), these are used internationally as markers of the safety of seafood contaminated by oil. The levels of PAH in the worst affected sample (tuatua at Papamoa Beach) have been steadily declining since. Biological communities on Bay of Plenty open coast beaches do not appear to have been catastrophically effected by the Rena oil spill, however further monitoring will help determine whether there will be more subtle or long-term impacts (University of Waikato, 2013).
Tourism	Astrolabe Reef is popular for diving, snorkelling, scenic trips, fishing, spear fishing, cray fishing, bird watching, dolphin watching and swimming and for big game fishing in waters nearby. At least 20 charter and tour companies used the reef as part of their operations prior to the Rena grounding (The Rena Project, 2013c).
Social Impacts	As a result of the Rena grounding, and the contamination of fish stocks, iwi have been excluded from their traditional resource, affecting their customary practices (Ministry for the Environment, 2011). The main concerns of iwi relate to the protection of kaimoana, access to the reef, and the spiritual values the reef has for some iwi (Office of the Attorney General, 2014).
References	Cawthron Institute, 2014. Application for Resource Consent - Marine Mammals Report. Maritime New Zealand, Rena Wildlife Response - Summary Statistics. Maritime New Zealand, Weekly Waste Train Stats. Ministry for the Environment, 2011. Rena Long-term Environmental Recovery Plan. Murdoch, S., 2013. Independent Review of Maritime New Zealand's Response to the MV Rena Incident. Office of the Attorney General, 2014. Crown Position on the Resource Consent Application for the Rena Wreck. Rena Recovery, Rena Monitoring Results 2 Years on Info Sheet. The Rena Project, 2013a. Ecology and Fisheries Assessment Poster. The Rena Project, 2013b. Marine Mammals Poster. The Rena Project, 2013c. Recreation, Tourism, Dive Safety Assessment Poster. University of Waikato, 2013. Report of the Rena Environmental Recovery Monitoring Programme Executive Summary



Case History Cost Summary

Case Study Cost and Spill Relationships

Details	Sea Empress	Rena
Oil Spilt (barrels)	540,000	2,940
Shoreline Oiled (km)	200	30
Substantial Clean-up Duration (months)	1.4	5.3
Total Clean-up duration (months)	18.3	5.3
Clean-up Cost	23m	40m
Currency	GBP	NZD
Date of Reference	Feb-96	Jan-13
CPI on Date of Reference	87.5	1,174.0
CPI on March 2015	128.0	1,193.0
Inflated to March 2015	34m	41 m
Exchange Rate to NZD (18/3/2015)	1.99	1.00
Total Costs (NZD) as at 18/3/2015	67m	41m

Clean-up Cost References

Details	Source
Sea Empress	http://www.georesources.co.uk/seclean.htm
Prestige	http://ecoagrasoc.org/arquivos/2006-ESTIMATED-COSTS-AND-ADMISSIBLE.pdf
Rena	Navigatus 2015 Oil Spill Clean-up Cost Model
CPI Int.	http://www.tradingeconomics.com/australia/consumer-price-index-cpi
CPI NZ	http://www.rbnz.govt.nz/monetary_policy/inflation_calculator/
Exchange Rate	http://www.xe.com/currencyconverter/

**Excludes other forms of damages.*

Annexure Two: Technical Reports

h) **Whangarei Harbour Entrance and Marsden Point Channel Realignment and Deepening: Assessment of Environmental (Airborne) Noise Effects. Styles Group. Jon Styles. Dated 31 July 2017**

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Prepared for: **Chancery Green on behalf of Refining NZ**

Date: **31 July 2017**

Title: **Whangarei Harbour Entrance and Marsden Point Channel Realignment and Deepening: Assessment of Environmental (Airborne) Noise Effects**

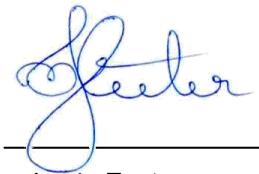
Revision Number: Final for Lodgement

Prepared by:



Jon Styles

Reviewed by:



Jamie Exeter

Executive Summary

Styles Group has been engaged by The New Zealand Refining Company (RNZ) to undertake an acoustic assessment for the proposed crude shipping project (CSP), comprising a proposal to realign and deepen the entrance to the Whangarei Harbour and the Marsden Point berthing area to allow more fully-laden tankers to berth and manoeuvre in front of the jetty. The project involves capital dredging and disposal, maintenance dredging and disposal and the construction of new and relocation of existing navigation aids.

This assessment comprises an investigation into the airborne noise levels and effects arising from the CSP for the project extent identified in Channel Option 4-2 of the proposal. Potential receivers have been limited to the Northport industrial site and residential properties along the coastline of the Whangarei Heads (from Reotahi Bay to Urquharts Bay).

Potentially affected sites have been identified as the residential areas along the coast of the Whangarei Heads, specifically, those at Reotahi Bay, Little Munroe Bay, McGregors Bay, Taurikura Bay, McKenzie Bay and Urquharts Bay. Residential properties at Marsden Bay have not been included as potentially affected sites as the nearest dwelling is approximately 1700m from the proposed dredging area and is outside the area that is predicted to be affected by dredging noise. Dredging activities taking place at the eastern limit of the Dredging Extent (shown in purple in Appendices A - G) are most likely to generate adverse noise effects for coastal dwellings on Whangarei Heads.

The project area covers several zones as set out in the NRCP maps, including dredging and installation of navigational aids in the Marine 2 (Conservation) Management Area and the Marine 5, (Port Facilities) Management Area. Rules 31.4.13 and 31.7.12 set out the noise controls for permitted activities for those zones, and cite the same content for both zones. Subsection (a)(iii) of both rules clearly devolves the determination of the permitted activity criteria to the Whangarei District Plan. Rule *NAV.6.2 Construction Noise* of the District Plan therefore sets the noise limits for permitted activities for the project. This rule requires compliance with the provisions of NZS6803:1999 *Acoustics – Construction Noise.*

To characterise the ambient noise environment on the north side of the harbour, noise measurements have been undertaken (MDA 2016) over two week-long periods in October 2015 utilising noise loggers. The noise measurements show that during the day time, ambient L_{Aeq} noise levels vary but are typically between 45dB to 50dB L_{Aeq} when the wind direction is from the west or south, and between 40dB and 45dB when the wind is offshore, or from the north or east. In our opinion, the measured ambient noise levels describe an area subject to a reasonably high level of acoustic amenity.

The CSP could utilise three common types of dredgers: a trailing suction hopper dredger (TSHD), a cutter-suction dredger (CSD) and a mechanical backhoe dredger (BHD). TSHDs are

self-propelled vessels coupled with hoppers and articulated dredging pipes that extend onto the sea-floor, while CSDs and BHDs are stationary systems that use either hydraulic pumps or mounted excavators, respectively (RHDHV 2016).

The final selection and procurement of the dredging plant and equipment has not been undertaken and will not be until closer to the commencement of the project. The selection of any particular vessel will be dependent many factors, including its availability. We have therefore based our assessment on published data for the types of dredging methods and vessels that are likely to be used.

Styles Group has used the globally recognised Bruel & Kjaer Predictor^{tm} acoustic modelling software to prepare predictions of the noise levels likely to be generated based on compliance with ISO9613-1/2 *Attenuation of sound during propagation outdoors*. Dredging and disposal activities outside of the harbour have not been modelled due to the noise emissions being so low at receivers that it will likely be inaudible and not measureable for all or most of the time. Only dredging inside the harbour (generally north of Busby Head) is included in this assessment.

A number of possible wind conditions have been utilised in the predictions based on the wind rose from the Marsden Point area (MetOceanSolutions, 2015) to demonstrate how wind from different directions will influence the propagation of noise from the dredging equipment. For the purpose of assessing the noise effects, and having regard to the uncertainty of the time of year that dredging may be undertaken, we recommend that the neutral to slightly positive meteorological conditions represented by the C0=0 modelling outputs are relied on.

The noise modelling shows that comfortable compliance with the relevant noise limits in Rules 31.4.13 and 31.7.12 of the NRCP for permitted activities is achieved for dredging inside the harbour, except when dredging is undertaken generally north of the No. 18 navigation buoy when the 45dB L_{Aeq} noise limit applies (at night and on Sundays and Public Holidays) and when the wind is blowing from any direction other than the northern quarter. We have therefore recommended that dredging work in these conditions is not undertaken in order to ensure that compliance is achieved, unless noise measurements of the dredging vessels commissioned show that compliance can be achieved. The predicted noise levels for all other dredging positions under various meteorological conditions show that compliance with all of the relevant noise limits at all times of the day can be achieved, in most cases by a large margin.

The noise effects of the dredging project will be unnoticeable for a large proportion of the project for the receivers on the northern side of the harbour. Dredging and disposal activities will be inaudible and not measureable when the vessels are outside of the harbour or generally east of Busby Head. For all other locations within the harbour, the dredging activity will be audible to some receivers but generally at noise levels less than 45dB L_{Aeq}. The ambient noise level during the day is generally considerably higher than this level and in such cases the dredging

will likely be inaudible over other sources in the environment such as traffic, birds, insects, wind in the trees or waves on the shore.

We recommend that the dredging operations are subject to a noise management plan (NMP). The NMP should include provisions for noise monitoring at the commencement of dredging for each dredge to determine actual noise emissions, and based on these noise measurements, a recalibration of the computer noise models for each dredging vessel to determine whether any change or refinement of the restrictions on dredging being required. Ongoing noise monitoring should be undertaken to ensure compliance and in response to reasonable complaints. A draft NMP is attached to this report at Appendix H. In our opinion, and if the recommendations in this report are adhered to, we consider that the noise effects arising from the CSP will be reasonable in terms of s16 of the Act and less than minor.

Table of Contents

Executive Summary ii

1. Introduction 1
   - 1.1 The Proposal 1
   - 1.2 The Existing Acoustic Environment and Potential Receivers 2
   - 1.3 Scope of Assessment 2
2. Potentially Affected Sites 2
3. Noise Performance Criteria 2
   - 3.1 District Plan / Regional Coastal Plan 3
   - 3.2 New Zealand Standard NZS6803:1999 4
   - 3.3 Resource Management Act 1991 6
   - 3.4 New Zealand Standards 7
4. Ambient Noise Environment 7
5. Noise Level Predictions 9
   - 5.1 Dredging Methods and Equipment 9
   - 5.2 Noise Modelling 10
   - 5.3 Meteorological Effects 12
   - 5.4 Modelling Results 13
   - 5.5 Assessment of Noise Effects – Capital and Maintenance Dredging 14
   - 5.6 Assessment of Noise Effects – Piling Associated with Navigation Aids 14
   - 5.7 Assessment of Noise Effects – Overall 15
6. Recommended Mitigation Measures 16
7. Recommended Monitoring 16
8. Summary and Conclusions 17
9. Literature Cited 19

Appendices:

Appendix A: Noise Level Predictions - BHD Jetty Area

Appendix B: Noise Level Predictions - BHD No. 17 Navigational Buoy

Appendix C: Noise Level Predictions - BHD No. 15 Navigational Buoy

Appendix D: Noise Level Predictions - TSHD No. 18 Navigational Buoy

Appendix E: Noise Level Predictions - TSHD No. 13 Navigational Buoy

Appendix F: Noise Level Predictions - TSHD No. 11 Navigational Buoy

Appendix G: Noise Level Predictions - TSHD No. 07 Navigational Buoy

Appendix H: Draft Noise Management Plan

1. Introduction

Styles Group has been engaged by The New Zealand Refining Company (RNZ) to undertake an acoustic assessment of the proposed crude shipping project (CSP), comprising a proposal to realign and deepen the entrance to the Whangarei Harbour and the Marsden Point berthing area to allow more fully-laden tankers to berth and manoeuvre in front of the jetty.

1.1 The Proposal

RNZ has identified the need to expand the berthing and channel capacity up to the Marsden Point oil refinery to allow more fully-laden ships to dock and manoeuvre at the refinery. It is proposed to deepen an 8.5km section of the existing channel from the 20m depth contour up to and including the berthing pocket at the RNZ refinery site on Marsden Point. RNZ has investigated multiple options for the dredging project and Channel Option 4-2 has been selected as the preferred option. The proposal estimates that the removal of 3,700,000m^3 of material is required to achieve a channel depth of 19 - 16.5m below the chart datum. Two marine disposal areas are proposed to accommodate the displaced material. Maintenance dredging may also need to be carried out every 2 - 5 years to maintain a sufficient clearance in the channel and berth pocket area. Similar dredging equipment is likely to be utilised for the maintenance dredging although a shorter works duration is expected.

It is anticipated that a Trailing Suction Hopper Dredger (TSHD) will be used for the majority of the CSP in conjunction with a Backhoe Dredger (BHD) for dredging works in close proximity to the berthing jetty and sections of the inner and mid channel areas. A Cutter Suction Dredger (CSD) may also be used for some sections of the alignment. For the majority of the dredging operation (using a TSHD), the estimated cycle time is 110 - 180 minutes and involves loading of the vessel, sailing to a marine disposal site, unloading and returning to the dredge site to recommence work. A TSHD is capable of operating 24/7 and the expected duration of the main dredging activity is around 6 months, with allowance for inoperable weather conditions. Several new navigation aids will also be installed and several of the existing aids will be relocated. These activities will be completed generally over six days per navigational aid by relatively low noise barge and lifting equipment, except that some piling work will be required for the installation of Taurikura Leads.

The use of a BHD for dredging in the berthing pocket is estimated to enable two barge sailings per day with works taking place during daylight hours only, seven days a week. In this case, a BHD would be used to load a barge to transfer the dredged material from the dredging site to a disposal area. Works in the berthing pocket area are projected to take up to 2 to 3 months to complete using this method. A CSD may also be used for dredging in the berthing pocket, inner / mid-channel areas and for maintenance dredging. A CSD may utilise a barge or a discharge pipeline for transport of dredged material. Production rates for a CSD are higher than a BHD but

lower than a TSHD. An assortment of smaller support vessels will also be required for surveying, crew transfer and for towing the barge to and from the disposal locations.

1.2 The Existing Acoustic Environment and Potential Receivers

Noise measurements carried out by Marshall Day Acoustics for other RNZ projects (MDA 2016) have been used to characterise the ambient noise environment for receivers on the northern side of the harbour. The receivers of noise are limited to occupied buildings on the Northport site and all occupied buildings on the northern side of the harbour.

1.3 Scope of Assessment

This assessment comprises an investigation into the airborne noise levels and effects arising from the CSP for the dredging extent identified in Channel Option 4-2 of the proposal. Potential receivers have been limited to the Northport industrial site and residential properties along the coastline of the Whangarei Heads (from Reotahi Bay to Urquharts Bay).

A detailed computer noise model has been prepared and analysed for a number of likely and worst case dredging positions. Multiple weather conditions have been included for each dredging location to predict the effect of different wind directions on noise propagation. A number of assumptions were necessary to construct the noise model.

2. Potentially Affected Sites

Potentially affected sites have been identified as the residential areas along the coast of the Whangarei Heads, specifically, those at Reotahi Bay, Little Munroe Bay, McGregors Bay, Taurikura Bay, McKenzie Bay and Urquharts Bay. Residential properties at Marsden Bay have not been included as potentially affected sites as the nearest dwelling is approximately 1700m from the proposed dredging area and is outside the area that is predicted to be affected by dredging noise. Dredging activities taking place at the eastern limit of the Dredging Extent (shown in purple) are most likely to generate adverse noise effects for coastal dwellings on Whangarei Heads.

The industrial site at Northport has been assessed as a potentially affected site. Dredging activities in the proximity of the Marsden Point berthing jetty are most likely to affect this site.

3. Noise Performance Criteria

The noise levels that are anticipated to be generated by the CSP have been assessed in accordance with New Zealand standards against the requirements of the Northland Regional Coastal Plan, (NRCP), the Whangarei District Plan (the District Plan), the Resource Management Act (the Act) and NZS 6803:1999 - *Acoustics: Construction Noise* (NZS6803).

We consider that the capital dredging works are deemed to be within the definition of construction as defined by NZS6803. Construction work is defined in section 3.1 of NZS6803 as (emphasis added):

> *CONSTRUCTION WORK means any work in connection with the construction, erection, installation, carrying out, repair, maintenance, cleaning, painting, renewal, removal, alteration, dismantling, or demolition of:*
>
> *a) Any building, erection, edifice, structure, wall, fence or chimney, whether constructed wholly or in part above or below ground level;*
>
> *b) Any road, motorway, harbour or foreshore works, railway, cableway, tramway, canal or aerodrome;*
>
> *c) Any drainage, irrigation or river control work;*
>
> *d) Any electricity, water, gas or telecommunications reticulation;*
>
> *e) Any bridge, viaduct, dam, reservoir, earthworks, pipeline, aqueduct, culvert, drive, shaft, tunnel or reclamation; or*
>
> *f) Any scaffolding.*
>
> *Construction work includes:*
>
> *g) Any work in connection with any excavation, site preparation, or preparatory work, carried out for the purpose of construction work;*
>
> *h) The use of any plant, tools, gear, or materials for the purpose of any construction work;*
>
> *i) Any construction work carried out underwater, including work on ships, wrecks, buoys, rafts, and obstructions to navigation; and*
>
> j) *Any inspection or other work carried out for the purpose of determining whether construction work should be carried out.*

Accordingly, we have referred to the relevant sections of the NRCP and District Plan to determine the criteria for permitted activities.

3.1 District Plan / Regional Coastal Plan

The area to be dredged covers several zones as set out in the NRCP maps, including Marine 2 (Conservation) Management Area and Marine 5, (Port Facilities) Management Area.

Rules 31.4.13 and 31.7.12 set out the noise controls for permitted activities for those zones, and cite the same content for both zones. Rules 31.4.13 and 31.7.12 state:

The following standards shall apply to all specified permitted, controlled, restricted discretionary and discretionary activities, and to all non-complying activities, listed in the (Marine 2 (Conservation) Management Area and Marine 5 (Port Facilities) Management Area)*:*

(a) Noise generated as a result of activity within the coastal marine area shall comply with the following standards:

(i) the activity shall not cause excessive noise as defined in section 326 of the Resource Management Act; and

(ii) any construction or maintenance activity near coastal subdivisions or other urban areas shall comply with the noise standards of the district council which is responsible for the use of the adjoining land.

Subsection (a)(iii) clearly devolves the determination of the permitted activity criteria to the Whangarei District Plan. Rule *NAV.6.2 Construction Noise* of the District Plan therefore sets the noise limits for permitted activities for the project.

NAV.6.2 Construction Noise

Noise from demolition and construction, including that undertaken as part of temporary military training activities, shall comply with the guidelines and recommendations of NZS 6803: 1999 "Acoustics - Construction Noise". Noise levels shall be measured and assessed in accordance with New Zealand Standard NZS 6803: 1999 "Acoustics - Construction Noise". NAV.6.2 shall not apply to permitted maintenance or utility works undertaken within the road carriageway of a road where:

a) It has been demonstrated to Council that these works cannot reasonably comply with the referenced noise guidelines at the time when they must be carried out; and

b) A construction noise and vibration management plan, as prepared by a Recognised Acoustician, has been provided to Council.

3.2 New Zealand Standard NZS6803:1999

Rule NAV6.2 of the District Plan prescribes compliance with the provisions of NZS6803 for permitted activities. We understand that the proposed dredging activity is expected to take slightly longer than 20 weeks to complete. Therefore, construction noise arising from dredging activities is assessed under the long-term duration criteria set out in Tables 2 and 3 of Table NZS6803:1999 (Tables 1 and 2 of this document). These noise limits apply at 1m from the most exposed facade of any occupied building used for activities which may be affected by construction noise.

Table 1 - Recommended upper limits for construction noise received in residential zones and dwellings in rural areas

Time of Week	Time Period	Long-term duration (dBA)	
		L_{eq}	L_{max}
Weekdays	0630-0730	55	75
	0730-1800	70	85
	1800-2000	65	80
	2000-0630	45	75
Saturdays	0630-0730	45	75
	0730-1800	70	85
	1800-2000	45	75
	2000-0630	45	75
Sundays and public holidays	0630-0730	45	75
	0730-1800	55	85
	1800-2000	45	75
	2000-0630	45	75

Table 2 - Recommended upper limits for construction noise received in industrial or commercial areas for all days of the year

Time Period	Long-term duration
	L_{eq} (dBA)
0730-1800	70
1800-0730	75

As set out later in this report, the noise emissions affecting the majority of the receivers of noise on the northern and eastern sides of the harbour will be subject to compliance with the criteria in Table 1 above, whereas noise affecting the commercial receivers on the western side of the harbour is subject to the limits in Table 2.

The noise levels at any occupied building are assessed typically over a 15 minute period. There is no averaging or other adjustment over the day, night or any other period. The noise

limits set out in NZS6803 must be complied with for every 15 minute period during which works are undertaken.

Clause 7.2.6 of NZS6803 states that when setting noise limits for construction activities, a major factor which should be considered is:

> *"...whether there is a relatively high background sound level (L_{90}) due to noise from sources other than construction work at the location under investigation. In such cases, limits should be based on a determination of the existing level of noise in the area (a "background plus" approach)*.

Based on the noise measurements undertaken by MDA (MDA 2016) the background sound level at the noise measurement locations is relatively high depending on the meteorological conditions. However, we do not consider that it would be appropriate to seek resource consent for higher noise limits at night, Sundays or Public Holidays or any other period for this project.

In our opinion, the adoption of the provisions of NZS6803 is appropriate and accords with the approach taken for numerous other projects around the country, including large scale infrastructure and roading and private projects. We consider that compliance with the noise limits in NZS6803 will provide a good balance of allowing higher noise limits to enable works to progress without undue delay whilst providing a good degree of protection of amenity at critical times such as night and on Sundays and Public Holidays.

3.3 Resource Management Act 1991

The dredging works are also subject to comply with the duties of s16 of the Act. Subsection (1) states:

> *Every occupier of land (including any premises and any coastal marine area), and every person carrying out an activity in, on, or under a water body or the coastal marine area, shall adopt the best practicable option to ensure that the emission of noise from that land or water does not exceed a reasonable level.*

This section introduces the duty that requires the occupier of land (and any coastal marine area) to ensure that the Best Practicable Option (BPO) is adopted such that the levels of noise and vibration generated by the construction activities are no greater than reasonable.

Importantly, the BPO is defined in the interpretations section of the Act (s2), which states:

> *Best practicable option, in relation to a discharge of a contaminant or an emission of noise, means the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to -*

(a) the nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and

(b) the financial implications, and the effects on the environment, of that option when compared with other options; and

(c) the current state of technical knowledge and the likelihood that the option can be successfully applied.

3.4 New Zealand Standards

NZS6803 requires that noise level measurements are undertaken in accordance with the requirements of NZS6801:2008 *Acoustics – Measurement of Environmental Sound*. The pertinent provisions relate to accuracy and calibration requirements for instrumentation used for measurement, measurement positions and duration, meteorological effects, noise level descriptors and uncertainty. The provisions of this standard need not be referenced in this report as they are generally only relevant for the measurement of noise from the project once works commence. Notwithstanding, our assessment has been prepared on the basis that the relevant provisions of this standard are complied with at all times.

4. Ambient Noise Environment

To characterise the ambient noise environment on the north side of the harbour, noise measurements have been undertaken by MDA (MDA 2016). Unattended noise measurements were carried out at two properties over two week-long periods in October 2015 utilising noise loggers. One noise logger was placed at 14 The Heights (Reotahi Bay), which had a direct view of the refinery and port areas, and the other at 73 Bay View Road (Little Munroe Bay), which had a direct view of the refinery but the port was obscured from view by Lort Point. Attended noise measurements were also taken at Taurikura and Urquharts Bay. The noise measurements show that during the day time, ambient L_{Aeq} noise levels vary but are typically between 45dB to 50dB L_{Aeq} when the wind direction is from the west or south, and between 40dB and 45dB when the wind is offshore, or from the north or east. The variation in noise level is to be expected for an environment such as this, with noise sources such as the Refining New Zealand and NorthPort sites and waves on the shore and in the harbour being more noticeable when the receivers are downwind. Conversely, when the wind is blowing offshore and towards the RNZ and Northport sites, the noise levels at the receivers are correspondingly lower.

By observation of the data obtained by MDA, noise levels at the measurement locations are up to 10dB higher when the measurement locations are downwind of the Refining New Zealand and NorthPort sites when compared to upwind conditions. This suggests a variation of +/- 5dB between upwind or downwind and neutral meteorological conditions over a distance of approximately 1.2km to 1.4km depending on the exact location of the noise source.

The noise levels on some days were considerably higher at up to approximately 60dB L_{Aeq}. Localised contamination is expected to be the cause of such high levels, including traffic, birds and insects, construction or other anthropogenic sources.

In our opinion, the measured ambient noise levels describe an area subject to a reasonably high level of acoustic amenity.

5. Noise Level Predictions

5.1 Dredging Methods and Equipment

The CSP could utilise three common types of dredgers: a trailing suction hopper dredger (TSHD), a cutter-suction dredger (CSD) and a mechanical backhoe dredger (BHD). TSHDs are self-propelled vessels coupled with hoppers and articulated dredging pipes that extend onto the sea-floor, while CSDs and BHDs are stationary systems that use either hydraulic pumps or mounted excavators, respectively (RHDHV 2016). Full descriptions and explanations of the operating mechanisms for each dredger-type are provided in RHDHV (2016).

The methods and dredging equipment that are proposed are based on the project team's evaluation of the best practicable methods and equipment available. The evaluation has taken into account a large number of advantages and disadvantages of each option and from an acoustical perspective the evaluation forms the majority of the determination of the BPO.

The final selection and procurement of the dredging plant and equipment has not been undertaken and will not be until closer to the commencement of the project. The selection of any particular vessel will be dependent many factors, including its availability. We have therefore based our assessment on published data for the types of dredging methods and vessels that are likely to be used. There may therefore be some variation between the noise levels predicted and those measured once the project commences, although we do not expect any difference to be appreciable.

Dredging of Channel Option 4-2 comprises the following general methods and equipment:

(i) A BHD may be utilised to dredge the Marsden Point berthing area. A BHD consists of an excavator mounted on a dredging pontoon and is usually anchored using spud poles to maintain a constant position while dredging. For the purpose of assessing noise levels a BHD generally remains stationary while an area is dredged.

(ii) A TSHD is likely to be used for the majority of the project, especially the outer channel section. A TSHD is a vessel that uses trailing arms to vacuum material from the seafloor while following a predetermined dredge route. Material is deposited onto the TSHD as it moves forward until the fill capacity is reached at which point the arms are lifted and the TSHD travels to the designated disposal area where the dredged material is deposited.

(iii) A CSD is a more efficient alternative to a BHD but is less precise for dredging around marine obstacles. A CSD is anchored using spud poles while a cutting head, fixed to the end of a suction arm, draws material onto a barge. For the purpose of assessing noise levels the CSD remains generally stationary while an area is dredged and once the barge reaches capacity it is towed to a disposal site.

No specific noise measurements were able to be undertaken for this project as the dredge type, size and specific vessel details are yet to be confirmed at this time. However, noise emission data from measurements undertaken by Delta, of BHD vessel MJØLNER R, has been used as a noise source input for the dredger within the computer noise model. Delta has published noise emission data, from two instances of measurements, of the same BHD vessel MJØLNER R made in 2006 (Delta 2006) and in 2011 (Delta 2011) which show good agreement (within 1dB) in the measured sound power levels. We understand that MJØLNER R, which is capable of excavating to depths of up to 22m below ocean surface level, is adequately sized and a realistic choice for the proposed works. Noise data for the TSHD vessel BRAGE R was also available (Delta 2005) and in this case the measurements show that the BHD vessel MJØLNER R is the louder of the two dredgers. As there is uncertainty over the exact equipment to be used for the dredging operations at this stage in the project, the louder BHD emission data has been used for the noise modelling of all dredging operations.

The noise data for MJØLNER R shows measured sound pressure levels of 66dBA at 100m from the vessel and 46dBA at 1km from the BHD, which equate to a sound power level (SWL) of 114dBA. The emission spectrum used in the computer noise model has been reproduced in Table 3 - Emission spectrum reproduced from the Delta Report for use in the noise model.

Table 3 - Emission spectrum reproduced from the Delta Report for use in the noise model

A-weighted sound power levels [dB re 1pW]									
	63Hz	**125Hz**	**250Hz**	**500Hz**	**1kHz**	**2kHz**	**4kHz**	**8kHz**	**Total**
MJØLNER R	91.3	104.3	106.4	106.6	108.6	108.2	102.4	95.7	114.4

The BHD emission spectrum comprises a relatively strong low frequency component which will be a fundamental component of the noise received onshore. The noise model has been calibrated using the supplied noise emission values for a BHD to a level of 66dB L_{Aeq} at 100m from the source.

To model the path of the faster moving TSHD dredge, a track has been used in the noise modelling predictions which assumes a dredging speed of approximately 2-3 knots. At this speed the dredge will cover a distance of up to approximately 1400m in any 15 minute period. The BHD advances at a much slower rate and for the purpose of this assessment has been assumed to remain stationary over a given 15 minute period.

5.2 Noise Modelling

Styles Group has used the globally recognised Bruel & Kjaer Predictor^{tm} acoustic modelling software to prepare predictions of the noise levels likely to be generated based on compliance with ISO9613-1/2 *Attenuation of sound during propagation outdoors*. The noise level predictions

are based on meteorological conditions that slightly enhance propagation in all directions in accordance with NZS6802:2008 *Acoustics – Environmental Noise*, and further noise level predictions have been prepared to show the effects of specific meteorological conditions which enhance or impede the propagation of noise towards receivers. The B&K Predictor^{tm} software has been successfully implemented on a large number of projects in New Zealand. Table 4 displays the input parameters used in our model.

Digital terrain data for use in the noise model has been provided to us by the Northern Regional Council in the form of 1m height contours around residential areas on Whangarei Heads and the Marsden Point area. Height data for the remaining area has been sourced from LINZ as 20m contours.

Dredging and disposal activities outside of the harbour have not been modelled due to the noise emissions being so low at receivers that it will likely be inaudible and not measureable for all or most of the time. Only dredging inside the harbour (generally north of Busby Head) is included in this assessment. We understand that including the work around the jetty, the works and movement of construction-related vessels inside the harbour will likely be less than half of the six months to complete the entire capital dredging phase of the project.

Dredging locations used in the noise model have been selected to represent the typical and worst case dredging locations within the proposed dredging extents, the latter being closest to receivers on the north and eastern sides of the harbour. See Appendices A to G for the dredging positions used for the prediction of noise levels. The noise levels arising from dredging in all other positions will be lower.

The noise level predictions for the piling associated with the installation of navigational aids has been undertaken using empirical data from a large number of noise measurements undertaken by Styles Group of piling operations around New Zealand. For the drop hammer or vibro-piling methods, a reference sound power level (SWL) of 118dBA has been used (equivalent to 90dB L_{Aeq} at 10m). This equates to a minimum separation distance of 100m to achieve compliance with the day time (Monday to Friday) noise limit of 70dB L_{Aeq}.

All noise modelling work has been undertaken in accordance with the requirements of NZS 6802:2008 - Environmental Noise.

Table 4 - Predictor noise model input parameters

Parameters/calculation settings	Details
Software	Brüel & Kjær Predictor
Calculation method	ISO 9613.1/2
Meteorological parameters (CONCAWE)	Single value, C0 = 0 or as otherwise described
Ground attenuation over land	General method, ground factor 0.9
Ground attenuation over water	Ground factor 0
Air temperature	293.15K
Atmospheric pressure	101.33kPa
Air humidity	60%
Source height (relative)	10-16m above sea level
Receiver heights (relative)	1.5m above ground

5.3 Meteorological Effects

A number of possible wind conditions have been utilised in the predictions based on the wind rose from the Marsden Point area (MetOceanSolutions, 2015) to demonstrate how wind from different directions will influence the propagation of noise from the dredging equipment.

For each dredging position or track that has been modelled, four probable wind directions (from the north, east, south and west) have been input into the model using a typical wind speed of 3-6ms^{-1} (6-12 knots). Other wind speeds have been tested but showed no appreciable variation in the model outputs. At higher wind speeds, a greater degree of masking of any dredging noise as a result of tree leaves rustling and wavelets crashing on the shore can be expected. The Pasquill Stability Category used in these prediction models is D based on the likely weather conditions although other stability criteria were tested in the model with no noticeable difference in the model outputs.

Although we have implemented four different wind conditions in our noise predictions, we note that the wind conditions are likely to be extremely variable. It is common practice to give weight to the effects of local weather conditions where any particular condition prevails for at least 30% of the assessment period. In this case, the most common wind direction prevails for only 15% of the time, based on annual wind observations. It is therefore our opinion that the most appropriate meteorological conditions for the prediction of noise levels are those that (theoretically) enhance propagation in all directions.

For this reason, we have included noise modelling results based on meteorological conditions that enhance the propagation of sound in all directions as an additional (and conservative) model for each dredging position or track. The meteorological correction term (C0) for this model is 0. The CONCAWE method has been utilised in all noise modelling. This method has been integrated into the noise modelling software.

5.4 Modelling Results

The noise modelling shows that comfortable compliance with the relevant noise limits is achieved for dredging inside the harbour, except when dredging is undertaken generally north of the existing No. 18 navigation buoy and including works in the jetty area when the 45dB L_{Aeq} noise limit applies (at night and on Sundays and Public Holidays) and when the wind is blowing from any direction other than the northern quarter (>315º and <45º). Appendices B, C and D show the noise level contours for this scenario.

The predicted noise levels for all other positions under various meteorological conditions show that compliance with all of the relevant noise limits at all times of the day can be achieved, in most cases by a large margin.

In general terms, and using a distance of 800m between the dredge and the receiver, the assessment of noise levels when the wind is blowing towards the dredge shows that the noise level will reduce by approximately 3.5dB compared to neutral or slightly positive meteorological conditions (C0=0). Conversely, the noise levels will increase by approximately the same amount when the wind is blowing generally from the dredge to the receiver.

Because the ambient noise levels rise and fall under the same meteorological conditions (where noise levels are generally higher during onshore winds) the slightly higher noise levels from dredging arising during downwind conditions will be somewhat masked. Conversely, when the wind is offshore for the receivers on the northern side of the harbour (generally) and the ambient noise levels lower, the noise from dredging will also be lower.

For the purpose of assessing the noise effects, and having regard to the uncertainty of the time of year that dredging may be undertaken, we have relied on the neutral to slightly positive meteorological conditions represented by the C0=0 modelling outputs. These modelling outputs represent the noise levels that could be expected during conditions that slightly enhance propagation in a hypothetical case where every receiver is downwind of the noise source. This represents a conservative assessment approach in that noise levels will be much less than those predicted when the receivers are not downwind of the source.

The prediction of noise from piling operations is comparatively simple, where the point source is stationary and known with a high degree of certainty. The noise level from piling activities will be compliant with the day time noise limit of 70dB L_{Aeq} at a distance of 100m. Given that the

piling will be no closer than approximately 400m from land, the noise levels will be compliant by a considerable margin and generally less than 55-60dB L_{Aeq}.

5.5 Assessment of Noise Effects – Capital and Maintenance Dredging

The noise effects of the dredging project will be unnoticeable for a large proportion of the project for the receivers on the northern side of the harbour. Dredging will be inaudible and not measureable when the vessels are outside of the harbour or generally east of Busby Head.

When dredging is undertaken inside the harbour, noise from the vessels will comply with the relevant noise limits by a significant margin except when dredging is undertaken generally north of the No. 18 navigation buoy at when the 45dB L_{Aeq} noise limit applies (at night and on Sundays and Public Holidays) and when the wind is blowing from any direction other than the northern quarter. Appendices B, C and D show the noise level contours for this scenario.

For all other locations within the harbour, the dredging activity will be audible to some receivers but generally at noise levels less than 45dB L_{Aeq}. The ambient noise level during the day is generally considerably higher than this level and in such cases the dredging will likely be inaudible over other sources in the environment such as traffic, birds, insects, wind in the trees or waves on the shore.

The noise effects for maintenance dredging will be generally less than that associated with the capital dredging phase as the volumes (and therefore timeframes) are less. Provided the maintenance dredging is undertaken in accordance with the conditions applied to the capital dredging, we consider that the effects will be less than minor and reasonable in terms of s16 of the Act also.

5.6 Assessment of Noise Effects – Piling Associated with Navigation Aids

The noise effects associated with the placement of navigation aids will be of short duration and relatively low noise level. The noise levels from piling activities will be the loudest of all activities associated with constructing or relocating navigational aids, and will generally be low 55-60dB L_{Aeq} at any receiver. The noise from other (non-piling) activities associated with the construction or relocation of navigational aids is expected to be very low, and likely inaudible and not measureable (with any reasonable degree of certainty) from shore. Provided the works are undertaken only when the noise limit of 70dB L_{Aeq} applies (Monday to Saturday 0730 to 1800) the noise levels will be readily compliant and reasonable in terms of s16 of the Act.

5.7 Assessment of Cumulative Noise Effects

Because the noise effects will only be temporary in nature, and generally over a very short term compared to the overall duration of the project, the utility of an assessment of cumulative noise effects is limited. It is our view that the cumulative effects are only a potential issue at night when the noise emissions from the CSP are permitted to be similar to that generated by the operation of the refinery generally.

The operational noise levels generated by the refinery are limited to a level of 45dB L_{Aeq} between the hours of 10pm to 7am at any receiver by NAV Rule 6.1 of the District Plan. This is the same noise limit that applies during the night[1] to the CSP as set out in Section 3.2 above. These noise limits are the same numerically, and theoretically this could allow for a combined noise level of 48dB L_{Aeq} to be received by the most exposed receivers. However, this would require the noise emissions of the refinery and the CSP to generating noise levels precisely at the maximum permitted which is very unlikely. Even if both activities were generating noise levels at their maximum respective limits at the same receiver, the combined noise level would be 48dB L_{Aeq}, being 3dB more than the respective noise limits. A difference of 3dB in this context would be just perceptible to the receiver.

When considering the very temporary nature of CSP activities which may approach the night time noise limit, the low probability that both the refinery and the CSP will be generating noise levels very close to their respective noise limits at the same time, and the very small potential increase in noise level, it is our opinion that the potential cumulative effects are negligible and no mitigation is required to address this issue.

5.8 Assessment of Noise Effects – Overall

The nature and scale of the CSP is similar to many large roading projects that have been or are being undertaken around the country in terms of earthworks volumes and timeframes. It is our opinion that the CSP will generate a significantly lesser degree of noise effects for the receivers than almost any other construction project of its size and nature undertaken on land. Compliance with the relevant noise limits for permitted activities will be achieved generally by a large margin.

In our opinion and based on our assessment, if the recommendations in this report are implemented, we consider that the noise effects arising from the CSP will be less than minor and reasonable in terms of s16 of the Act.

[1] Between the hours of 8pm and 6.30am Monday to Friday and 6pm to 6am on Saturdays, Sundays and Public Holidays.

6. Recommended Mitigation Measures

Our assessment has shown that during the day time, all potential methods of dredging will comply with the relevant noise limits by a considerable margin. During the night time and when the 45dB L_{Aeq} noise limit applies, dredging should not be undertaken inside the harbour north of the No. 18 navigation buoy when the wind direction is outside the northern quarter (>315º and <45º) i.e. from the east, west or south. Outside the harbour dredging can be undertaken at any time and without restriction for the purpose of managing noise effects.

Notwithstanding the above, we recommend that the noise emissions from dredging operations be monitored and managed throughout the project to ensure that the actual noise levels are no greater than what the relevant permitted activity noise limits allow.

We also recommend that the dredging operations are subject to a noise management plan (NMP) which should as a minimum address the following matters:

i) Noise monitoring at the commencement of dredging for each dredge to determine actual noise emissions;

ii) Based on these noise measurements, recalibration of the computer noise models for each dredge to determine whether any change to the restrictions on dredging are required;

iii) Ongoing noise monitoring to ensure compliance and in response to complaints (with a trigger to be defined);

iv) Promotion of awareness of the management of noise for the crew of the dredging vessels, including the maintenance of any unusually or unnecessarily noisy plant or equipment on the vessels that may be giving rise to unreasonable noise effects onshore;

v) A procedure for the receipt, response and management of any noise-related complaints that RNZ may receive during the project.

A draft NMP is attached at Appendix H of this report. It is our opinion that if the NMP is adopted and adhered to the noise levels and effects of the project will be no greater than what we have predicted.

7. Recommended Monitoring

We recommend that monitoring of noise emissions is undertaken during the project to confirm whether compliance with the relevant noise limits is being achieved and to ensure that the restrictions and allowances on the times and locations of works being undertaken remain valid. The noise monitoring requirements, including the timing and location will be highly variable and

dependent on the activity taking place at the time and also the meteorological conditions during the works.

As set out in Section 6 of this report, we recommend that noise monitoring is undertaken at the commencement of use of the dredging vessels as they arrive to determine whether any updates are required to the restrictions that are noted in this assessment. Such restrictions may relate to a combination of the time of day, location and weather conditions under which a particular vessel may be operated within in order to maintain compliance with the relevant noise limits.

Noise level monitoring should be used in conjunction with updating the noise prediction models (based on the actual measured levels) to assist with the determination of compliance under any particular scenario.

We also recommend that noise monitoring be undertaken throughout the project on a periodic basis and during times when dredging is being undertaken closest to the shoreline on the northern side of the harbour and also in response to any complaints. Whilst it would be inappropriate to require noise level measurements in response to *any* complaint, we do consider it reasonable to undertake noise level measurements in response to a reasonably justified complaint. For the purpose of determining whether monitoring should be undertaken, reference to 'the reasonable request of the Council' is often made in conditions of consent and could be used in this instance also.

8. Summary and Conclusions

Styles Group has been engaged by Refining NZ to undertake an acoustic assessment of the proposed crude shipping project (CSP), to determine the airborne noise levels and effects arising from the CSP. Potential receivers have been limited to the NorthPort industrial site and residential properties along the coastline of the Whangarei Heads (from Reotahi Bay to Urquharts Bay).

Rules 31.4.13 and 31.7.12 of the NRCP (indirectly) requires compliance with the provisions of NZS6803:1999 *Acoustics – Construction Noise.* It is our view that compliance with the noise limits contained in NZS6803 will ensure that the noise effects are less than minor and reasonable in terms of s16 of the Act. We have used the sophisticated acoustic modelling software to prepare predictions of the noise levels likely to be generated by the CSP and to determine what, if any restrictions are necessary to ensure compliance with these provisions.

The noise modelling shows that comfortable compliance with the relevant noise limits is achieved for dredging inside the harbour, except when dredging is undertaken generally north of the No. 18 navigation buoy when the 45dB L_{Aeq} noise limit applies (at night and on Sundays and Public Holidays) and, during unfavourable wind conditions, when the wind is blowing from any direction other than the northern quarter. The predicted noise levels for all other dredging

positions under various meteorological conditions show that compliance with all of the relevant noise limits at all times of the day can be achieved, in most cases by a large margin. We have recommended that dredging activities are not undertaken north of the No. 18 buoy during unfavourable wind conditions (identified above) at times when the 45dB L_{Aeq} noise limit applies. This limitation is subject to refinement or removal (if justified) based on the collection of noise measurement data from the dredges that are commissioned for the project.

The noise effects of the dredging project will be unnoticeable for a large proportion of the project for the receivers on the northern side of the harbour. Dredging will be inaudible and not measureable when the vessels are outside of the harbour or generally east of Busby Head. For all other locations within the harbour, the dredging activity will be audible to some receivers but generally at noise levels less than 45dB L_{Aeq}.

We recommend that the dredging operations are subject to a noise management plan (NMP) including provisions for noise monitoring at the commencement of dredging for each dredge to determine actual noise emissions and to determine whether any change to the restrictions on dredging are required. Ongoing noise monitoring should be undertaken to ensure compliance and in response to reasonable complaints.

The noise levels from piling works associated with the construction and relocation of navigational aids will be compliant with the relevant noise limits by a considerable margin provided they are undertaken between 0730 and 1800 Monday to Friday when the higher noise limit of 70dB L_{Aeq} applies.

In our opinion, and if the recommendations in this report are adhered to, we consider that the noise effects arising from the CSP will be reasonable in terms of s16 of the Act.

9. Literature Cited

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Delta. 16 February 2006 (Delta 2006). Technical Note: Noise Emission from Backhoe Aquadigger MJØLNER R. Journal No. AV 114/06.

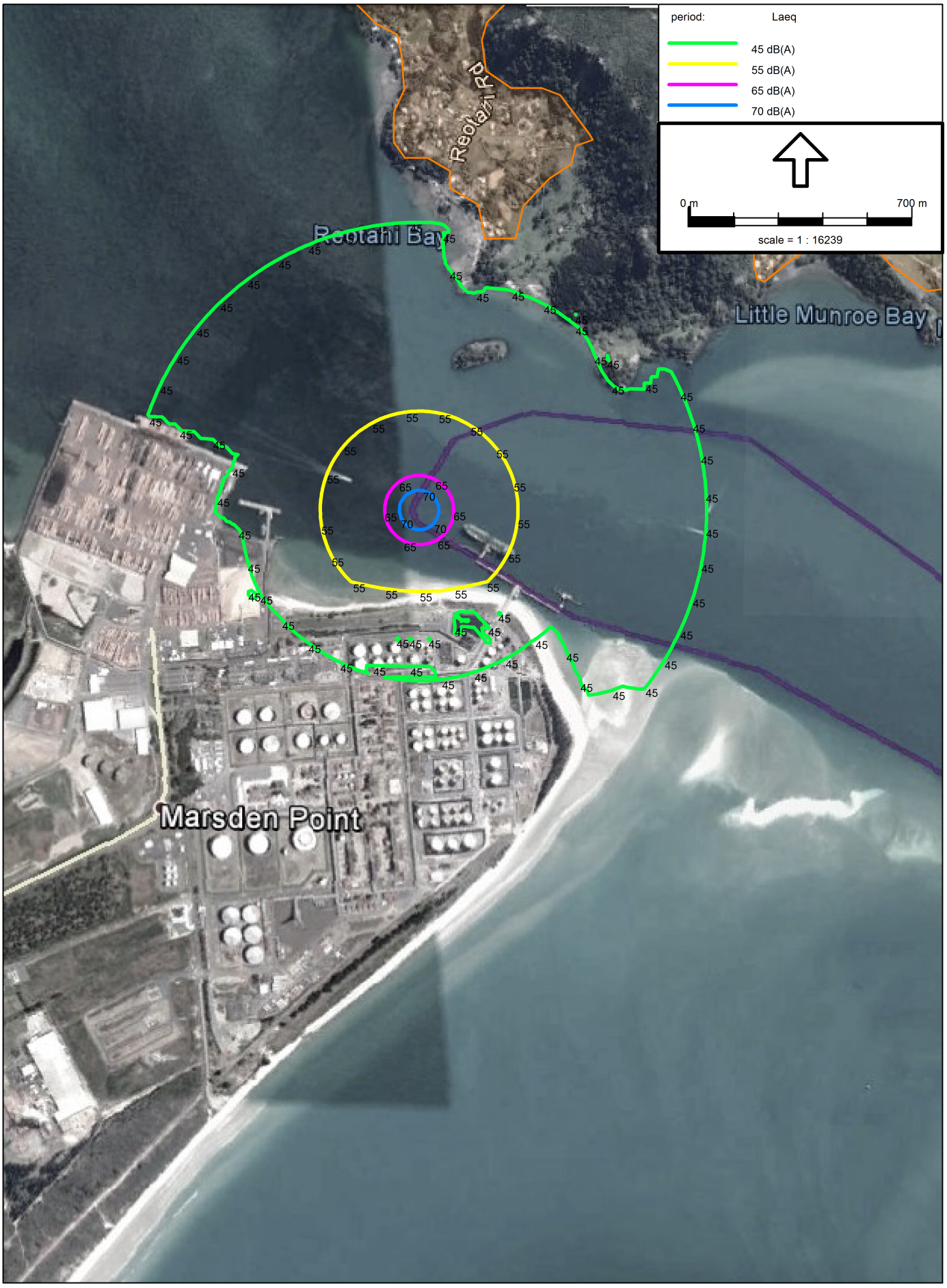
Delta. 31 January 2005 (Delta 2005). Technical Note: Noise Emission from Booster Station BRAGE R. Journal No. AV 55/05.

Appendix A

Noise Level Predictions - BHD Jetty Area

BHD Inner Channel: Jetty Area

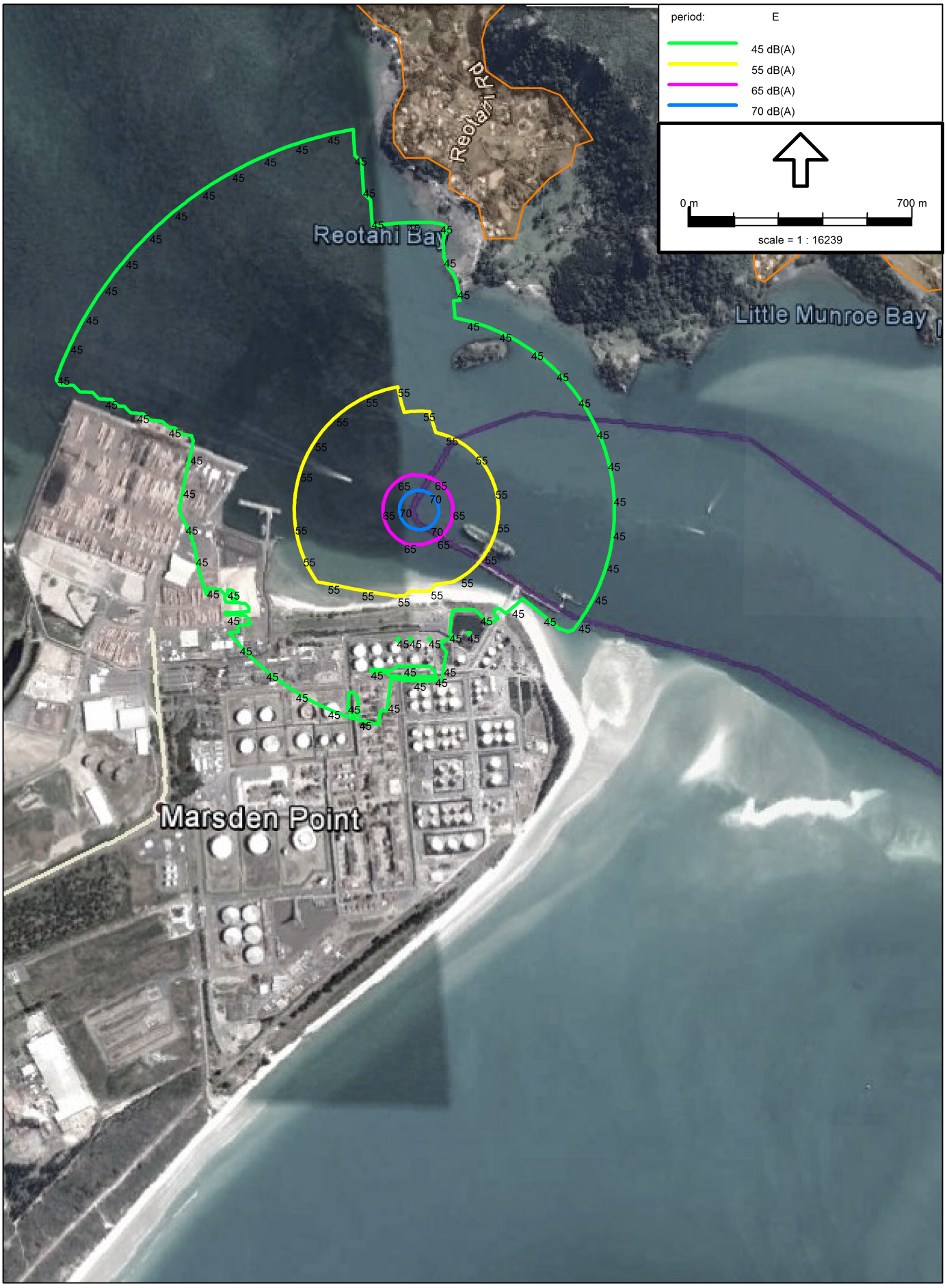
Weather Condition: C0 = 0



Industrial noise - ISO 9613.1/2, [Weather - Inner_NorthPort C0] , Predictor V11.10

BHD Inner Channel: Jetty Area

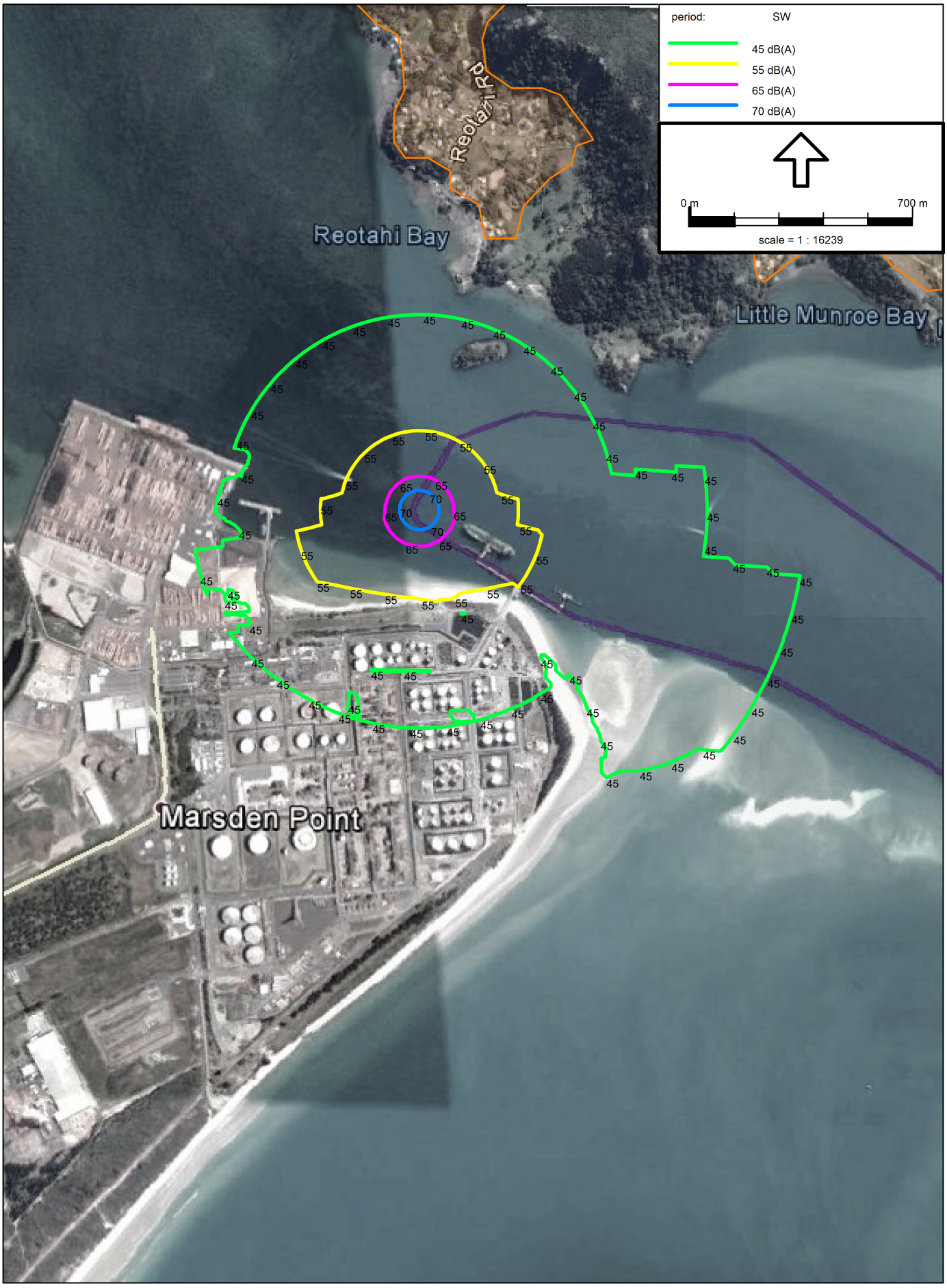
Easterly Wind



Industrial noise - ISO 9613.1/2, [Weather - Inner_NorthPort 3m/s] , Predictor V11.10

BHD Inner Channel: Jetty Area

Northerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Inner_NorthPort 3m/s] , Predictor V11.10

BHD Inner Channel: Jetty Area

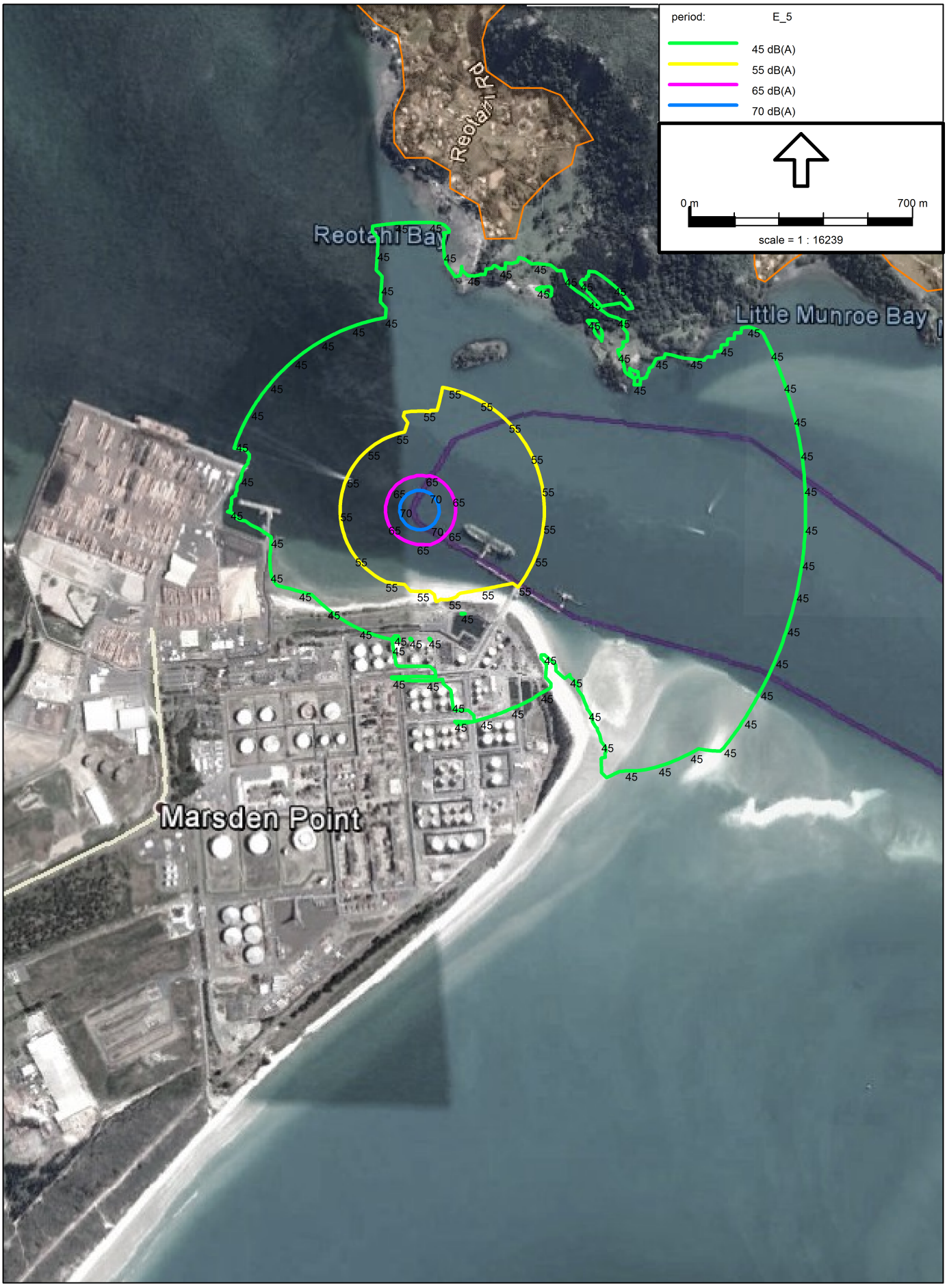
Southerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Inner_NorthPort 3m/s] , Predictor V11.10

BHD Inner Channel: Jetty Area

Westerly Wind



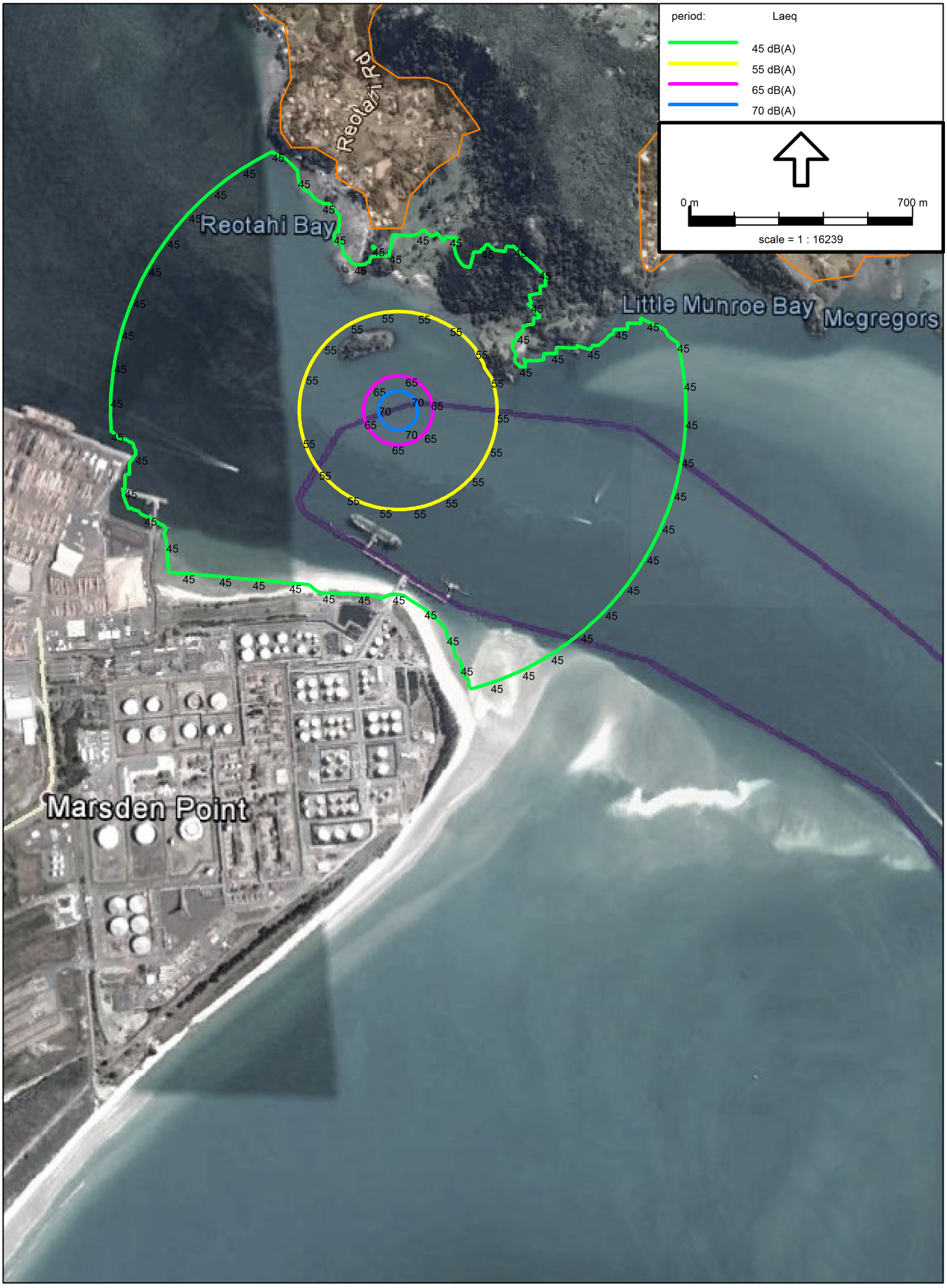
Industrial noise - ISO 9613.1/2, [Weather - Inner_NorthPort 3m/s] , Predictor V11.10

Appendix B

Noise Level Predictions - BHD No. 17 Navigational Buoy

BHD Inner Channel: No.17 Buoy

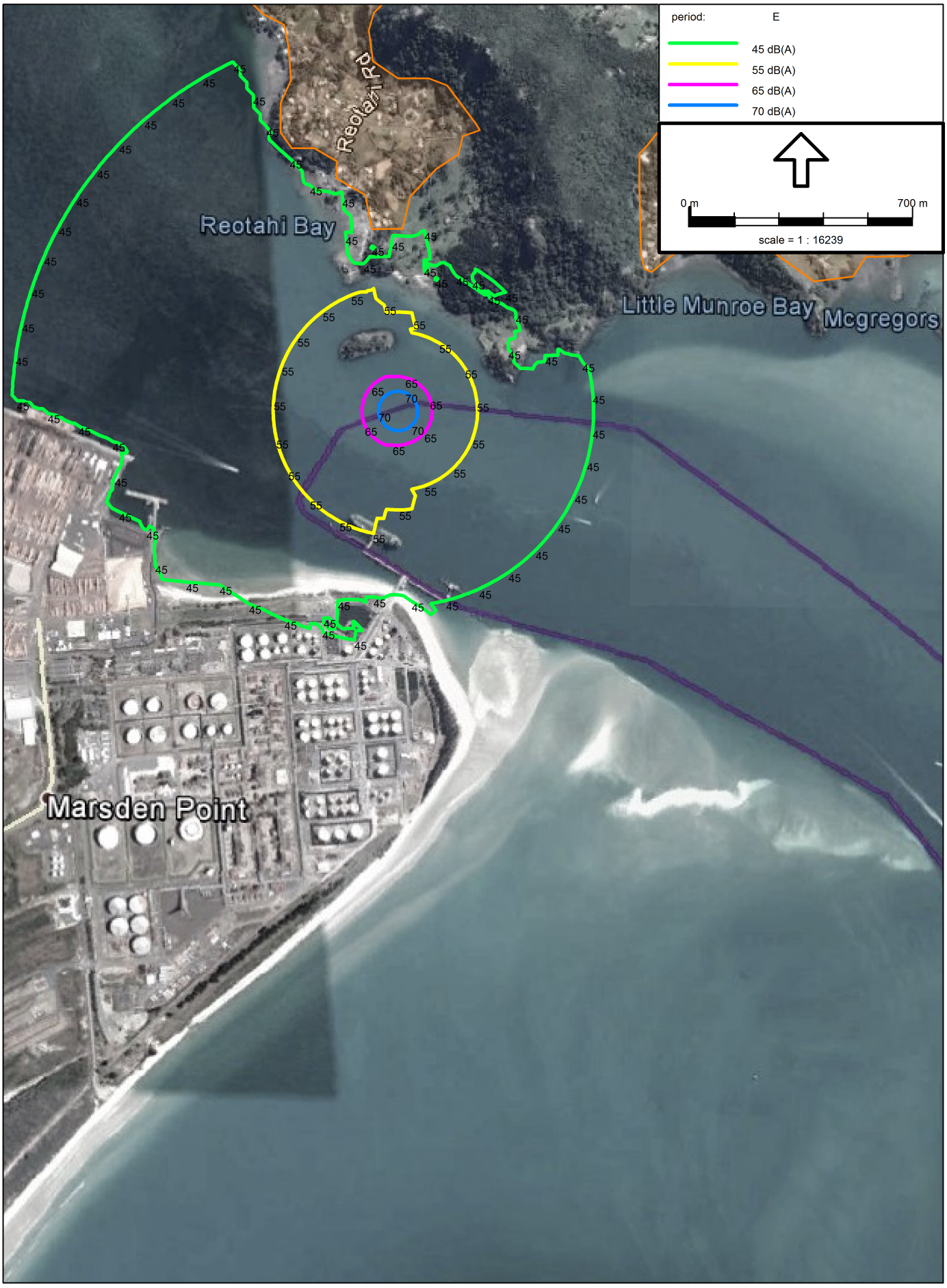
Weather Condition: C0 = 0



Industrial noise - ISO 9613.1/2, [Weather - Inner_Pos1a_C0] , Predictor V11.10

BHD Inner Channel: No.17 Buoy

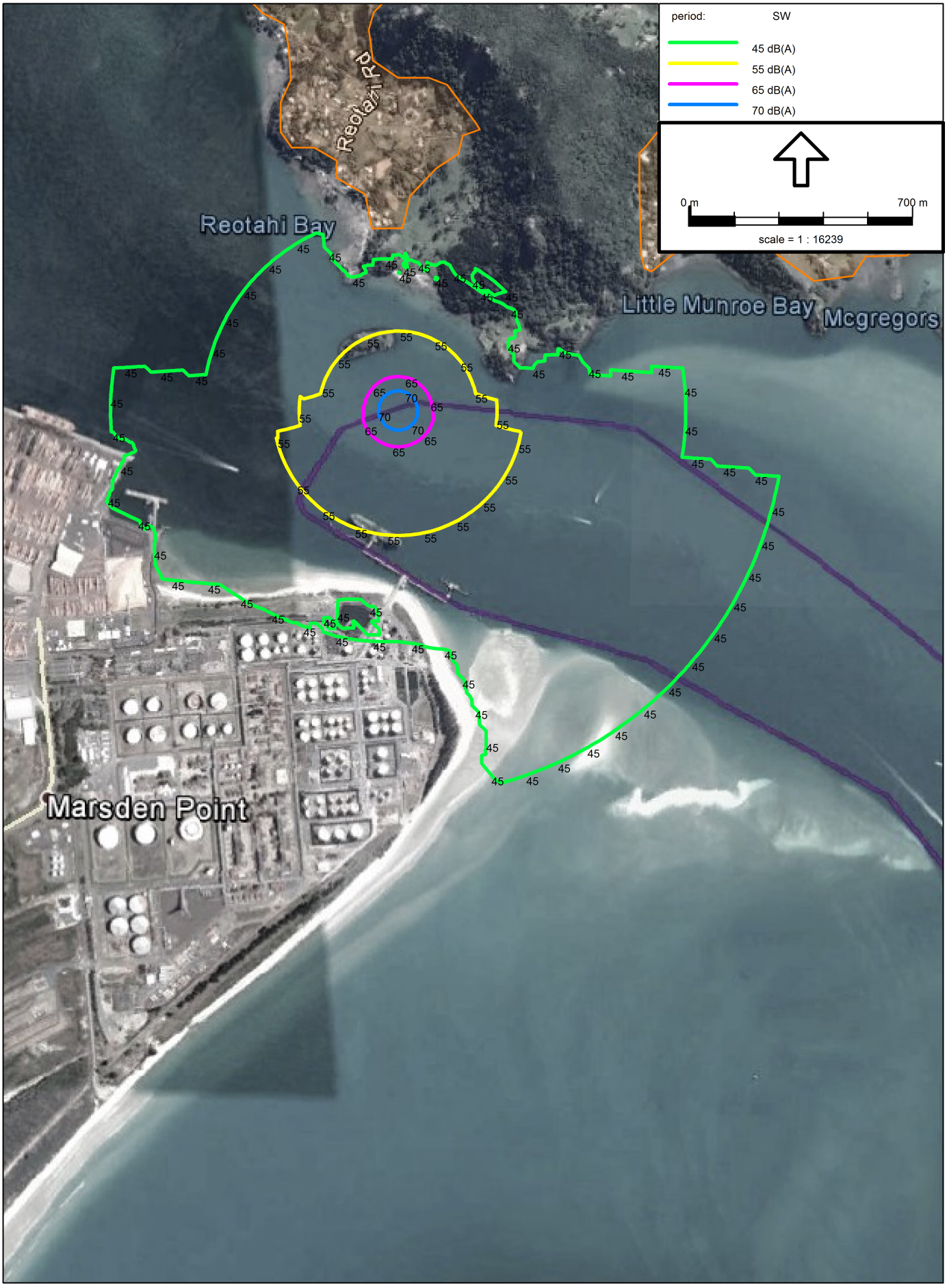
Easterly Wind



Industrial noise - ISO 9613.1/2, [Weather - Inner_Pos1a] , Predictor V11.10

BHD Inner Channel: No.17 Buoy

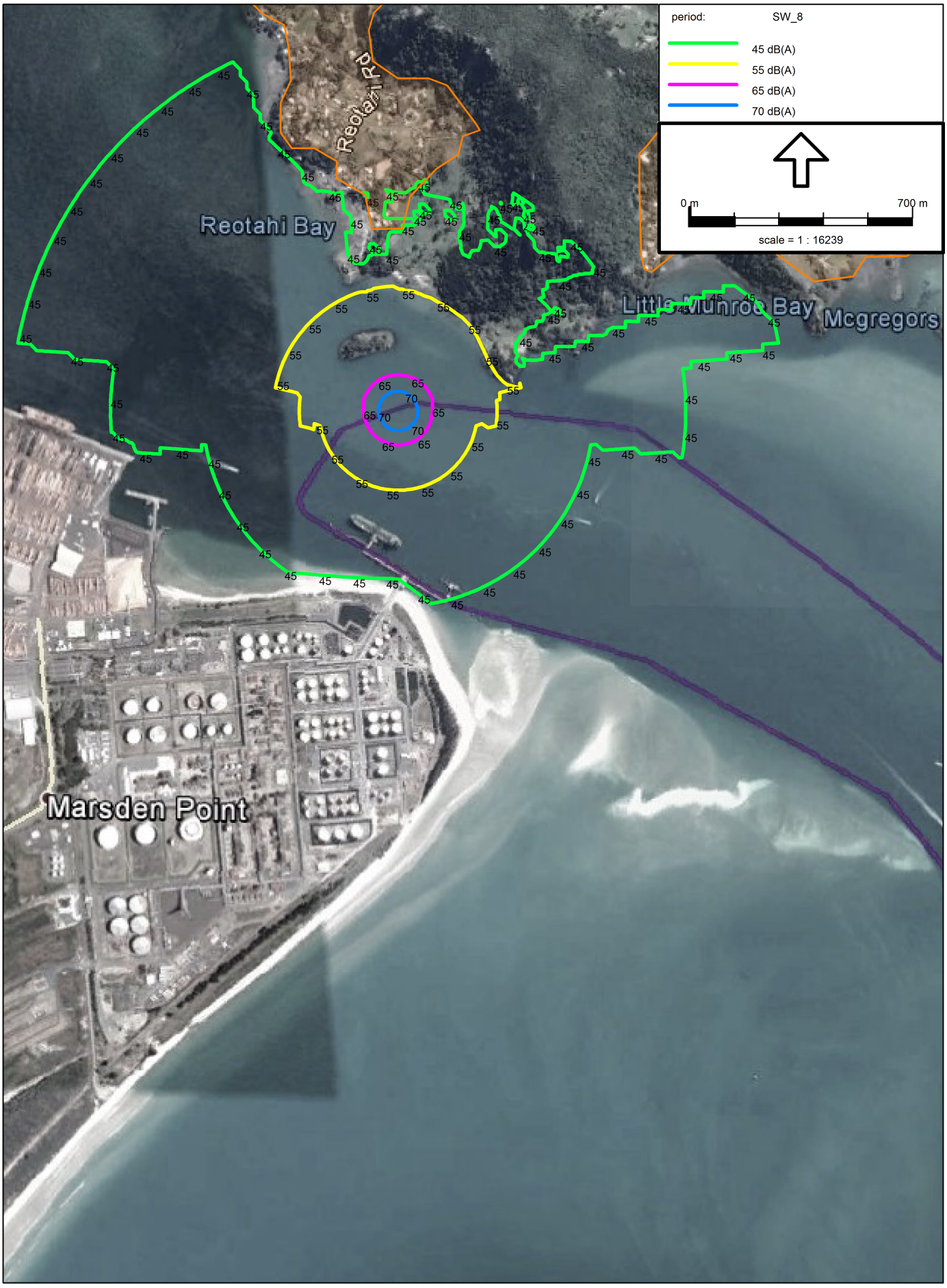
Northerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Inner_Pos1a] , Predictor V11.10

BHD Inner Channel: No.17 Buoy

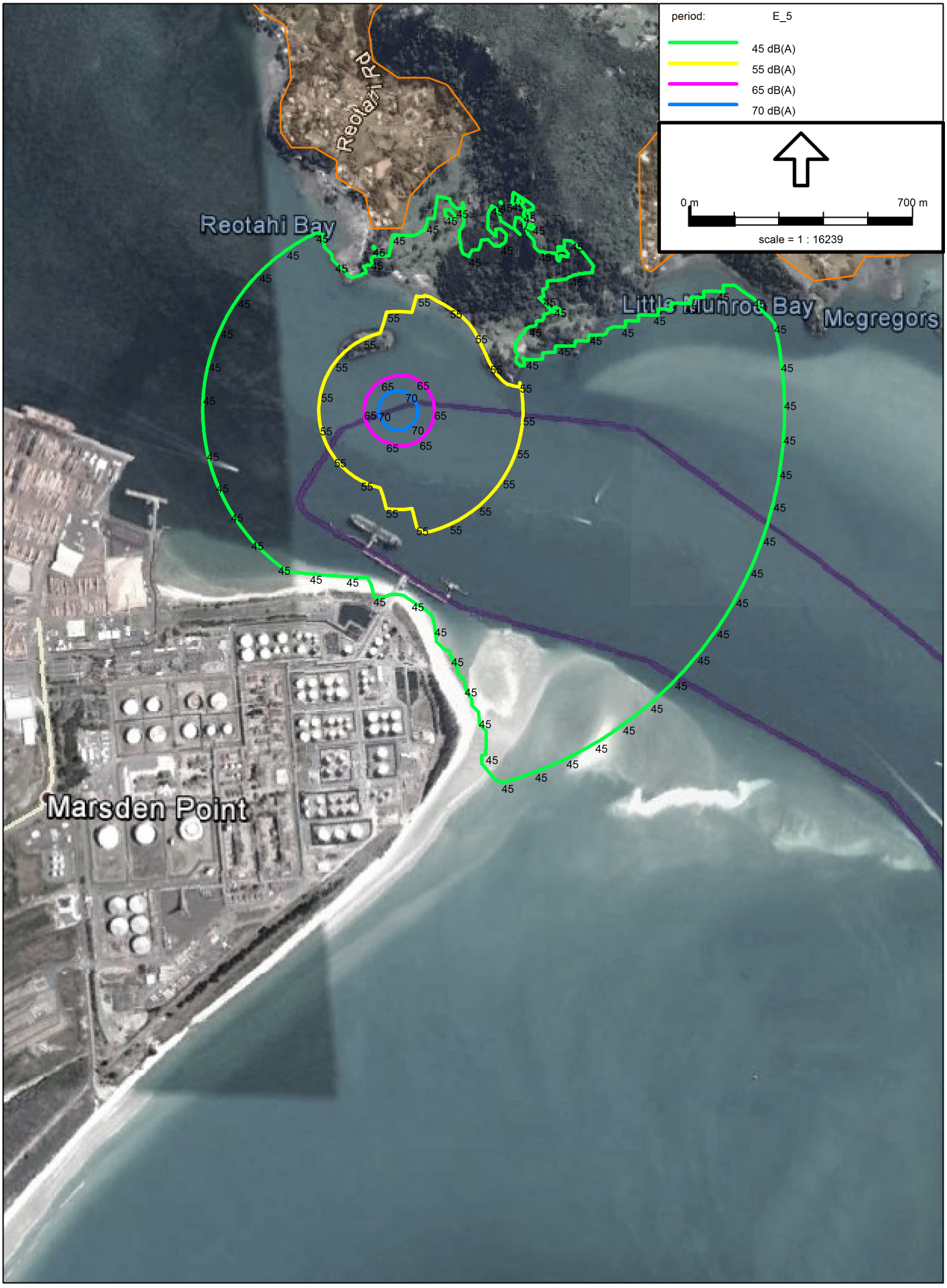
Southerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Inner_Pos1a] , Predictor V11.10

BHD Inner Channel: No.17 Buoy

Westerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Inner_Pos1a] , Predictor V11.10

Appendix C

Noise Level Predictions - BHD No. 15 Navigational Buoy

BHD Inner Channel: No.15 Buoy

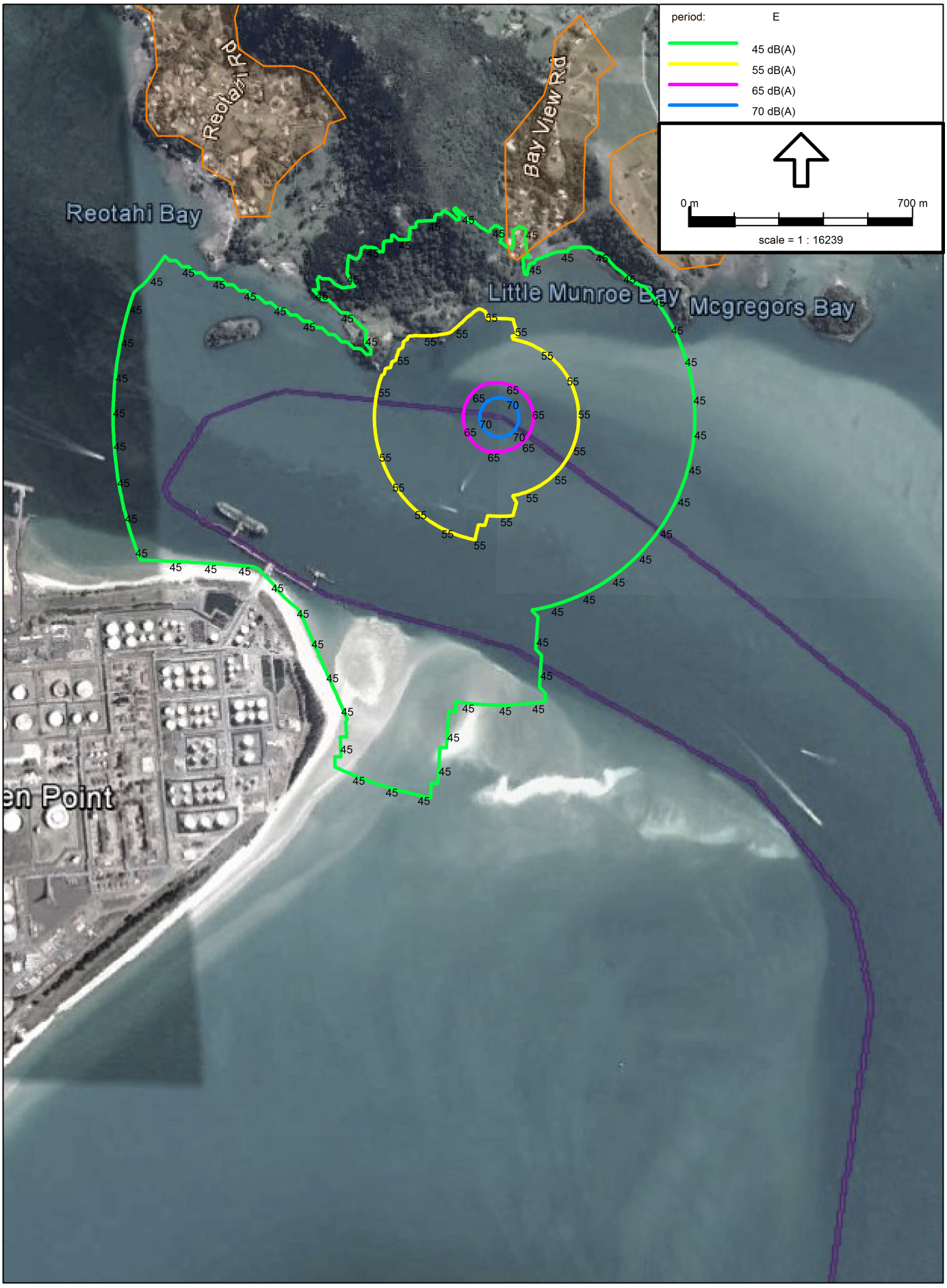
Weather Condition: C0 = 0



Industrial noise - ISO 9613.1/2, [Weather - Inner_Pos2a_C0] , Predictor V11.10

BHD Inner Channel: No.15 Buoy

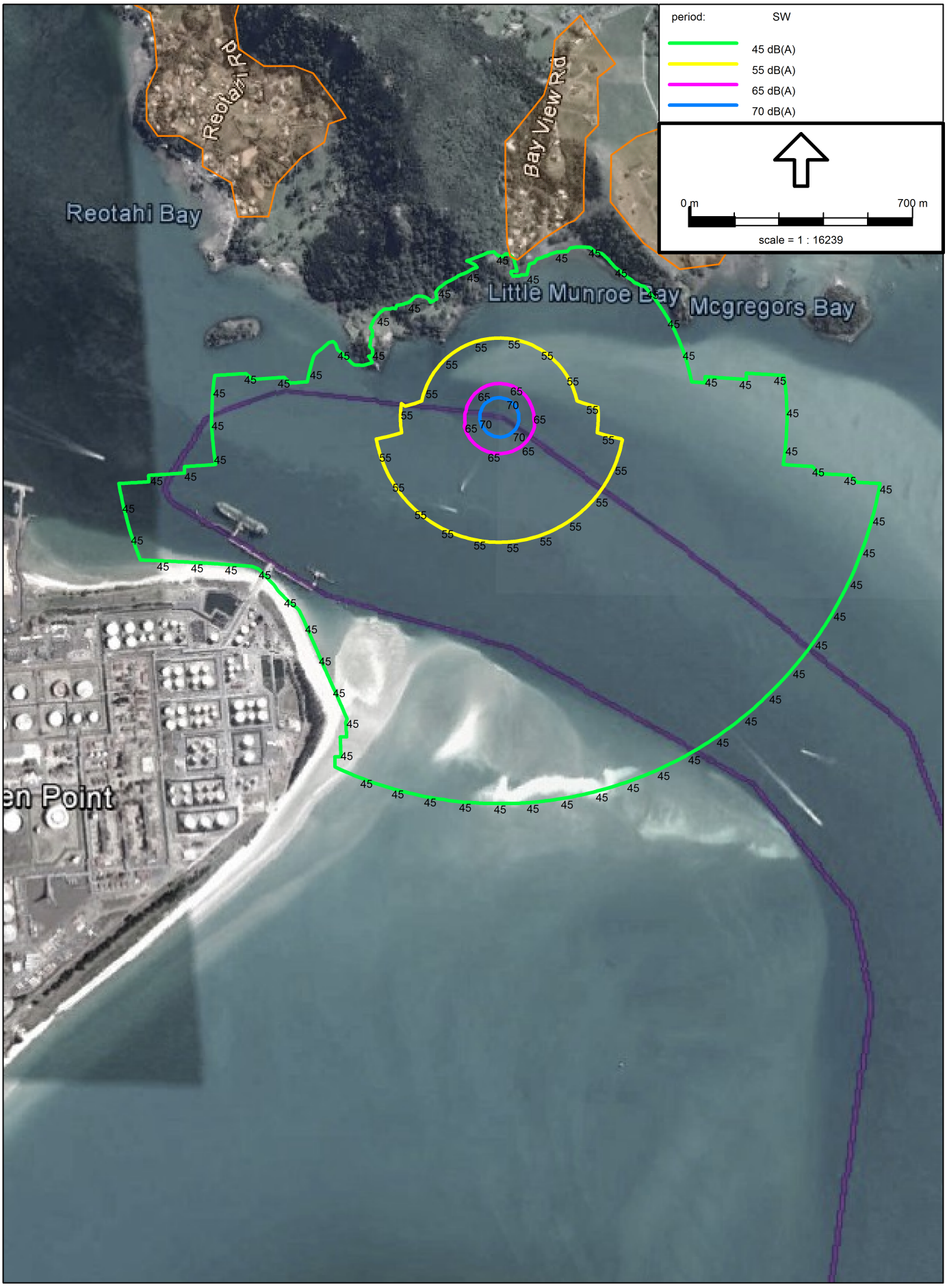
Easterly Wind



Industrial noise - ISO 9613.1/2, [Weather - Inner_Pos2a] , Predictor V11.10

BHD Inner Channel: No. 15 Buoy

Northerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Inner_Pos2a] , Predictor V11.10

BHD Inner Channel: No.15 Buoy

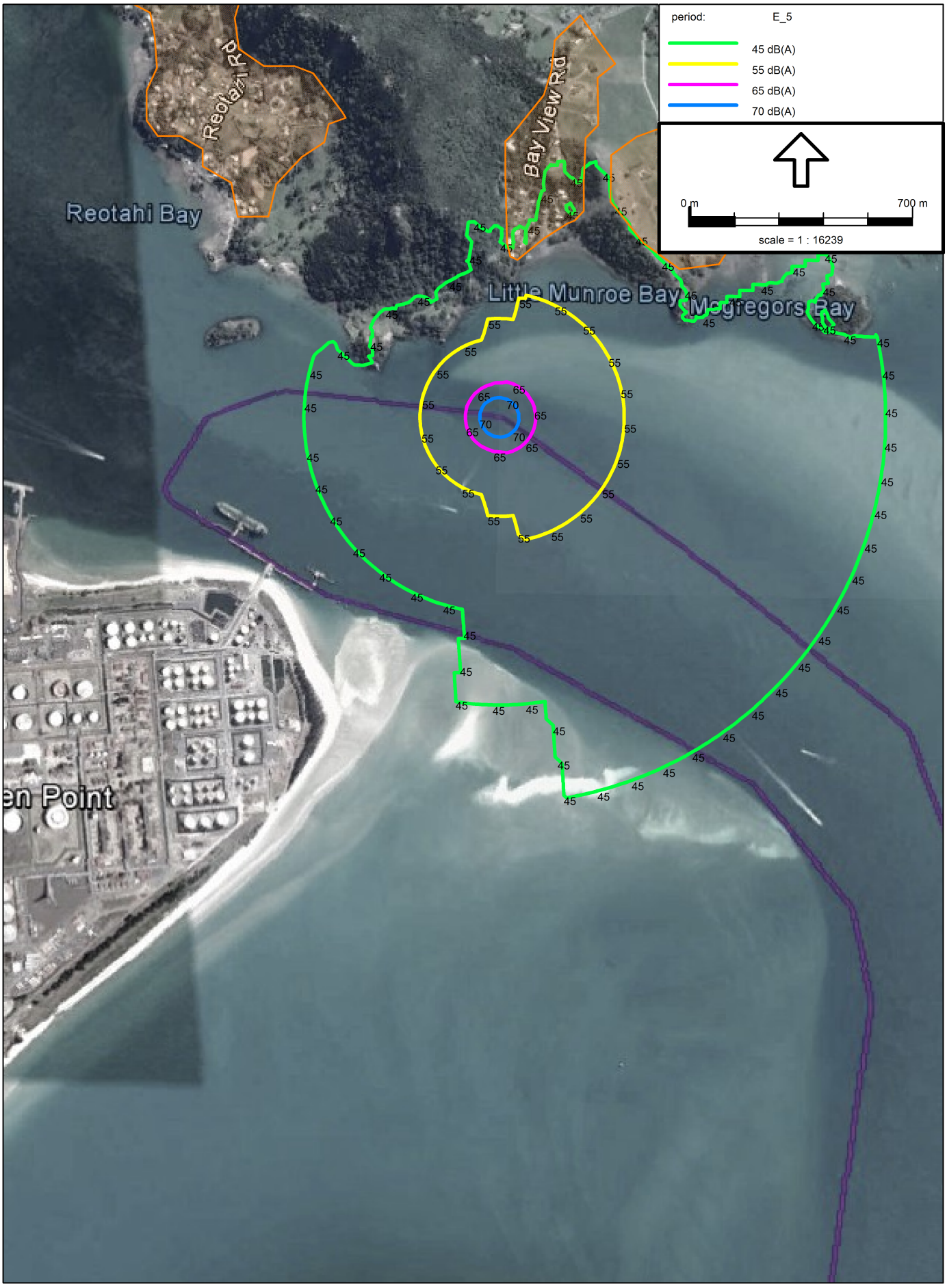
Southerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Inner_Pos2a] , Predictor V11.10

BHD Inner Channel: No.15 Buoy

Westerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Inner_Pos2a] , Predictor V11.10

Appendix D

Noise Level Predictions - TSHD No. 18 Navigational Buoy

TSHD Inner Channel (Marsden Point): Average Channel Position Weather Condition: C0 = 0



Industrial noise - ISO 9613.1/2, [Centre(C0) - Copy of LInes_1] , Predictor V11.10

TSHD Inner Channel (Marsden Point): Worst Case Channel Position Weather Condition: C0 = 0



Industrial noise - ISO 9613.1/2, [Centre(C0) - LInes_1] , Predictor V11.10

TSHD Inner Channel (Marsden Point): Worst Case Channel Position

Easterly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_1_3m/s] , Predictor V11.10

TSHD Inner Channel (Marsden Point): Worst Case Channel Position Northerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_1_3m/s] , Predictor V11.10

TSHD Inner Channel (Marsden Point): Worst Case Channel Position Southerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_1_3m/s] , Predictor V11.10

TSHD Inner Channel (Marsden Point): Worst Case Channel Position Westerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_1_3m/s] , Predictor V11.10

Appendix E

Noise Level Predictions - TSHD No. 13 Navigational Buoy

TSHD Inner Channel (Mair Bank): Average Channel Position

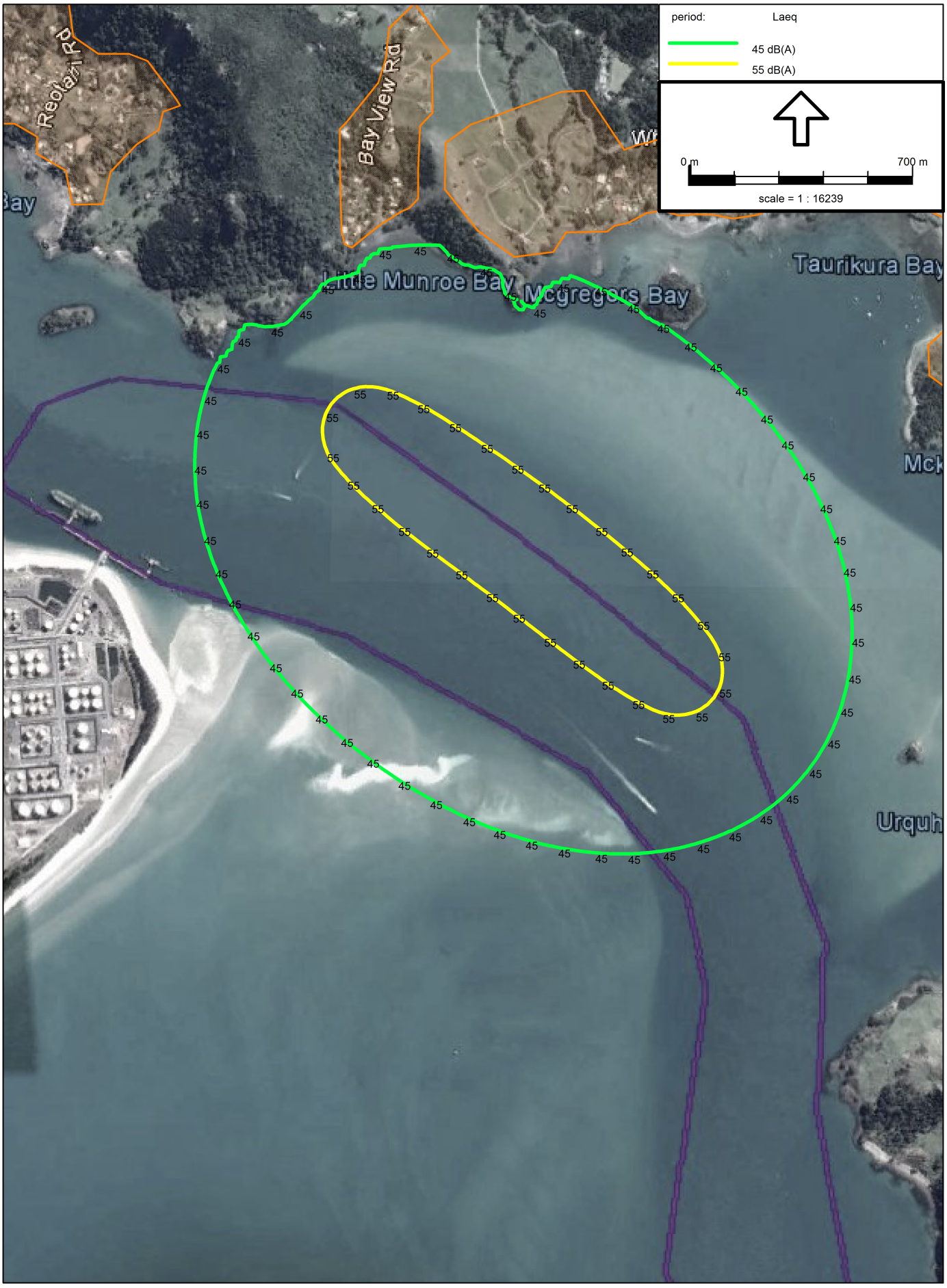
Weather Condition: C0 = 0



Industrial noise - ISO 9613.1/2, [Centre(C0) - Copy of LInes_2] , Predictor V11.10

TSHD Inner Channel (Mair Bank): Worst Case Channel Position

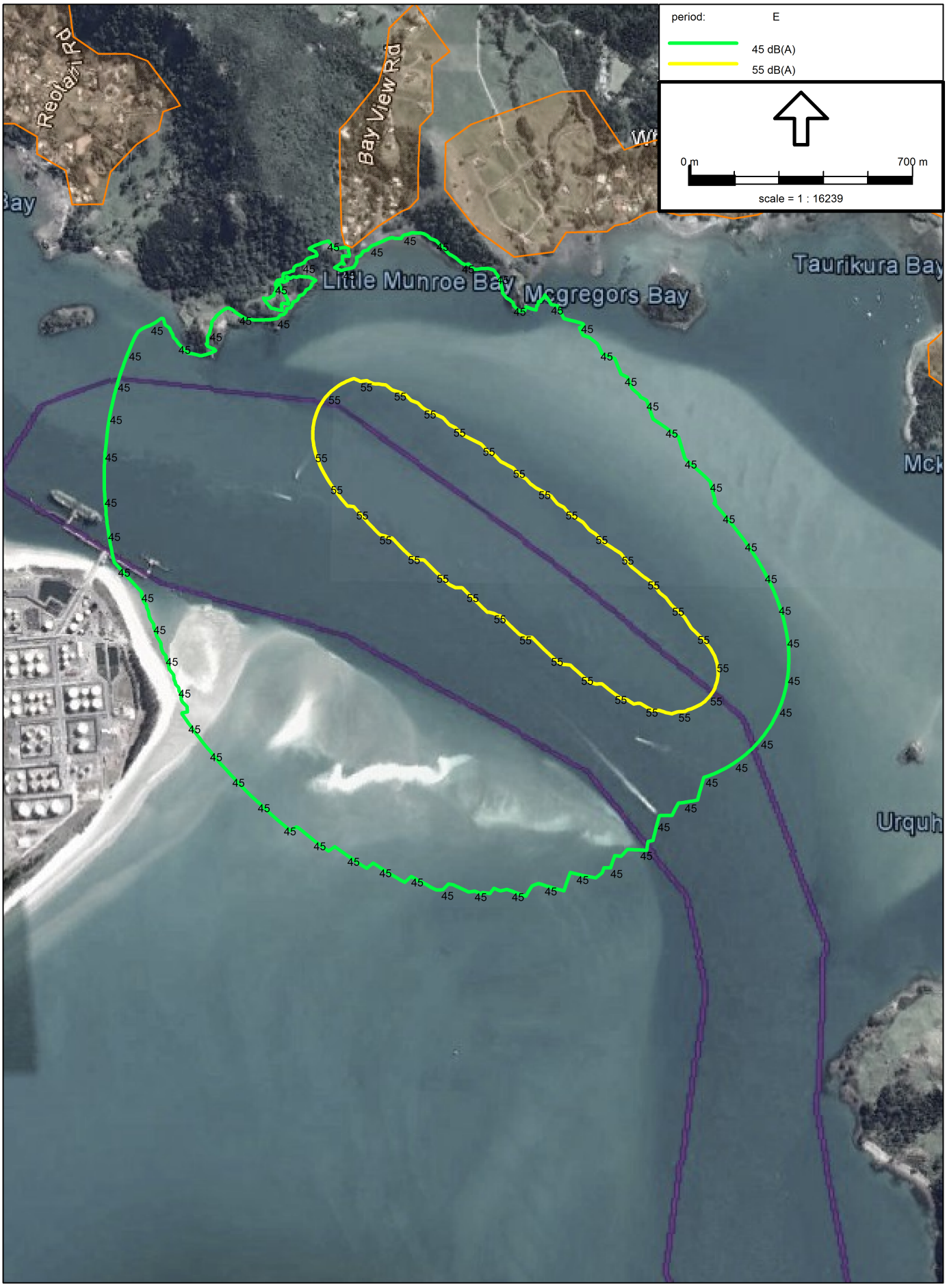
Weather Condition: C0 = 0



Industrial noise - ISO 9613.1/2, [Centre(C0) - LInes_2] , Predictor V11.10

TSHD Inner Channel (Mair Bank): Worst Case Channel Position

Easterly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_2_3m/s] , Predictor V11.10

TSHD Inner Channel (Mair Bank): Worst Case Channel Position

Northerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_2_3m/s] , Predictor V11.10

TSHD Inner Channel (Mair Bank): Worst Case Channel Position

Southerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_2_3m/s] , Predictor V11.10

TSHD Inner Channel (Mair Bank): Worst Case Channel Position

Westerly Wind



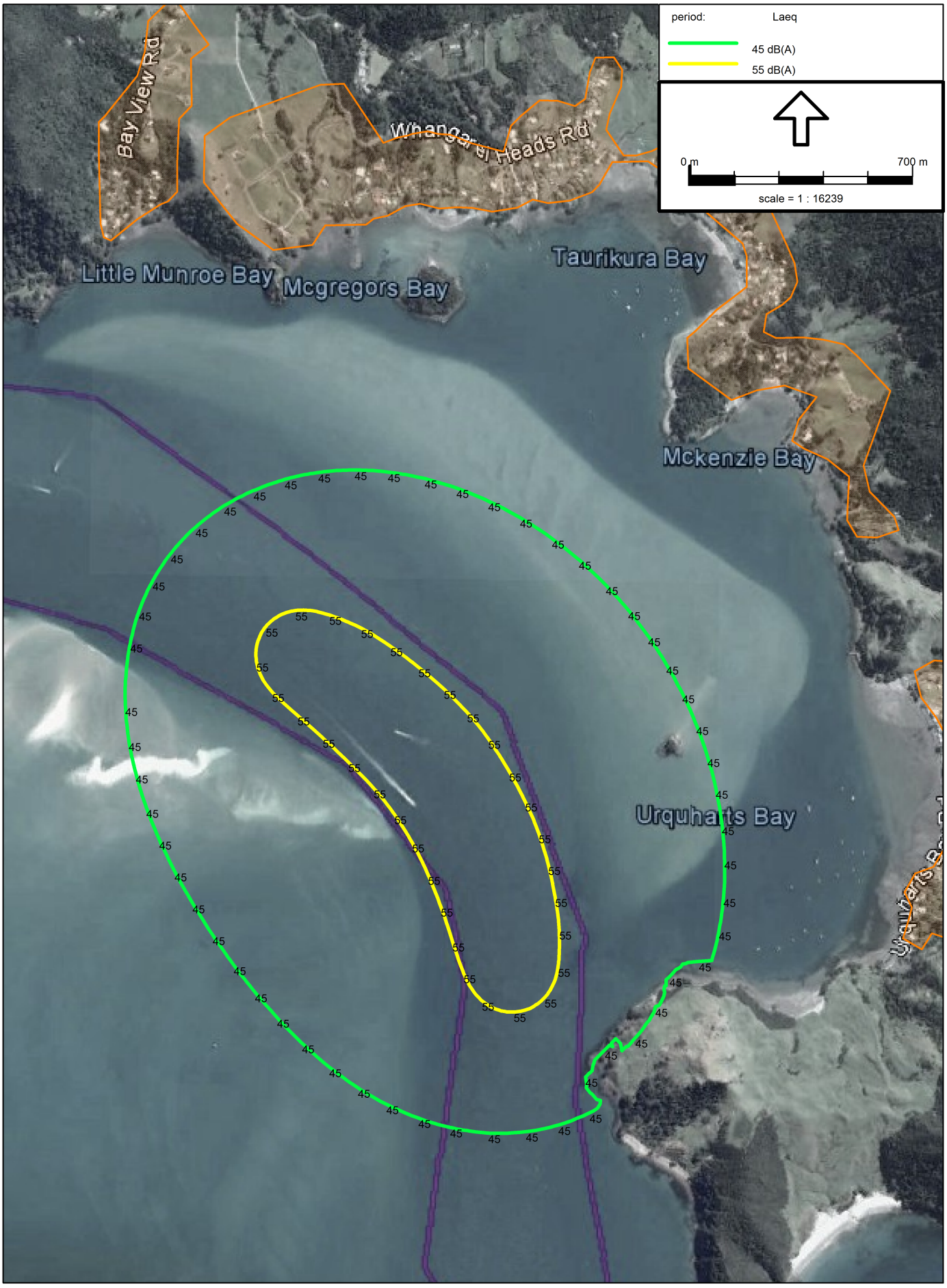
Industrial noise - ISO 9613.1/2, [Weather - Lines_2_3m/s] , Predictor V11.10

Appendix F

Noise Level Predictions - TSHD No. 11 Navigational Buoy

TSHD Mid Channel (Mair Bank): Average Channel Position

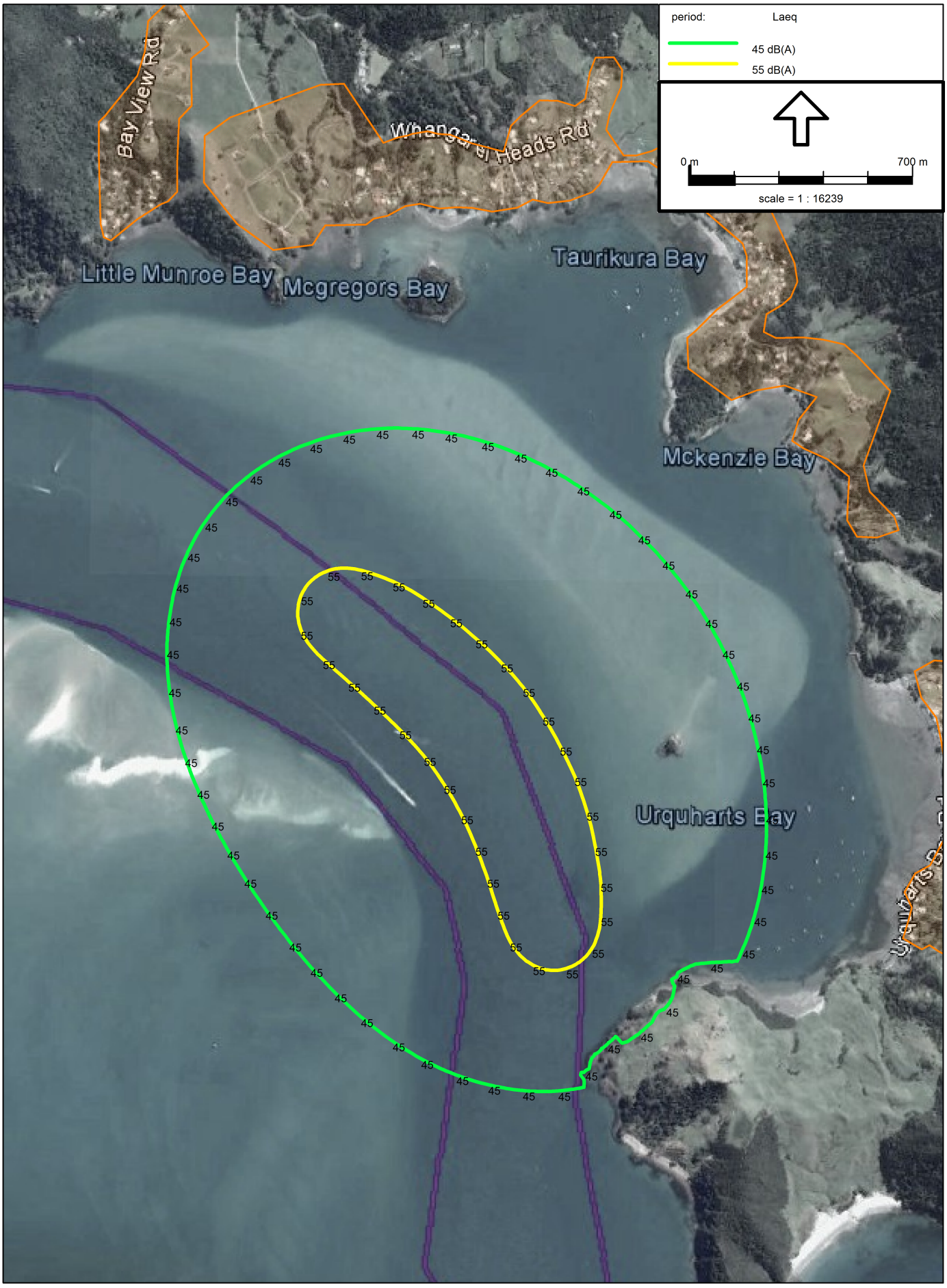
Weather Condition: C0 = 0



Industrial noise - ISO 9613.1/2, [Centre(C0) - Copy of LInes_3] , Predictor V11.10

TSHD Mid Channel (Mair Bank): Worst Case Channel Position

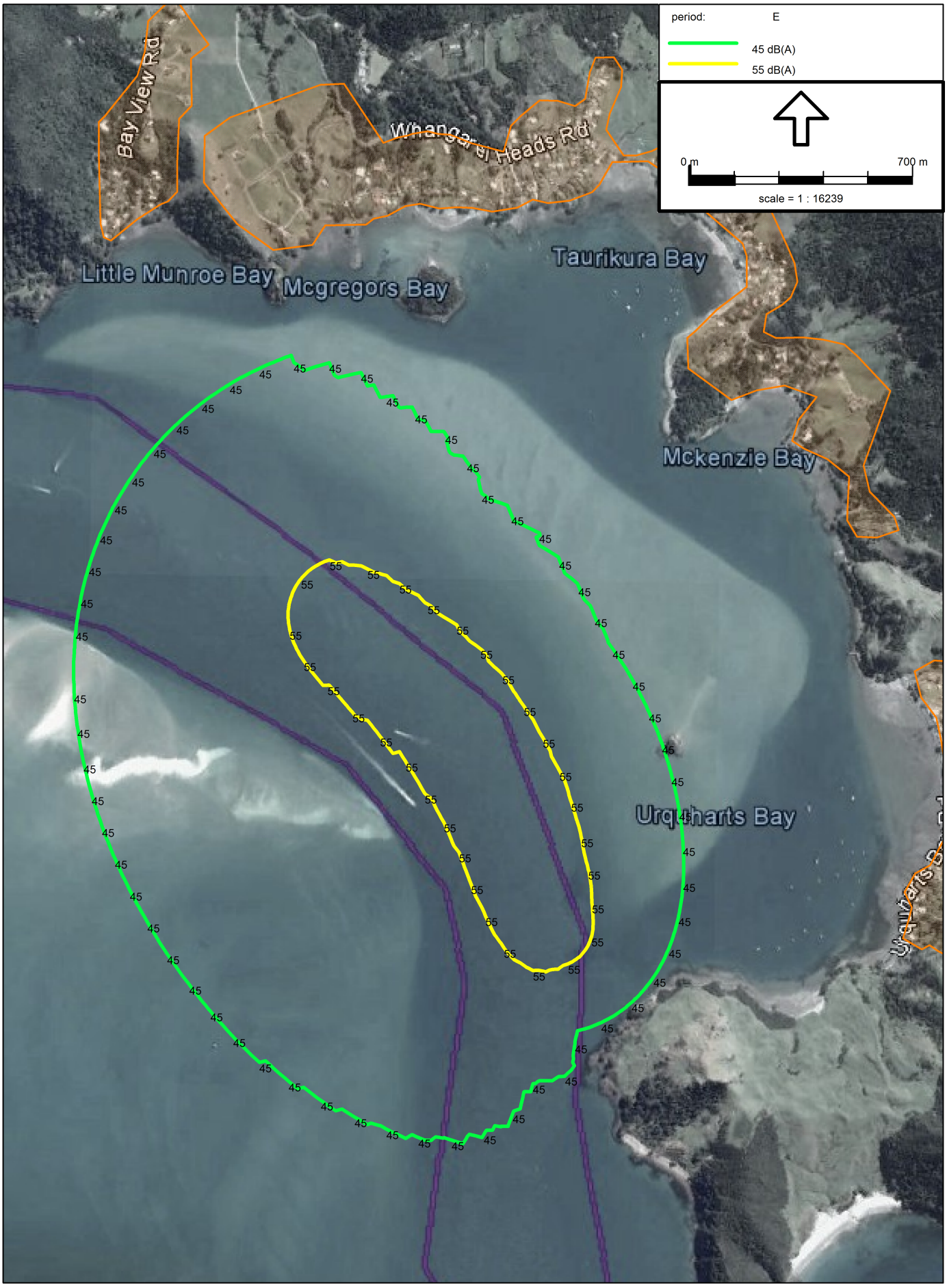
Weather Condition: C0 = 0



Industrial noise - ISO 9613.1/2, [Centre(C0) - LInes_3] , Predictor V11.10

TSHD Mid Channel (Mair Bank): Worst Case Channel Position

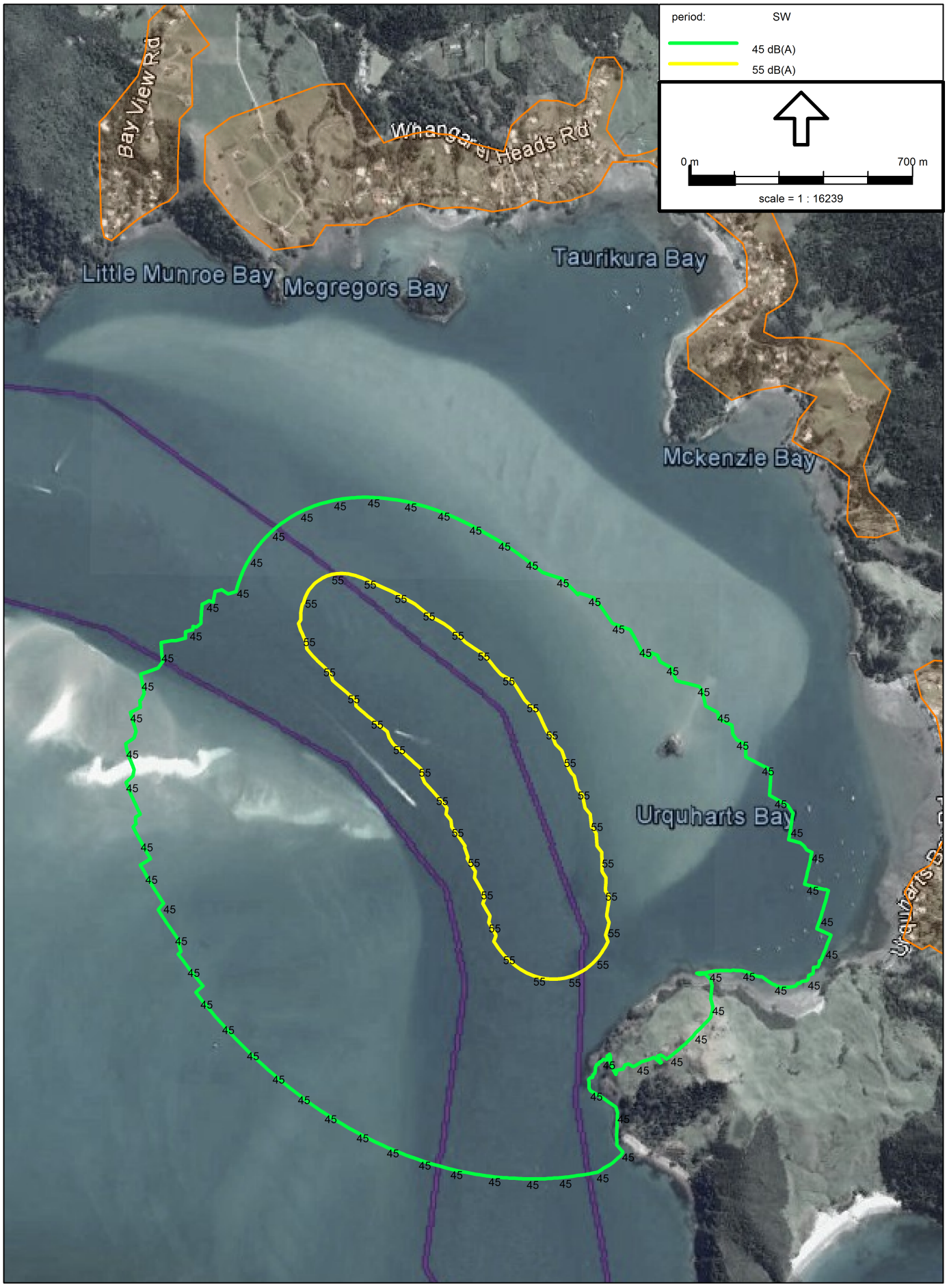
Easterly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_3_3m/s] , Predictor V11.10

TSHD Mid Channel (Mair Bank): Worst Case Channel Position

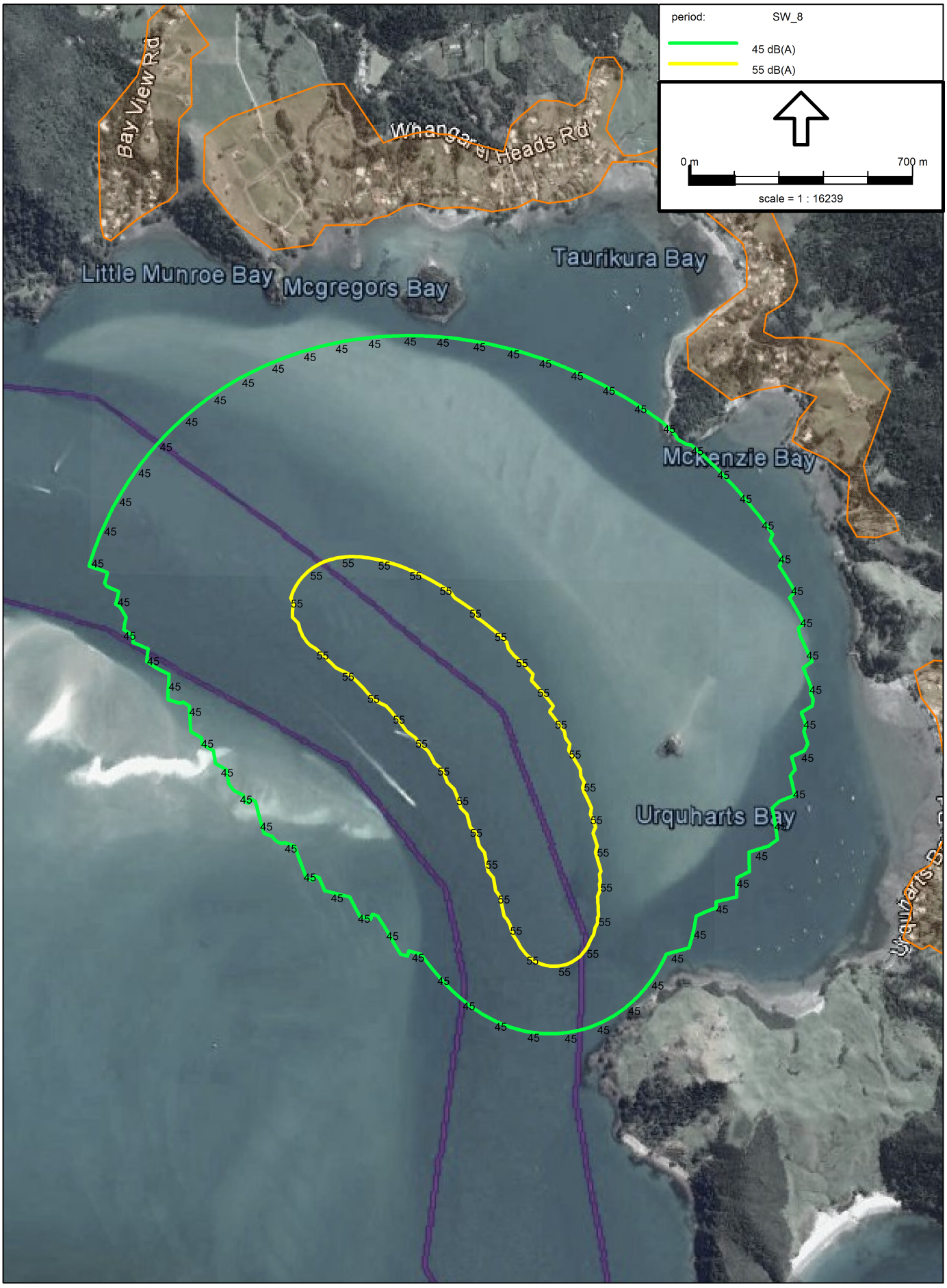
Northerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_3_3m/s] , Predictor V11.10

TSHD Mid Channel (Mair Bank): Worst Case Channel Position

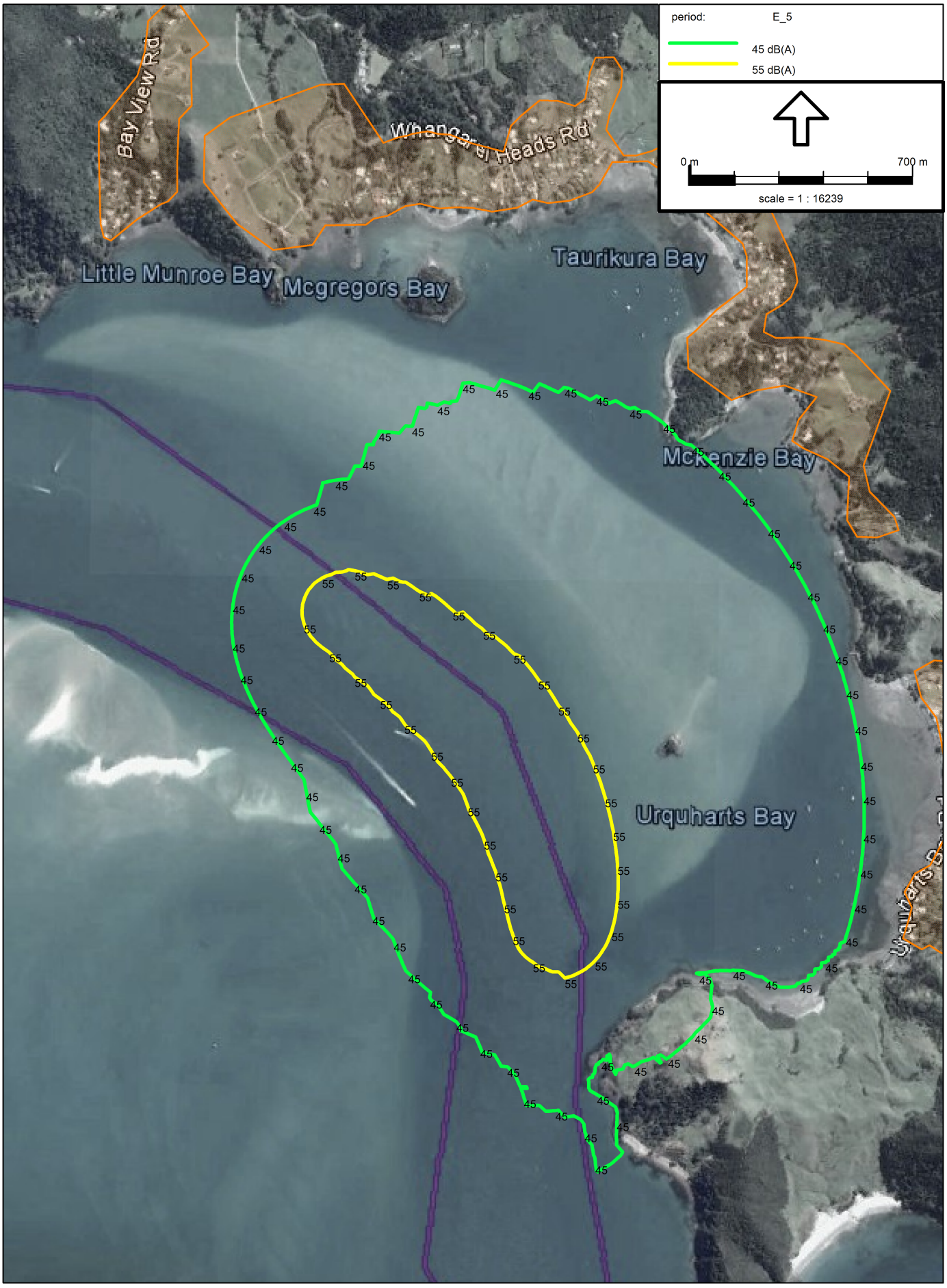
Southerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_3_3m/s] , Predictor V11.10

TSHD Mid Channel (Mair Bank): Worst Case Channel Position

Westerly Wind



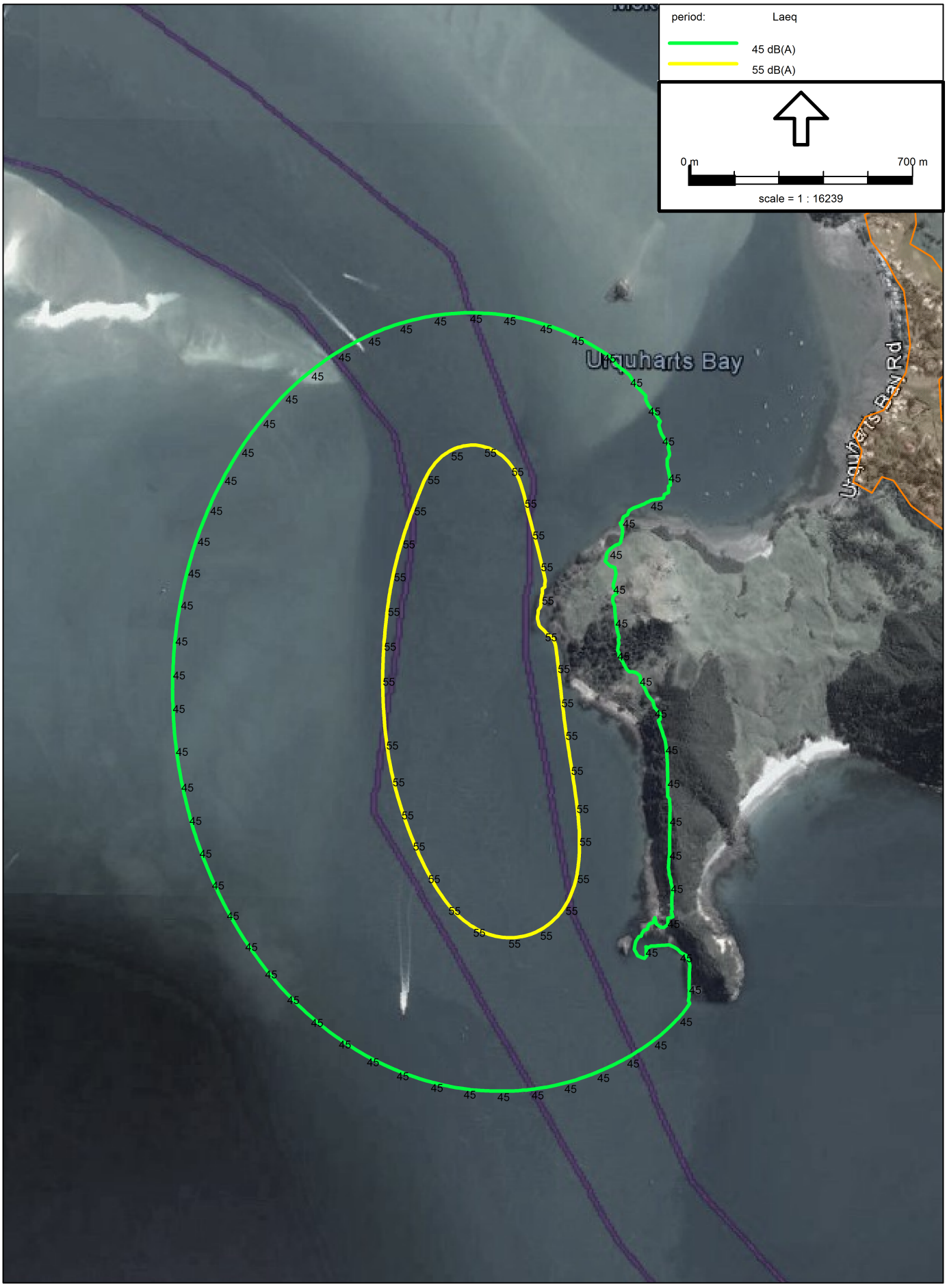
Industrial noise - ISO 9613.1/2, [Weather - Lines_3_3m/s] , Predictor V11.10

Appendix G

Noise Level Predictions - TSHD No. 07 Navigational Buoy

TSHD Mid Channel (Home Point): Average Channel Position

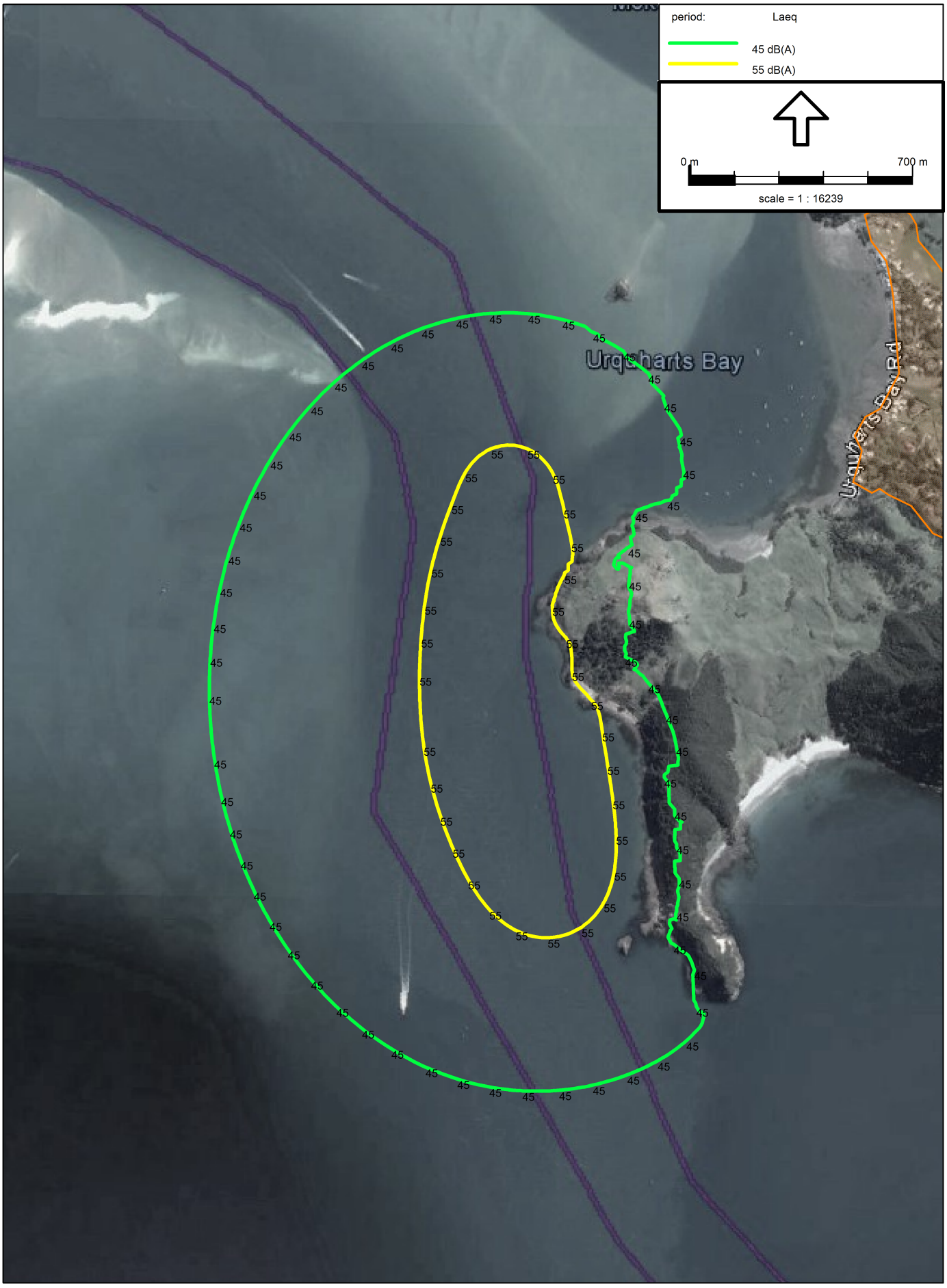
Weather Condition: C0 = 0



Industrial noise - ISO 9613.1/2, [Centre(C0) - Copy of LInes_4] , Predictor V11.10

TSHD Mid Channel (Home Point): Worst Case Channel Position

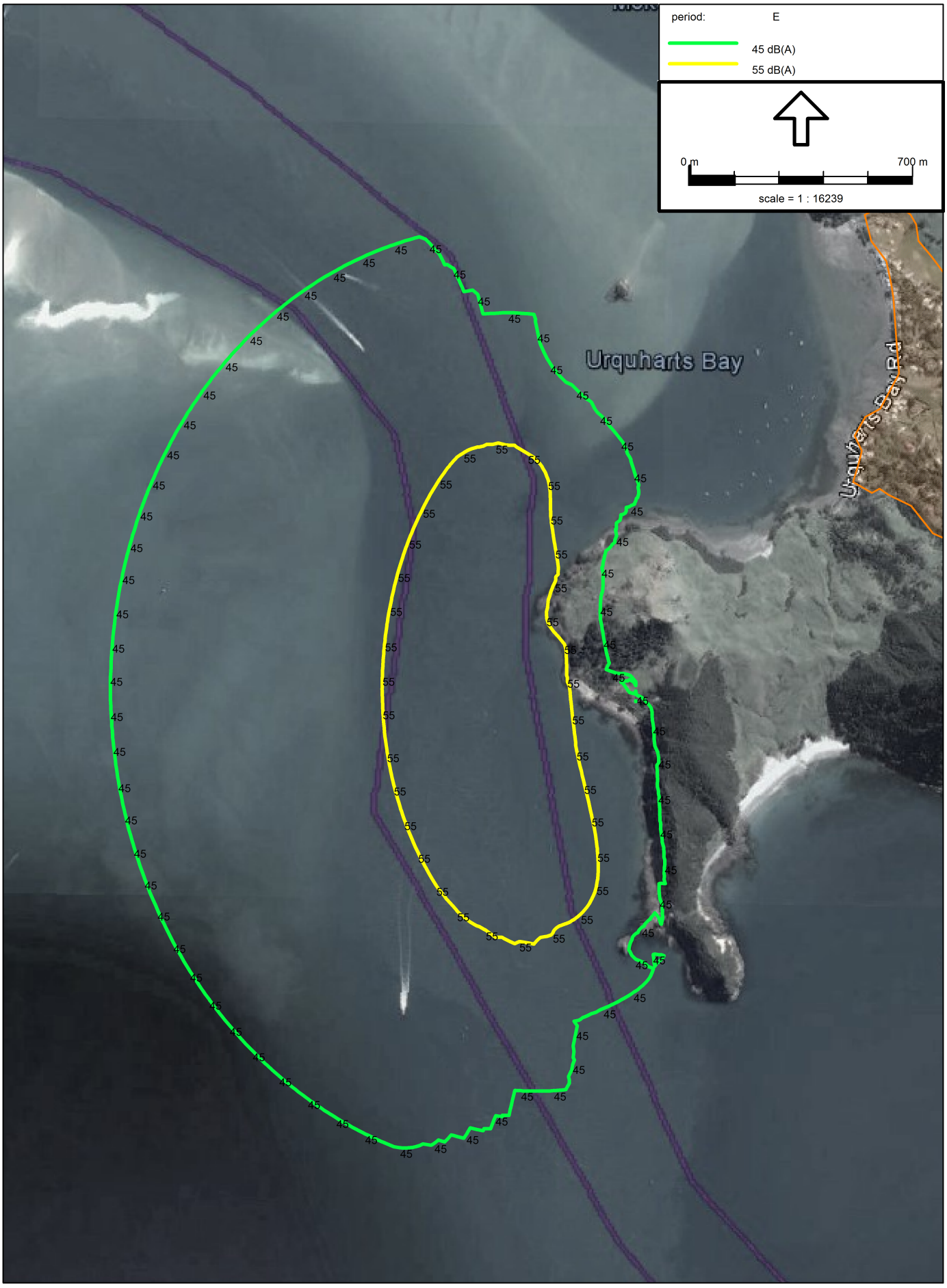
Weather Condition: C0 = 0



Industrial noise - ISO 9613.1/2, [Centre(C0) - LInes_4] , Predictor V11.10

TSHD Mid Channel (Home Point): Worst Case Channel Position

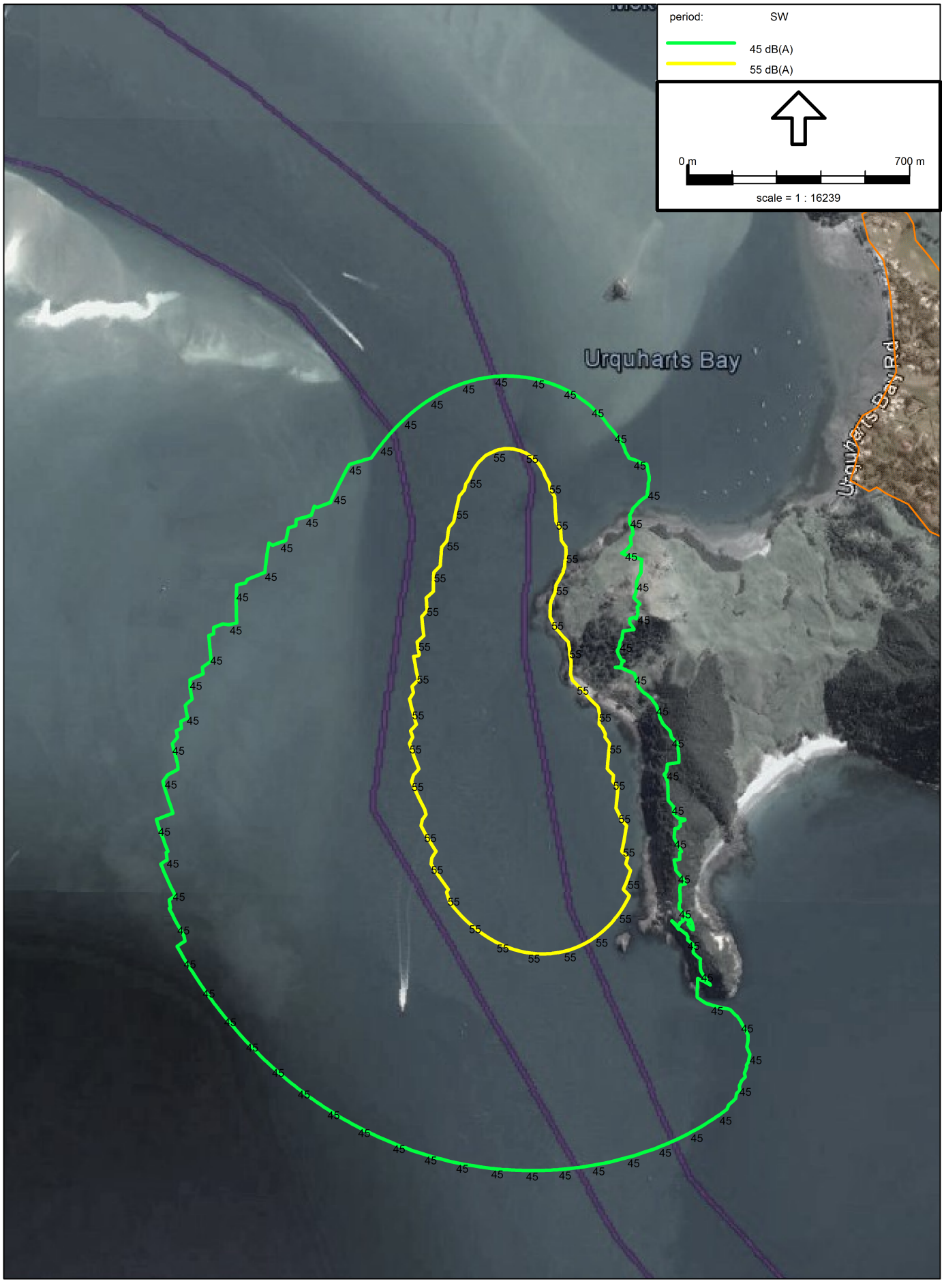
Easterly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_4_3m/s] , Predictor V11.10

TSHD Mid Channel (Home Point): Worst Case Channel Position

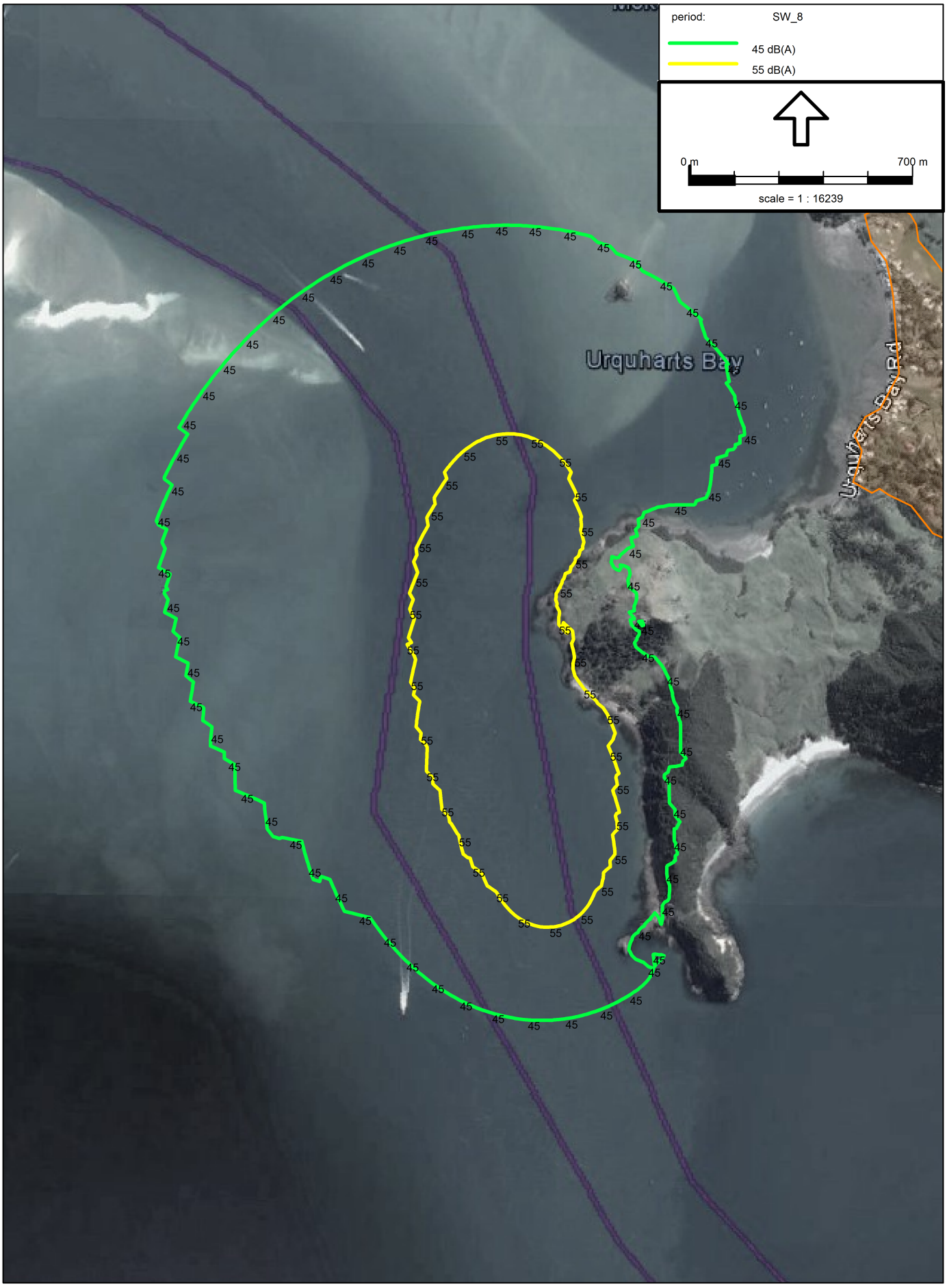
Northerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_4_3m/s] , Predictor V11.10

TSHD Mid Channel (Home Point): Worst Case Channel Position

Southerly Wind



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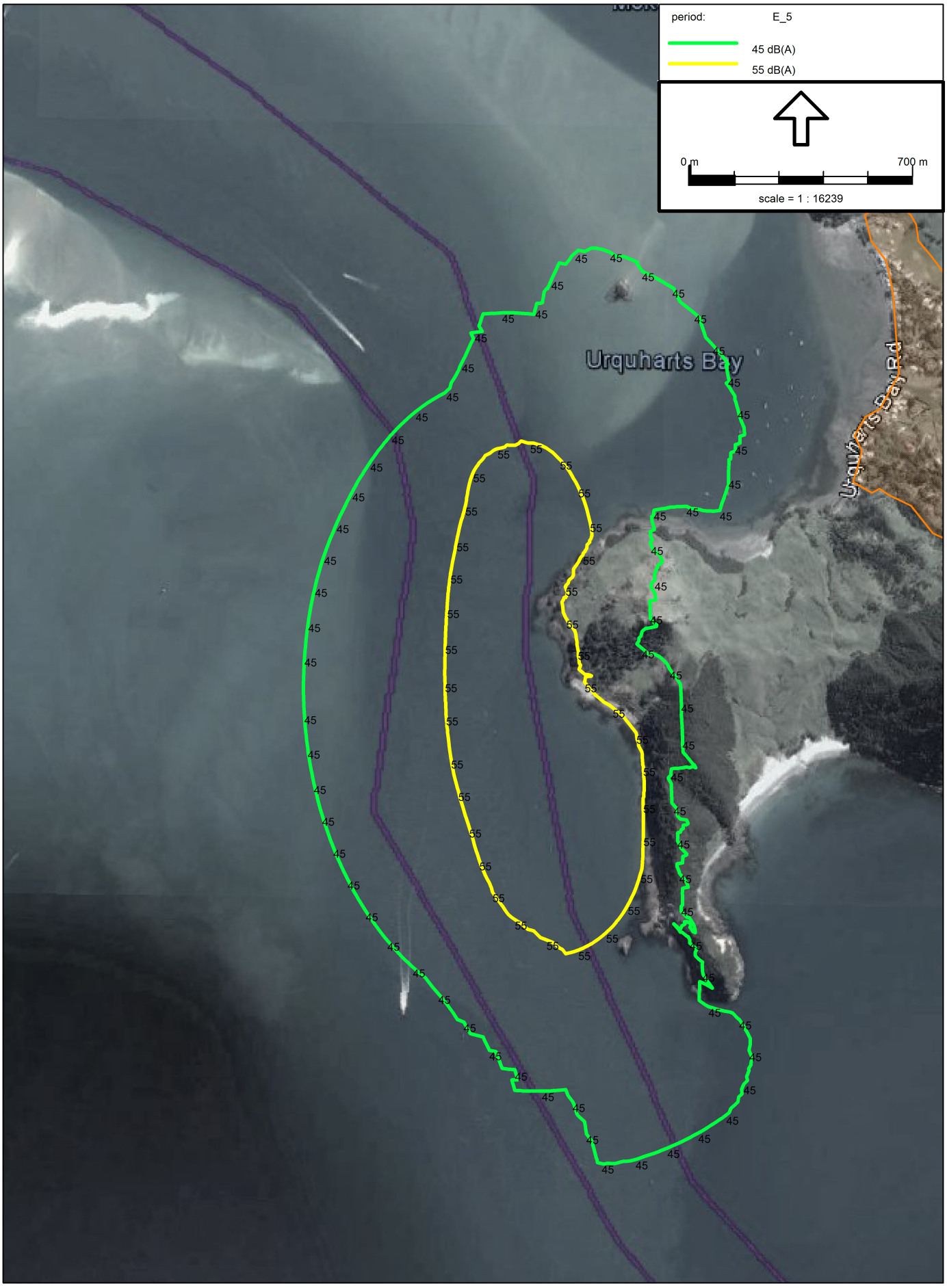
TSHD Mid Channel (Home Point): Worst Case Channel Position

Westerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_4_3m/s] , Predictor V11.10

Annexure Two: Technical Reports

i) **Assessment of effects on marine mammals from proposed deepening and realignment of the Whangarei Harbour entrance and approaches ('Marine Mammals Assessment'). Cawthron Institute. Deanna Clement and Deanna Elvines. Dated August 2017**

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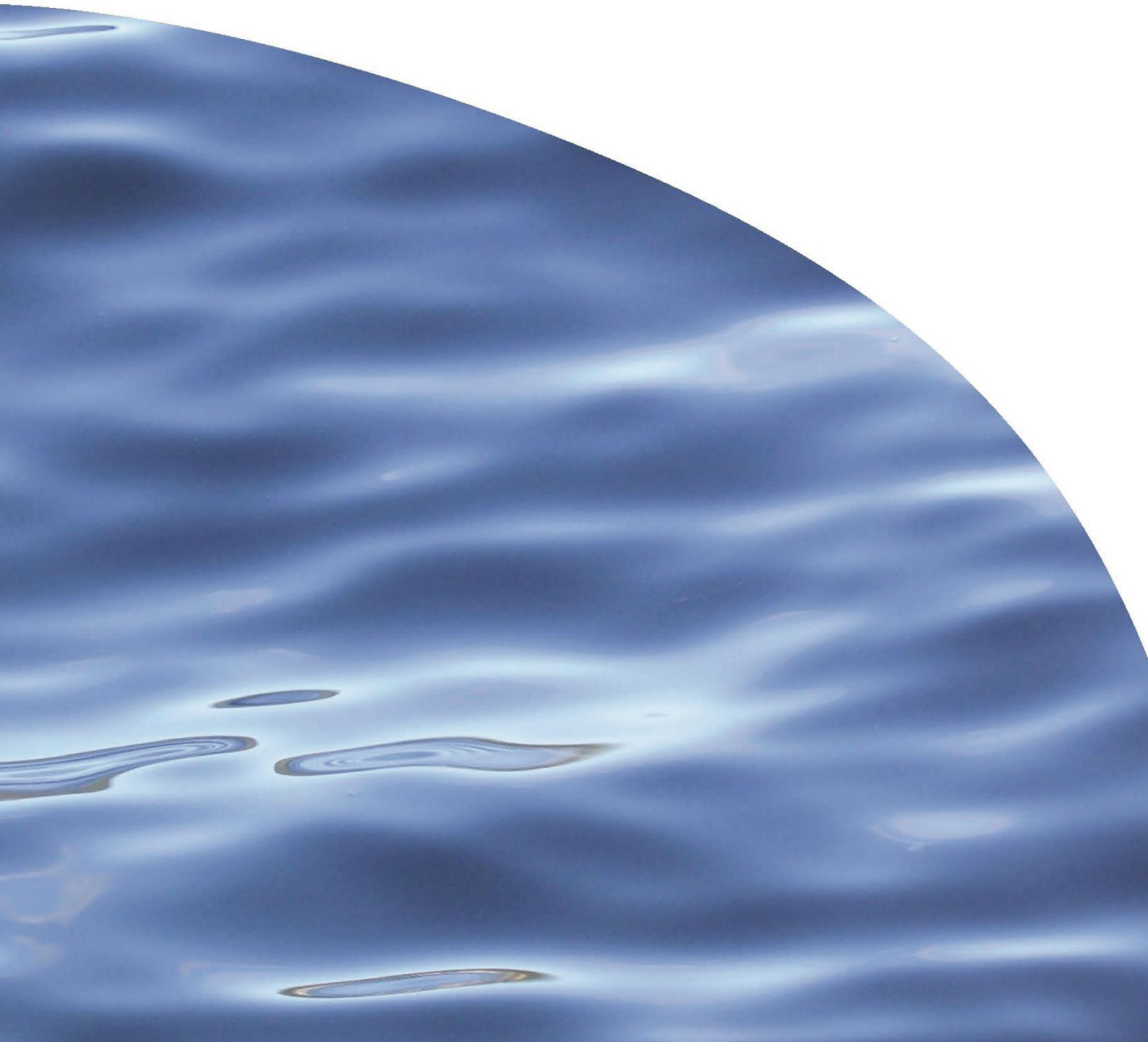
REPORT NO. 2910

ASSESSMENT OF EFFECTS ON MARINE MAMMALS FROM PROPOSED DEEPENING AND REALIGNMENT OF THE WHANGAREI HARBOUR ENTRANCE AND APPROACHES



ASSESSMENT OF EFFECTS ON MARINE MAMMALS FROM PROPOSED DEEPENING AND REALIGNMENT OF THE WHANGAREI HARBOUR ENTRANCE AND APPROACHES

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Prepared for Chancery Green on behalf of the New Zealand Refining Company Limited (trading as 'Refining NZ')

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ISSUE DATE: 11 August 2017

RECOMMENDED CITATION: Clement D, Elvines D 2017. Assessment of effects on marine mammals from proposed deepening and realignment of the Whangarei Harbour entrance and approaches. Prepared for Chancery Green. Cawthron Report No. 2910. 46 p. plus appendices.

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EXECUTIVE SUMMARY

Refining NZ (RNZ) is proposing to utilise more heavily-laden tankers to transport crude oil to its refinery in Whangarei Harbour, which would ultimately result in fewer crude oil shipping movements compared to current numbers. To accommodate heavier vessels, Whangarei's inner harbour, harbour entrance and various locations along the shipping channel would need to be dredged, some areas re-aligned and navigational aids modified accordingly. As part of the resource consent application process, RNZ contracted the Cawthron Institute to investigate possible environmental effects of the proposal on local and regional marine mammal species. This report outlines and assesses the potential effects of dredging, disposal and pile-driving activities on the relevant marine mammals.

Out of the 29 marine mammal species that have been sighted or stranded within Whangarei and Bream Bay waters, only four species regularly or seasonally frequent these coastal waters. These species are bottlenose dolphin, orca, Bryde's whale and common dolphin. Several other species, that visit the area less frequently, are also considered in this report because various life history dynamics (e.g. low population numbers) or species-specific sensitivities (e.g. acoustically sensitive) make them potentially vulnerable to effects of dredging. Tangata Whenua also hold most of these species in high regard, as their name for the harbour, Whangarei te rerenga parāoa, means 'the gathering place of whales'.

The direct effects of dredging and pile-driving activities that are most relevant to marine mammal species in the Whangarei region are: vessel strike, increased underwater sound production and possibly the risk of entanglement. While these effects have the greatest potential consequences (i.e. injury or death of a marine mammal), the actual likelihood of them occurring in this case is low, and overall the effects are deemed *de minimis* with proposed mitigation actions.

Indirect effects of dredging and disposal activities on marine mammals may result from physical changes to the habitat itself that adversely affect the health of the local ecosystem and/or impinge on important prey resources. Given the location and habitats associated with the dredging proposal, the review of possible indirect effects to the ecosystem focused on: quality of spoil; and ecological effects on the benthos and associated fish assemblages, including the effects of any resulting turbidity plumes. Overall, any indirect effects of project activities are not expected to be detrimental for local or visiting marine mammals in the region, and any such effects will be temporary.

Several avoidance/remediation/mitigation and monitoring measures are recommended, including an informative (rather than an impact) monitoring plan. Recommended measures involve a combination of visual sightings (both opportunistic and from the project vessels themselves) with simultaneous passive underwater acoustic monitoring collected within the proposal area before, during and after dredging and disposal activities. Such a programme will report on the actual effects of dredging and pile-driving on New Zealand marine mammals while also assessing the effectiveness of the mitigation measures employed.

TABLE OF CONTENTS

1. SCOPE OF WORK 1
1.1. Description of proposal 1
1.2. Scope of assessment 1
2. DESCRIPTION OF EXISTING ENVIRONMENT 2
2.1. General site description 2
2.2. Species of concern 2
3. ASSESSMENT OF ACTUAL AND POTENTIAL EFFECTS 5
3.1. Direct effects 5
3.1.1. Vessel strikes 5
3.1.2. Underwater noise 7
3.1.3. Possible entanglement in operational debris 19
3.2. Indirect effects 19
3.2.1. Quality of dredge spoil 20
3.2.2. Effects on habitat and prey species 21
3.3. Recommended avoidance, remediation and mitigation measures 23
3.4. Recommended monitoring 29
3.4.1. Capital dredging 30
3.4.2. Monitoring during dredging and disposal 31
3.4.3. Maintenance dredging 33
3.4.4. Pile driving 33
4. PRE-SUBMISSION CONSULTATION 35
4.1. Issues raised in the Tangata Whenua O Whangarei Te Rerenga Paraoa draft cultural effects assessment 35
4.1.1. Vessel strikes 35
4.2. Issues raised by Forest & Bird 37
4.2.1. Underwater noise issues 37
4.2.2. Lack of proposed marine mammal surveys 38
4.2.3. Resulting shipping issues 39
4.2.4. Other issues 39
5. CONCLUSIONS 41
6. REFERENCES 43
7. APPENDICES 47

LIST OF FIGURES

Figure 1. Opportunistic sightings (left) and strandings (right) of marine mammals prevalent in northeastern coastal waters between the Bay of Islands to the north and Whangaparaoa and Great Barrier Island to the south 3
Figure 2. Schematic summary of overlap in frequency of marine mammal communication/hearing, dredge noise production. 12
Figure 3. Expected behavioural response range for marine mammal groups during dredging using the medium-sized trailing suction hopper dredge at both the mid- and outer-channel locations.. 15

LIST OF TABLES

Table 1. Marine mammal species potentially affected by the proposal and areas of concern. 4
Table 2. Summary of potential effects on marine mammal species from the dredging of Whangarei Harbour entrance and associated disposal within Bream Bay with mitigation measures. 9
Table 3. Auditory masking and behavioural impact ranges for the three modelled species in Pine and Styles (2016), using both the small and medium-sized trailing suction hopper dredge (TSHD) in the various channel locations.. 14
Table 4. Proposed mitigation goals and practices to mitigate or minimise the risk of any adverse effects of dredging activities on marine mammals in Whangarei Harbour and Bream Bay. 28

LIST OF APPENDICES

Appendix 1. Short-term passive underwater acoustic survey of Whangarei Harbour entrance and Marsden Point: preliminary investigation by Pine and Styles 2015. 47
Appendix 2. Theoretical zones of auditory influence and sound threshold criteria..... 70
Appendix 3. Marine wildlife management plan for the proposed capital dredging and pile driving. 73
Appendix 4. Description of the recommended marine mammal monitoring for the proposed capital dredging. 80
Appendix 5. Reported occurrences of marine mammals in the Whangarei coastal region and harbour since March 2015. 85

1. SCOPE OF WORK

1.1. Description of proposal

Refining NZ (RNZ) operates New Zealand's only oil refinery based at Marsden Point at the entrance to Whangarei Harbour. In order to improve competitiveness by reducing freight costs, the company is investigating options to deepen and realign the entrance channel to Whangarei Harbour so that more heavily-laden tankers (which require deeper drafts) can access its jetty, resulting in fewer ship movements. To accommodate heavier vessels, the inner harbour, harbour entrance and various locations along the shipping channel would need to be dredged and some areas realigned. Inner harbour dredging is likely to involve creation or deepening of 'jetty pockets' to allow for berthing of vessels with deeper drafts. The proposal will also include disposal of dredge spoil in the coastal marine area, as well as periodic maintenance dredging (every 2–20 years depending on location) to address subsequent sedimentation in the proposal area. It will also include the relocation of some existing navigation aids and installation of five new navigation aids.

1.2. Scope of assessment

This report constitutes the second of a two-phase assessment. The first (Phase 1) report (Clement & Elvines 2015) consisted of a desktop review of the marine mammal populations utilising Whangarei Harbour and the wider Bream Bay ecosystem; and a literature review of the potential effects currently associated with dredging/disposal activities and marine mammals. The Phase 1 report, along with additional information from other consultancy reports, forms the basis of the final Phase 2 assessment. This Phase 2 report is a comprehensive assessment of effects of the proposed activities on local and visiting marine mammals, with recommended avoidance, remediation and mitigation options, and is intended to support the final resource consent application. It specifically includes:

- a summary description of the existing environment in terms of those marine mammal species most susceptible to any effects of the proposed activities
- categorisation of any impacts in the context of the actual project area and environment, based on the findings of other relevant reports (e.g. underwater noise, ecology, hydrodynamics)
- categorisation of the overall risk of any resulting effects in terms of scale, duration/persistence, likelihood and possible consequences
- recommendations for avoidance, remediation and mitigation options based on the final risk assessment of effects.

2. DESCRIPTION OF EXISTING ENVIRONMENT

2.1. General site description

Whangarei Heads is also known as 'Whangarei te rerenga parāoa', which means 'Whangarei, the gathering place of whales'. While this reference is also thought to be a metaphor for the gathering place of chiefs[1], the significance of whale migrations past this region is supported by the number of whaling stations found north near Whangamumu and along the entire eastern coastline of the North Island during the late 1800s and early 1900s (Dawbin 1956).

Out of the more than 50 species of cetaceans (whales, dolphins and porpoises) and pinnipeds (seal and sea lions) known to live or migrate through New Zealand waters, at least 27 cetacean and two pinniped species have been sighted or stranded along the north-eastern coastline of the North Island. When considering potential implications of coastal developments on marine mammals, the importance of Whangarei waters needs to be considered in the context of the species' regional and New Zealand-wide distributions, given that most species regularly range for hundreds to thousands of kilometres. Hence, Figure 1 highlights the various marine mammal species found to frequent north-eastern coastal regions between the Bay of Islands to the north and the entrance to the Hauraki Gulf and Great Barrier Island to the south.

2.2. Species of concern

The marine mammals most likely to be affected by the proposed project include those species that frequent the Whangarei Harbour and Bream Bay regions year-round or on a semi-regular basis, including bottlenose dolphins (*Tursiops truncatus*), orca (*Orcinus orca*), Bryde's whale (*Balaenoptera edeni)* and common dolphins (*Delphinus delphis*; Clement & Elvines 2015). Although infrequent visitors, other species of concern include those that are more vulnerable to anthropogenic (human-made) impacts due to various life-history dynamics (e.g. southern right whales due to low population numbers) or species-specific sensitivities (e.g. pilot whales due to underwater noise sensitivities). Given the reference to whales in their name for the harbour, Tangata Whenua o Whangarei Te Rerenga Paraoa are also concerned about the continued presence of several marine mammals in the region. Table 1 summarises those marine mammal species considered further in terms of any dredging/disposal effects associated with this proposal.

.

[1] A history of Ngati Wai – First of Four Instalments by Morore Piripi (http://teaohou.natlib.govt.nz/journals/teaohou/image/Mao37TeA/Mao37TeA018.html).

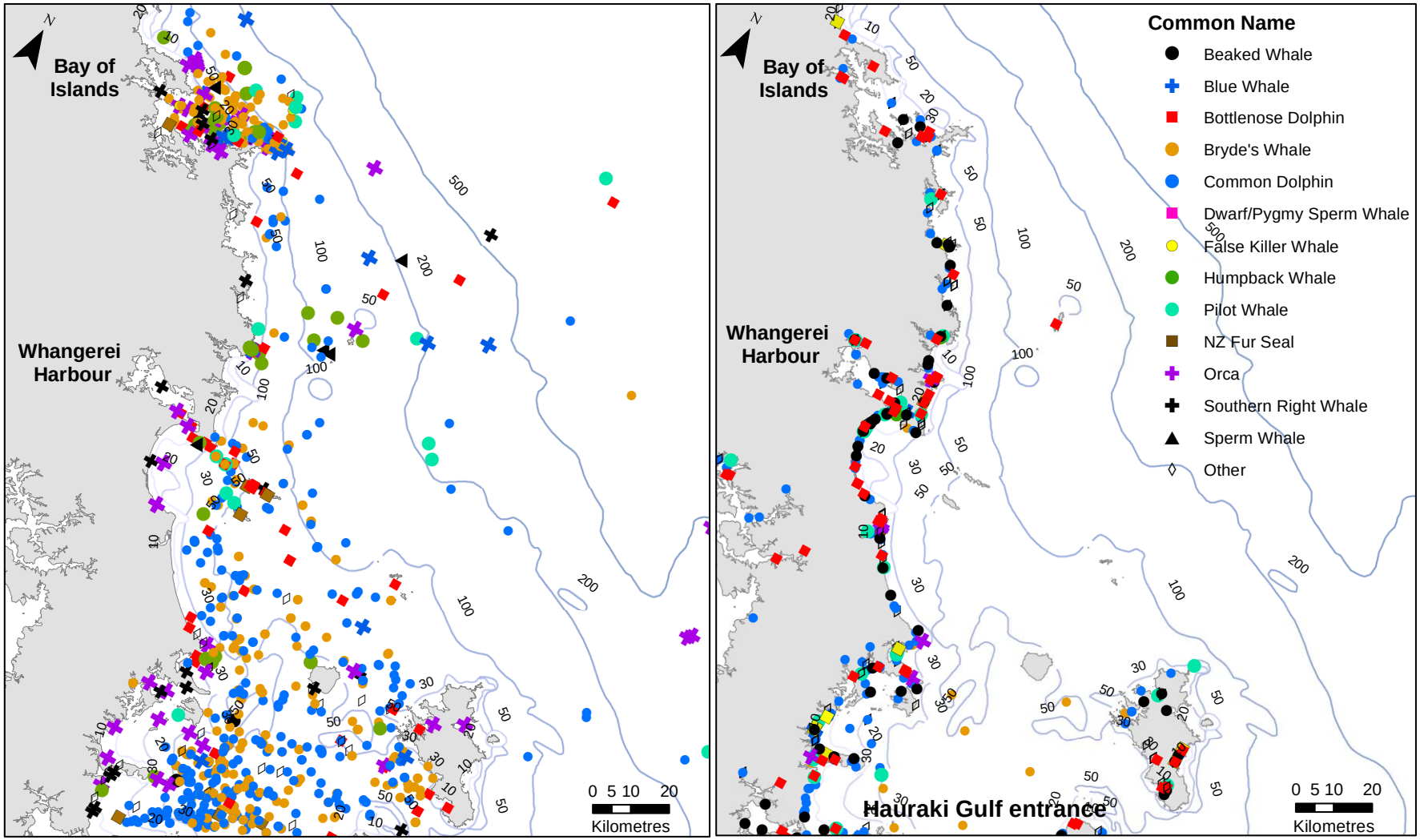

Figure 1. Opportunistic sightings (left) and strandings (right) of marine mammals prevalent in north-eastern coastal waters between the Bay of Islands to the north and Whangaparaoa and Great Barrier Island to the south (Department of Conservation's sighting and stranding database).

Table 1. Marine mammal species potentially affected by the proposal and areas of concern (modified from Clement & Elvines 2015).

Species	Resident or semi-resident	Conservation concern	Acoustic concern	Tangata whenua concern
Bottlenose dolphin	✓	NE	MF	✓
Orca	✓	NC	MF	✓
Bryde's whale	✓	NC	LF	✓
Common dolphin	✓		MF	✓
NZ fur seal			OP	✓
Pilot whale			MF/AS	✓
Beaked whale			MF/AS	✓
Southern right whale		NV	LF	✓
Humpback whale			LF	✓
Sperm whale			MF	✓
Pygmy sperm whale			HF/AS	✓

The definitions used in the table are:

- NC – Nationally Critical, NE- Nationally Endangered, NV – Nationally Vulnerable (Baker et al. 2016)
- LF – Low-Frequency cetacean hearing group; 7 Hz-35 kHz, all baleen whales
- MF - Mid-Frequency cetaceans – 150 Hz-160 kHz, all toothed cetaceans except those listed in high-frequency category
- HF - High-Frequency cetaceans - 275 Hz-160 kHz (i.e. *Kogia*, cephalorhynchid (Hector's dolphin) (NOAA 2016)
- AS – species thought to be more Acoustically Sensitive to underwater noise than other species (Clement & Elvines 2015, Appendix 1)
- OP – acoustic sensitivity (60 Hz to 39 kHz) consistent with the generalised Otariid Pinniped group for sea lions and fur seals underwater (NOAA 2016).

This north-eastern coastline represents some of the largest groupings of common dolphins and beaked whale species around the North Island, while potentially supporting isolated sub-populations of bottlenose dolphins, orca and Bryde's whale (Clement & Elvines 2015). However, based on the available species data, and in reference to Section 6(c) of the Resource Management Act (RMA) [2], Policy 11 of the New Zealand Coastal Policy Statement (NZCPS), and Method 9.2.5.2 of Northland's Regional Coastal Policy (RCP)[3], Whangarei Harbour and nearby Bream Bay waters are not considered ecologically significant in terms of feeding, resting or breeding habitats for any particular species relative to other regions along the north-eastern coastline. Instead, Whangarei Harbour and Bream Bay coastal waters represent a small fraction of similar habitats available to support these species that utilise the larger north-eastern coastal region (Clement & Elvines 2015). While several whale species have their regular migration routes through this region, the Harbour and Bream Bay are not considered as ecologically important migration corridors as most animals generally pass by the area further offshore.

[2] Section 6(c) - the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna.

[3] Appendix 9 - The Council has used the following criteria to determine those areas of important conservation value identified in the Plan as Marine 1 Management Areas. 5 – Marine Mammals and Birds Area including or near any: (a) marine mammal breeding or haul-out site.

3. ASSESSMENT OF ACTUAL AND POTENTIAL EFFECTS

The purpose of the Phase 1 report was to review and determine which effects of dredging and / or disposal on marine mammals needed to be considered further in the context of this proposal. These effects, including any associated with pile driving, are outlined in this section and discussed in further detail below.

3.1. Direct effects

Most consequential interactions between marine mammals and coastal development usually result from a direct overlap between the spatial location of anthropogenic activity and important habitats of the species (i.e. feeding or nursing grounds). The act of disturbing and / or removing bottom substrate in itself is not expected to directly affect any marine mammals known to frequent Whangarei waters. Instead, the associated increase in vessel activity, resulting production of underwater sound, and physical activities within the general harbour entrance region are the more likely factors by which marine mammals will be affected.

3.1.1. Vessel strikes

A recent worldwide review of dredging effects suggests that the risk of collision between dredge vessels and marine mammals will be minimal if the activity avoids critical habitats and seasons when the species of concern may be more 'distracted' while feeding or resting (Todd et al. 2015). Particular species (i.e. baleen whales) and certain age groups (i.e. calves and juveniles) are noted as being more susceptible to vessel strike than others. In this case, the species considered most vulnerable to any potential vessel collisions include Bryde's, humpback and southern right whales and to a lesser extent, bottlenose dolphins and orca given their current endangered species status rather than proneness for vessel strike.

The likelihood of vessel strike also depends on a number of operational factors including vessel type, speed, and location (Van Waerebeek et al. 2007). The greatest increase in both the risk of a collision and the likelihood that it will result in severe injury or death occurs at speeds over 11 knots (Vanderlaan & Taggart 2007; Gende et al. 2011). This might explain why dredge vessels, which generally have maximum transit speeds of only 12–16 knots (Brunn et al. 2005), have been involved in only one out of the 134 worldwide collision cases (in which the vessel type was known) reported between 1975 and 2002 (Jensen & Silber 2004).

The proposed capital dredging of the Whangarei Harbour entrance will involve the removal of up to 3,700,000 m^3 of dredge spoil to the proposed disposal site(s) in Bream Bay. Sediment volumes for maintenance dredging are likely to be ~3.4% (per annum) of the capital disposal volume. Depending on the type of dredge vessel used,

this removal will involve several thousand return trips (relatively fewer trips will be associated with larger vessels) between the various locations over an approximate six-month period of capital dredging. Significantly reduced time scales and vessel movements will be associated with maintenance dredging (Tonkin & Taylor 2016).

Despite an overall increase in vessel traffic during dredging[4], the likelihood of a vessel strike (injury or mortality) associated with the proposal is assessed as *low* for migrating baleen whales, odontocete and pinniped species and the significance of the effect is considered *de minimis* with proposed mitigation actions (Table 2, see Section 3.3 for details). This conclusion is based on local species information (Clement & Elvines 2015) and relevant factors as summarised below:

Spatial and temporal factors

- Relatively temporary increase in capital dredge vessel traffic (approximately six months) within a fairly localised area compared to the rest of Whangarei Harbour and the wider Bream Bay system (i.e. ~3–7 km distance between proposed channel and disposal sites).
- Low probability of the dredge vessel encountering a migrating whale as currently only 1–3 individual whales are sighted within Whangarei Harbour and Bream Bay each year; the majority passing by Hen (Taranga) and Chicken Islands in deeper, more offshore waters (e.g. further than 5 to 10 nm) (Clement & Elvines 2015).
- Most whales occur in the area for a limited period each year; mainly in the winter months and some spring months, and most only remain for a day up to a week (the exception being Bryde's whales).
- Most odontocete and pinniped species known to frequent Whangarei waters are in regular contact with all types and speeds of commercial and recreational vessels throughout their entire distributional range.

Known collision factors

- Low probability of the dredge vessel striking an individual animal given the vessel will be stationary (cutter-suction dredges and back-hoe dredges) or slow moving (trailer-suction hopper dredges) while dredging. When travelling to the disposal site, the normal operating speed of the dredge vessel (15 knots or less, depending on dredge vessel used; Tonkin & Taylor Ltd 2016) should be slow enough for the animals to manoeuvre out of the path of the vessel.
- Most dolphin species have a general attraction to boats and safely approach and/or bowride with numerous vessels. Fur seals often respond neutrally to boats when in the water (although they may bowride occasionally).
- Whangarei Harbour and Bream Bay are not considered unique or important feeding, resting or nursery habitats for any residential or visiting species, hence

[4] While harbour traffic will temporarily increase during the capital dredging project, it will decrease over the long-term as the same, but more heavily-laden, tankers will result in fewer overall ship movements (Navigatus 2016; section 4.5, pg. 12).

individuals are less likely to be 'distracted' by such activities, and are thus less vulnerable to collision risk.

3.1.2. Underwater noise

The proposed capital and maintenance dredging activities, as well as the relocation and placement of navigation aids, will introduce a source of vessel traffic and mechanical activities that will generally increase the amount of anthropogenic underwater sound produced in the area (e.g. CEDA 2011; WODA 2013). Materially increasing underwater noise can affect marine mammals because they rely heavily on underwater sounds for communication, orientation, predator avoidance and foraging. Additional underwater noise may adversely affect marine mammals through changes in behaviour, masking of important noise signals, temporary auditory shifts (TTS; temporary threshold shift), or permanent injury (PTS; permanent threshold shift) (Todd et al 2015; Clement & Elvines 2015, Madsen et al. 2006).

Dredge noise

Generally, the noises produced from dredging activities are continuous, broad-band sounds at frequencies mostly below 1 kHz (Todd et al. 2015). Underwater noise reviews by CEDA (2011) and WODA (2013) found that trailer-suction hopper dredges (TSHD), cutter-suction dredges (CSD) and back-hoe dredges (BHD), [the main types of dredges considered for this proposal], produce mostly low frequency, omni-directional sounds between 100-500 Hz (Figure 2). Their bandwidths can fluctuate as low as 20 Hz and as high as 20 kHz. Dredge-related sound levels will be dependent on the specific vessel selected to undertake the proposed works (Pine & Styles 2016). However, sound levels generated from dredgers similar to that considered for this proposal generally range between 164 and 185 dB *re*1 µPa rms @ 1 m [5] (Pine & Styles 2016). These are generally lower sound levels than a powerful ship which is between 180-190 dB *re*1 µPa rms @ 1 m (OSPAR 2009; Todd et al. 2015). The exact sound ranges of dredges are also dependent more on the sediment extraction process and the types of sediment being extracted, with coarser gravel causing greater sound levels (WODA 2013 and references therein). Sediments being removed for the proposal are predominantly sand and shell fragments (MSL 2016).

[5] The term 'dB *re*1 µPa rms @ 1 m' represents the sound pressure level that has been back calculated to a standardised distance of one metre distance from the source, and termed source level. RMS = root mean square or mean squared pressure and rms levels are often used for the assessment of continuous noise sources. The averaged square pressure is measured across some defined time window that encompasses the signal.

Table 2. Summary of potential effects on marine mammal species from the dredging of Whangarei Harbour entrance and associated disposal within Bream Bay with mitigation measures.

Potential environmental effects	Spatial scale of effect on marine mammals	Persistence / duration of effect for marine mammals	Consequences for marine mammals	Likelihood of effect	Avoidance Factors / Mitigation Options (see Section 3.3 and Table 4 for more details)	Significance Level of Residual Effect
Marine mammal / vessel strike due to increased vessel activity	**Medium to Large** Limited to vessel movements between the harbour entrance and disposal site (~3-7km)	**Short to Moderate** Whales are only present in area for a day to weeks; approximately 6 months for local dolphins and pinnipeds (during capital dredging), and < 6 months periodically every 2–20 years (for maintenance dredging).	**Population Level:** Death or injury of endangered or threatened species **Individual Level** Death or injury of non-threatened species	**Low**	• Very low probability of whale encounter • Often stationary and relatively slow speeds of dredging vessels • Adoption of boating behaviour guidelines • Liaison with DOC about possible whale presence in area while dredging	***De Minimis***
Behavioural and / or physical responses to underwater sound from: • **Dredging / disposal activities**	**Small to Large** Dependent on sounds produced; behavioural / masking responses predicted at large distances (several kms), potential TTS within close proximity (< 10 m)	**Short to Moderate** Whales are only present in area for a day to weeks; approximately 6 months for local dolphins and pinnipeds (during capital dredging), and < 6 months periodically every 2–20 years (for maintenance dredging).	**Individual to Regional Level:** Individuals may avoid or approach dredging activities; individuals subject to potential TTS; possible acoustic masking between conspecifics (regional).	**Low -** TTS, masking **to** **Moderate -** behavioural	• Very low probability of whale presence • BPO (best practicable option) used in dredge vessel selection • Regular maintenance and proper up-keep of all dredging equipment and the vessel • Designated marine mammal observer and precautionary safety zone (50 m) for cessation of active dredging while any marine mammals present within zone (daylight hours only)	**Nil –** TTS (daylight) **to** ***De Minimis* –** TTS (overnight), behavioural, masking
• **Pile driving for navigational aids**	**Small to Large** Behavioural / masking responses predicted at large distances (several kms), potential hearing injury/impairment with close proximity	**Short** Estimated 2 days	**Individual to Regional Level**: Individual avoidance or hearing injury/impairment (TTS/PTS), possible acoustic masking between conspecifics (regional)	**Low –** PTS, TTS **to** **High** - masking, behavioural	• BPO used in pile and pile-driving technique selection • Regular maintenance and up-keep of equipment • Ramping up and/or soft starts • Safety zone enforced by marine mammal observer	**Nil –** TTS / PTS **to** ***De Minimis* –**, behavioural, masking
Marine mammal entanglement in operational gear and / or debris	**Small to Medium** Limited to immediate waters around operating dredge vessels	**Short to Moderate** Mainly while dredge vessel is operating; approximately 6 months (during capital dredging), and < 6 months periodically every 2–20 years (during maintenance dredging).	**Population Level:** Death or injury of endangered or threatened species **Individual Level** Death or injury of pinniped or dolphin	**Low**	• Avoid use of loose rope and other lines • Compliance with NZ Maritime Rules Part 180	***De Minimis***
Contaminant effects on marine mammals from dredge sediments and / or spoil	**Medium to Large** Limited to immediate waters and habitats adjacent to dredge and disposal sites (< 1–3 km)	**Short to Persistent** Dependent on type and level of contamination in sediments	**Individual Level** Limited potential for any individual to consume more than few prey species exposed to dredging sediments	**Not Applicable to Low**	• Tested sediments have low to less than trace levels of contaminants and a low silt content (i.e. relatively lower potential for contaminant accumulation), with limited bioavailability and solubility • Continue to test sediments to ensure no contamination (i.e. prior to maintenance dredging)	**Nil to *De Minimis***
Marine mammal habitat and / or prey disturbance from loss of benthic habitat and increased turbidity from dredging and spoil disposal	**Medium to Large** Limited to immediate waters and habitats adjacent to dredge and disposal sites (< 1–3 km)	**Short to Persistent** Re-colonisation of benthos will begin during ongoing activities, and recovery within disposal site only after disturbance has ceased (e.g. 6-24 months). 99% of any given turbidity plume expected to settle out within less than a day.	**Individual Level** Possible avoidance of disturbed area, some individuals may approach disposal site(s) for foraging	**Not Applicable to Low**	• No unique feeding habitats in the proposed areas, and areas represent only a small portion of similar available habitat • Use of green valve disposal and monitoring thresholds to ensure turbidity limits	**Nil to *De Minimis***

Ranking of terms used in table:

- Spatial scale of effect: Small (tens of metres), Medium (hundreds of metres), Large (> 1 km)
- Duration of effect: Short (days to weeks), Moderate (weeks to months), Persistent (years or more)
- Consequence: Individual, Regional, Population
- Likelihood of effect: Not Applicable (NA), Low (< 25%), Moderate (25–75%), High (> 75%)
- Significance of effect: Nil (no effects at all), De Minimis (effect too small to be discernible or of concern), Less than Minor (discernible effect but too small to affect others), Minor (noticeable but will not cause any significant adverse effects), More than Minor (noticeable that may cause adverse impact but could be mitigated), Significant (noticeable and will have serious adverse impact but could be potential mitigated)

Understanding ambient underwater sound levels is important in assessing the potential scale and impact of additional underwater noises as these background noises, along with the physical environment, will influence the propagation and detection of any introduced sounds. In a study undertaken by Pine and Styles (2015; Appendix 1), the ambient background sound levels for the Whangarei Harbour region varied but were generally less than 119 ± 0.08 dB_{rms} re 1 µPa (based on no shipping in the area) and considered comparable to other nearshore habitats around New Zealand. The harbour was also similar to other New Zealand harbours in that lower frequencies (below 1 kHz) tended to dominate due to high vessel activity.

Marine mammal hearing

The lower frequency vocalisation ranges of southern right whales suggest their best hearing capabilities are at least between 50 Hz and 2 kHz (Parks & Tyack 2005) and 20 Hz to 12 kHz for humpbacks (McCauley & Cato 2003), while the generalised hearing range of most baleen whales is thought to be between 7 Hz and 35 kHz (NOAA 2016). These frequency ranges overlap with most anthropogenic underwater noise, including dredging activities as discussed above, meaning baleen whales are the species most susceptible to any noise effects from dredging (e.g. Clark et al. 2009).

Odontocetes (e.g. orca, bottlenose and common dolphins) generally communicate over a wider frequency range than baleen whales. They also have the capability to echolocate (produce biological sonar) for navigation and hunting. While most dolphins' functional hearing ranges are estimated to be quite large (mid-frequency hearing groups 150 Hz–160 kHz; NOAA 2016), and they can likely detect low-frequency sounds, their sensitivity significantly decreases at frequencies below 1–2 kHz (Au 2000; Southall et al. 2007). Pinnipeds' hearing ranges are thought to vary more widely (otariid pinnipeds e.g. NZ fur seal; 60 Hz–39 kHz; NOAA 2016), including some ultrasonic frequencies, and are quite sensitive to frequencies below 1 kHz (based on overseas research on Atlantic grey and harbour seals; Thomsen et al. 2009).

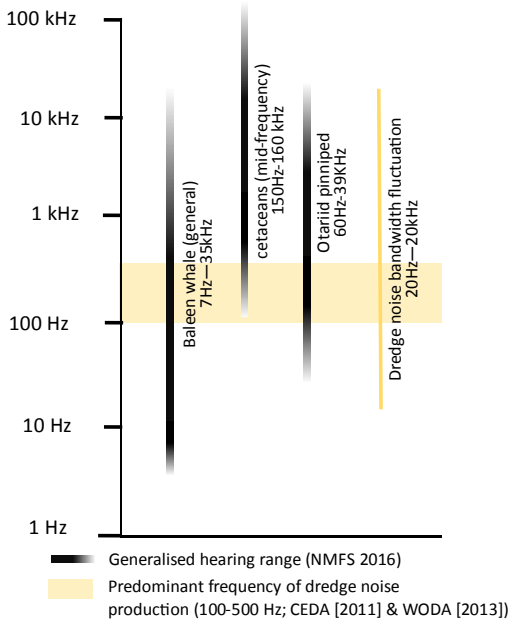

Figure 2. Schematic summary of overlap in frequency of marine mammal communication/hearing, dredge noise production.

Potential underwater noise effects

As evidenced by the spatial modelling results of Pine and Styles (2016) and local species information, the likelihood of any migrating baleen whales, odontocetes and fur seals being able to hear and behaviourally respond to underwater noise produced by dredging activity in the proposal areas is *low* to *moderate* (Table 2). This is dependent on the location of the animal in relation to the harbour, the dredge's location in the harbour entrance, and the size of the dredge vessel. A TSHD dredging in the outer channel location is expected to generate the largest spatial extent of noise, which is estimated to extend throughout the vicinity of Bream Bay (Figure 3), compared to other dredge types (CSD, BHD) and dredge locations (mid- and inner channel; Pine & Styles 2016).

The precautionary modelled scenarios in Pine and Styles (2016) estimate the potential onset for behavioural responses (e.g. changes in swimming direction, speed, surface intervals, respiration rates, vocalisation behaviours) in baleen whales to dredging noises may occur as far away as 18.5 km when using a medium-sized TSHD in the outer channel (Figure 3 and Table 3), and are based on NOAA's 120 dB re 1 µPa rms threshold[6] (Appendix 2). This radius is significantly less for mid-

[6] The 120 dB threshold has been used as a general guideline for assessing the possible spatial extent in which various marine mammals may detect and / or react behavioural to capital dredging sounds in the Whangarei and Bream Bay region. We have applied this particular threshold in the absence of any more up-to-date threshold information but acknowledge that this threshold, and its site- and species-specific approach in this proposal, is not necessarily the most appropriate threshold or approach for other such applications. See Appendix 2 for more details.

frequency cetaceans (i.e. orca, bottlenose, common dolphins) and otariid pinnipeds (i.e. fur seals). Any short-term auditory masking of particular communication signals for orca, bottlenose dolphin and NZ fur seal would be limited to 7.6, 4.7, and 14.7 km radius (respectively) from the dredge location when in the outer channel (Table 3) as a worst-case scenario.

The potential for the onset of temporary threshold shifts (TTS) are estimated to occur only when an animal is within 1–10 m of the TSHD during dredging operations, and only within 1 m for other dredge types (Pines & Styles 2016). No permanent hearing injuries (PTS) are predicted for any marine mammals regardless of dredge type or location, based on the estimated sound exposure levels being below the PTS thresholds. Noise generated from spoil disposal will be significantly lower than dredge noise, and will have a short duration (several minutes).

Table 3. Auditory masking and behavioural impact ranges for the three modelled species in Pine and Styles (2016), using both the small- and medium-sized trailing suction hopper dredge (TSHD) in the various channel locations. OP = Otariid Pinniped group, LF = Low Frequency group, MF = Mid-Frequency group (includes all other cetaceans considered for this proposal except pygmy sperm whale).

	Masking range (km)*		**Behavioural response range (km)†**	
Small TSHD	**Inner/mid-channel**	**Outer-channel**	**Inner/mid-channel**	**Outer-channel**
Orca	1.0	3.4	-	-
Bottlenose dolphin	1.1	3.3	-	-
Fur seal**	2.3	13.3		
LF (includes baleen whales)	-	-	2.2	17.8
MF (orca, bottlenose & common dolphin)	-	-	0.7	1.2
OP (i.e. fur seal)			1.1	5.2
Medium TSHD				
Orca	3.5	7.6	-	-
Bottlenose dolphin	3.2	4.7	-	-
Fur seal*	3.7	14.7	-	-
LF (i.e. baleen whales)	-	-	5.1	18.5
MF (e.g. orca, bottlenose & common dolphin)	-	-	1.1	1.8
OP (i.e. fur seal)			1.9	6.2

* Where available, these were based on the relevant species audiogram data (Pine & Styles 2016).

† Based on NOAA interim sound threshold guideline of 120 dB for behavioural disturbance, using hearing frequency for generalised group rather than individual species (see details in Appendix 2).

** Masking range based on northern fur seal audiogram data in the absence of NZ fur seal audiogram.

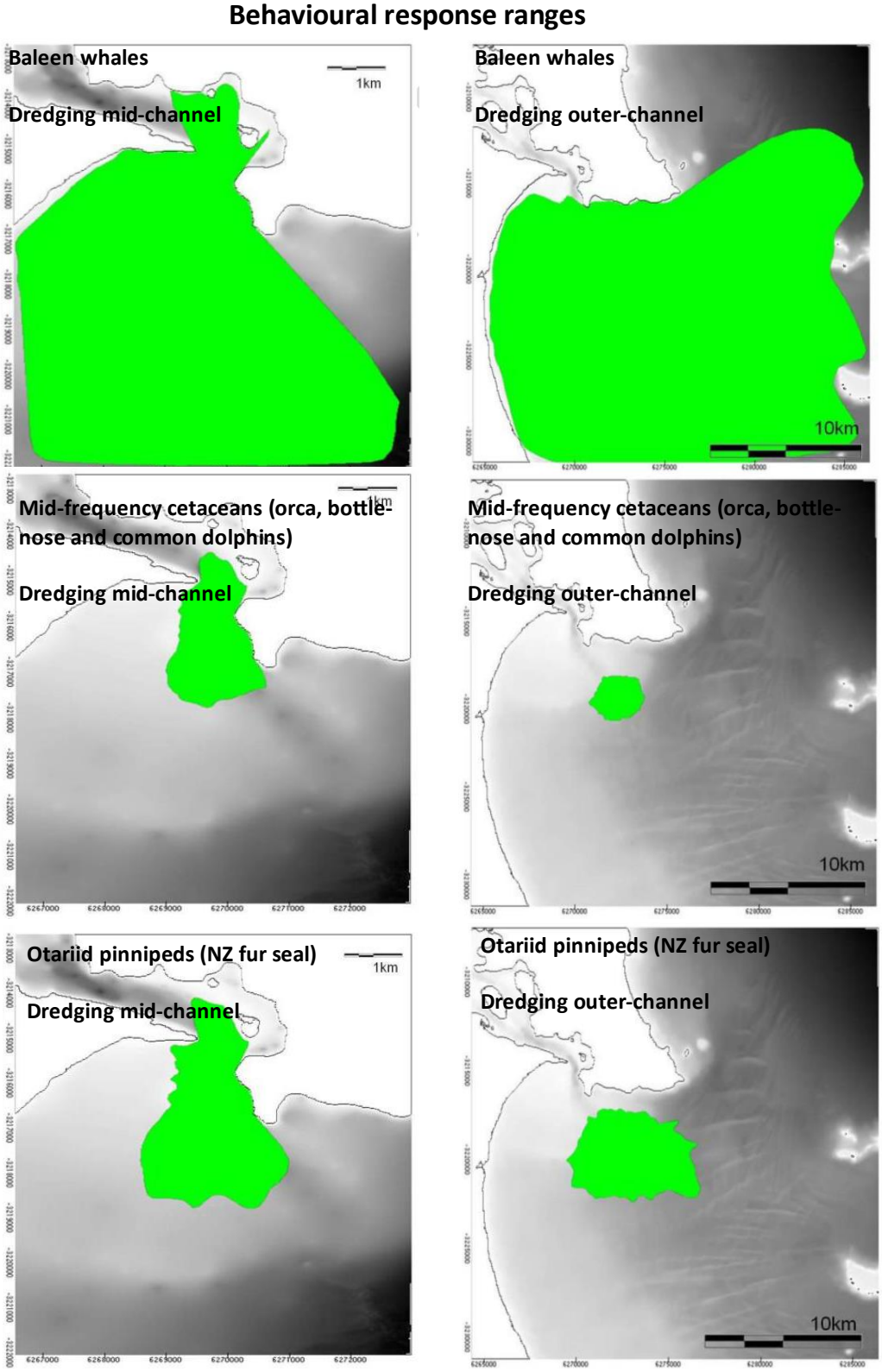

Figure 3. Expected behavioural response range for marine mammal groups during dredging using the medium-sized trailing suction hopper dredge at both the mid- and outer-channel locations. Note the change in map extent between dredge locations. Figures from Pine and Styles (2016).

Based on these modelled results and our Phase 1 review, any effects from additional underwater noise generated from the dredging proposal will likely be transitory and non-injurious. The overall levels and character of dredging noise will be generally comparable to existing vessel movements currently travelling to and from the harbour. Effects will be predominantly limited to the momentary masking of some noise signals (for example, members of the same species may find it more difficult to communicate across particular frequencies / levels while in proximity of the operating dredge); and a range of potential behavioural responses (for example, avoidance by mothers with calves but equally possible, attraction of lone males to areas in proximity of the operating dredge) depending on the species and individual animal (Pine & Styles 2016). The likelihood of any TTS effects occurring is considered *low* and any hearing injury effects (PTS) are *not applicable* based on modelling results. Therefore, with the recommended mitigation actions, the significance of any acoustic effects are considered to be *nil* to *de minimis* for both local and visiting species (Table 2; see Section 3.3 for more details). The most relevant factors contributing to this assessment are summarised below:

Spatial and temporal factors

- Relatively temporary increase in underwater noise from capital (approximately 6 months) and maintenance dredging activities based on proposed dredge schedule.
- Mainly lower-frequency noise generated by proposed dredge vessels and activities propagate farther underwater and may be detected several kilometres away (e.g. Figure 3); similar to the majority of commercial vessels currently entering and leaving the harbour.
- Only 1-3 migrating whales are sighted within the wider Bream Bay area each year, the majority pass by Hen (Taranga) and Chicken Islands in deeper, more offshore waters (e.g. further than 5 to 10 nm; Clement & Elvines 2015).
- Most whales occur in the area for a limited period each year; restricted mainly to winter months and some spring months when most only remain for a day or up to a week (the exception being Bryde's whales).
- Most odontocete and pinniped species known to frequent Whangarei waters are regularly exposed to similar types and levels of underwater noise from commercial and recreational vessels throughout their entire distributional range.
- Marine mammals may travel past the vessel while dredging is underway in order to enter or leave the harbour. However, no individuals are expected to approach and remain in close enough proximity to the vessel (i.e. 1–10 m) long enough for more than minor adverse effects to occur.

Known acoustic factors

- Dredge sound levels are not expected to exceed any permanent injury threshold criteria (Pine & Styles 2016, Appendix 2).

- Extremely close proximity to the dredge vessel sufficient for the onset of TTS to occur combined with visiting marine mammals' short-term visits to the area (i.e. dolphins—hours to days; and whales—days to weeks) ensure that the likelihood of exposure effects will be *low* to *not applicable* with mitigation (for more details see Section 3.3),
- Relevant environmental factors (i.e. shallow depths, relatively soft sediments; Coffey 2017; Pine & Styles 2016) may help dampen some underwater noise production in the lower, and some higher, frequency ranges.
- Limited overlap between the lower frequency sounds produced by dredge activities, and the functional hearing frequency ranges and sensitivities of odontocetes and pinnipeds.
- Whangarei Harbour and Bream Bay are not considered unique or particularly important feeding, resting or nursery habitats for any residential or visiting species.

Pile driving noise

Pile driving has been identified as one of the 'noisiest' of all construction sounds. It produces a very high source level as broadband impulses and has a high potential to disrupt marine mammal behaviour up to many kilometres away (Madsen et al. 2006). In close proximity, these impulses could induce acute stress and hearing impairment (i.e. permanent auditory threshold shift-PTS).

Bailey et al. (2010) measured actual pile-driving sounds off northeast Scotland at various distances ranging from 100 m to 80 km away from the source to determine potential impacts on marine mammals in the vicinity. The authors found any possible hearing impairments or injuries (TTS or PTS) were only possible within 100 m or less from the source and depended on exposure duration. Within 2 km of the source, peak sound energy was recorded between 100 Hz to 2 kHz, which decreased with increasing distance. The authors suggested, in this case, noise levels would more likely affect low- to mid-frequency marine mammals (e.g. baleen whales, orca, bottlenose and common dolphins).

To date, no known published studies have focused on the reactions of baleen whales to pile-driving activities and very few have observed cetaceans other than harbour porpoises. Based on their *in situ* measurements, Bailey et al. (2010) predicted that pile-driving sounds have the potential to elicit disturbance behaviours in minke whales and bottlenose dolphins as far as 40 and 50 km from the source, respectively.

The effect of pile driving on pinnipeds is less straightforward, with reported reactions of overseas pinnipeds ranging from little to no response in ringed seals (*Phoca hispida*: Blackwell et al. 2004) to significantly fewer harbour seals (*Phoca vitulina*) observed in haul-out areas located 10 km from pile-driving activities (Edrén et al. 2004). However, the authors noted that changes in haul-out numbers were short term

as the general abundance of seals showed no decrease over the whole construction period.

High-frequency cetaceans (*e.g.* pygmy sperm whales) will detect pile-driving sounds at similar distances to low- and mid-frequency cetaceans. However, as greater energy was generally found in the lower frequencies, Bailey et al. (2010) predicted strong avoidance behaviours occurring only within 20 km or less of the source for these species. For example, Tougaard et al. (2003) noted that harbour porpoises (a high frequency cetacean) in Danish waters showed strong negative responses to pile driving up to 15 km away with all porpoises leaving the area when the driving began, but later returning once the activity finished.

The proposed pile-driving activities will be of very short duration (approximately 4 hours per pile, or up to 2 days in total) and will involve the driving of steel tube piles at two different locations within Calliope Bay, just past the harbour entrance (RHDHV 2016; see figure E3 or appendix A drawing PA1028-MA-1121). It will likely involve either vibro hammer (continuous noise production) or traditional hammer (impulsive noise) piling techniques (summarised in RHDHV 2016). Bottom substrates at these locations are predominantly soft-sediments and within relatively shallow depths (~10 m), which means fewer impacts (or shorter duration vibro-hammer bursts) will be needed to drive the pile to the required sediment depth. In addition, soft sediments help attenuate (absorb or dampen) some of the lower frequency sounds and thus reduce the distance at which they can be detected (e.g. Gerstein & Blue 2006).

Underwater noise propagation modelling undertaken for similar coastal pile-driving activities in New Zealand suggest pile-driving noise may be detectable and with potential behavioural responses (e.g. avoidance / abandonment of the area) occurring at a scale of several kilometres (pers. comm. M Pine, Styles Acoustic Group). However, the distance within which PTS and TTS could occur are likely to be relatively small (e.g. < 300 m from work area; DPTI 2012). While pile-driving activities do have the potential to cause injury within a small radius, it is unlikely that PTS would be caused by a single impact nor would an individual animal remain within close enough proximity of the source for an extended period for any cumulative exposure to occur.

In this case, effects from piling noise are more likely to involve temporary acoustic masking or behavioural responses of marine mammals in the immediate vicinity (several kilometres) of the pile-driving works, which may see animals moving to other regions of the proposal area (e.g. up into the inner harbour or other areas of the wider Bream Bay area) while piling is underway. The likelihood of TTS or PTS as a result of pile driving is considered *low* due to the short duration, expected small spatial envelope for the onset of any physical hearing effects and an extremely short exposure time to any individual marine mammal; and with the recommended mitigation actions, the effects will be *nil* to *de minimis*. The relevant factors

contributing to this conclusion are very similar to those listed above for dredging effects. Any additional factors specific to pile driving are summarised below:

Spatial and temporal factors

- Any underwater noise produced from the proposed pile driving will be extremely short-term (~4 hrs and up to 2 days) and localised mainly to the surrounding harbour entrance area and some nearby Bream Bay areas.

Known acoustic factors

- A small estimated spatial zone for the onset of TTS or PTS to occur,(e.g., < 300 m; DPTI 2012) will be confined mainly to Calliope Bay and ensures that the likelihood of exposure effects will be *low to not applicable* with mitigation (for more details see Section 3.3).
- The semi-confined nature of the pile-driving locations means the spatial area for any behavioural responses will be relatively small (several kilometres) and unlikely to affect most odontocetes or any whales migrating offshore.
- All pile driving will occur in shallow (~10 m) and soft sediment areas, which has natural attenuation properties that will help dampen some noise production.

3.1.3. Possible entanglement in operational debris

The major hazard associated with marine debris from coastal development projects to marine mammals is the possibility of entanglement (Laist et al. 1999). Whales, dolphins and pinnipeds are often attracted to floating debris, with a potential risk of becoming entangled in floating lines and netting (e.g. Suisted & Neale 2004; Groom & Coughran 2012). Loose, thin lines pose the greatest entanglement risk (e.g. lines used to tie up boats, floats and other equipment) and especially lost ropes and lines.

However, the only ropes required as part of this proposal are to secure the barge to the BHD or CSD during dredging of the inner- or mid-channel. Thus, the nature of dredge operating activities and equipment involved means the likelihood of entanglement in marine debris from dredging and disposal is *low* (Table 2). Any subsequent effects to marine mammals are expected to be *de minimis* in well-maintained coastal development projects with proper waste management programmes in place (e.g. secure onboard storage of lines, ropes, and waste) in order to comply with the NZ Maritime Rules Part 180.

3.2. Indirect effects

Coastal dredging and the associated spoil disposal within any established ecosystem will result in some change to that system (e.g. loss of habitat; Todd et al. 2015). It is unlikely that the actual changes themselves will affect marine mammals directly; rather, concern relates to possible indirect flow-on effects that these changes might

have on the ecosystem as a whole and, more specifically, on the health of prey resources of marine mammals. As such, potential indirect effects from this proposal that may affect marine mammals include bioaccumulation of contaminants that may be associated with dredge spoil, loss or disturbance of prey species due to habitat loss, benthic disturbance or turbidity plumes.

3.2.1. Quality of dredge spoil

The level of exposure to contaminants for any local marine mammals will depend on the chemical characteristics of the dredge spoil and the subsequent uptake by relevant prey resources (e.g. plankton, fish, rays, cephalopods), as well as the feeding habits and ranges of the marine mammal species (e.g. Jones 1998; Evans 2003). Whangarei Harbour and Bream Bay, relative to other regions along the north-eastern coastline, are not currently considered unique or important feeding habitats for local or visiting marine mammals (see Section 2.2). In fact, most local species, such as bottlenose dolphins, common dolphins and fur seals, are generalist feeders that will opportunistically forage throughout the entire proposal area as well as more offshore waters, and along most north-eastern coastal regions (see Clement & Elvines 2015). While orca are considered more specialist feeders, they regularly forage for rays among estuarine mud and sand flats areas from the Bay of Islands to Auckland Harbour (Visser 1999). Some migrating species (i.e. humpback whales), may not even feed while passing through New Zealand waters during parts of their migration (Dawbin 1956).

Todd et al. (2015) noted that risks are greatest to marine mammals only when dredging *contaminated* sediments (i.e. not all sediments have heavy contaminant loads), and concluded that in even those cases, exposure was still spatially restricted. Sediment sampling associated with the capital dredge spoil has not identified any contaminants that represent a risk for the ecology of Whangarei Harbour or the specified spoil ground (Coffey 2017). Therefore, the likelihood for bioaccumulation and biomagnification effects on local marine mammal species from the resuspension and dispersal of any contaminants in dredge sediments is *not applicabl*e to *low* and the overall effect assessed as *nil to de minimis*. This conclusion is supported by the following factors:

- low contaminant levels in sampled sediments (Coffey 2017)
- generalist diet and roving nature of local marine mammal individuals is expected to limit contact with any prey species exposed to dredged sediments
- rapid settlement of dredged sediments resulting in limited spatial exposure to individual prey species (99% of the plume expected to settle within 14 hrs; MSL 2016)
- insolubility of some contaminants while others are not expected to be bioavailable (i.e. bound in mineral forms with very limited solubility).

3.2.2. Effects on habitat and prey species

Benthic disturbance and loss

Capital and maintenance dredging of the entrance channel is expected to cause immediate loss of the existing benthic biota and alteration of the habitat within the immediate region of the activity (Coffey 2016). However, Coffey (2016) concluded that this habitat loss is unlikely to affect the bay ecosystem to more than a moderate degree as it constitutes only a small proportion[7] of similar and available benthic habitat in the harbour and bay as a whole. Once capital dredging and channel construction is finished, it is likely that a temporary colonisation of some benthic species, along with the re-establishment of soft sediments in the channel itself, will occur between periodic maintenance dredging (Coffey 2017).

Coffey (2016) also concluded that while smothering of benthic communities within the disposal site will initially take place, it will involve an incremental build-up of the deposited layer over time. Benthic recovery will continue at any single location as soon as a single depositional event[8] takes place and will not be interrupted until another deposition happens in that same location. Benthic survival and recovery around the spoil grounds will be dictated by the adopted dump release pattern and rate of spoil deposition, rather than the nominal thickness of the final deposition layer. The benthic communities within the spoil grounds are expected to effectively recover between 6–24 months after spoil disposal ceases (Coffey 2017).

Based on the above ecological effects, Coffey (2016) suggested that most finfish are expected to temporarily leave the immediate vicinity due to the physical disturbance and subsequent loss of existing food sources. However, some fish species, including known prey species of orca (e.g. various ray species) and bottlenose and common dolphins (e.g. mullet; *Aldrichetta forsteri*) are likely to be attracted to and / or forage in the disturbance area (Coffey 2016). As a result, any associated benthic changes at these project sites are expected to affect only individual fish, and not any particular species as a whole.

Coffey's (2016) conclusion that the ecological effects of dredging activities will be limited in their spatial extent, displacing (or even attracting) a small portion of individual fish temporarily from disturbance sites means that any short or long-term flow-on effects to local marine mammals will be *nil* to *de minimis*.

This conclusion is based on the following factors:

[7] For the capital dredging, the total 'disturbance' area is 4.37 km^2. Maintenance dredging disturbance area will be less than this.

[8] Within each dredging event (i.e. capital dredging event or maintenance dredging event), disposal events will occur on the order of several hours. Each dredge cycle will typically have a single disposal 'phase'. Maintenance dredging events are likely to occur at a frequency ranging from 2 – 20 years.

- a relatively small percent of benthic habitat loss within the Harbour entrance and Bay, which is expected to periodically recover after capital dredging and between maintenance dredging
- benthic smothering effects are predicted to be confined to a limited region around the spoil disposal site, and affected fauna expected to fully recover
- only temporary and localised avoidance of capital and/or disposal sites by individual prey fish with no effect on species recruitment
- general lack of evidence that dredging and disposal sites serve as unique and / or rare habitat for any marine mammal species in terms of feeding activities
- home ranges of local species are large and overlap with similar types of habitats in other parts of the Bay and along other north-eastern coastline regions.

Turbidity plumes

Increased turbidity/turbidity plumes are generated from the re-suspension of sediments at the dredging site and any marine location where dredged spoil is later deposited. High turbidity levels and movements of any sediment plumes created by dredging and / or disposal activities can be of concern to some fauna within or adjacent to work sites (e.g. Coffey 2017). However, marine mammals are known to inhabit fairly turbid environments worldwide and especially within New Zealand's nearshore environments (Clement & Elvines 2015). While they have very good vision, it does not appear to be the sense marine mammals rely upon most for foraging. Instead, odontocetes mainly depend on echolocation systems for underwater navigation and searching for food, hence, elevated turbidity does not directly affect these species' general movements or ability to find prey. Even baleen whales, which do not have the ability to echolocate, regularly forage in dark, benthic environments stirring up sediments to find prey. Gibbs and Childerhouse (2000 and references therein) noted that turbidity, along with similar environmental factors, is unlikely to have any direct effects on humpback migration routes. Turbidity plumes are thus more likely to only indirectly affect marine mammals via their prey resources.

Hydrodynamic modelling by MSL (2016) has demonstrated that plumes associated with the actual dredging (draghead and overflow) will generally settle onto the seabed in a relatively short timeframe, due to the sandy nature of the sediments. Due to this rapid settlement, modelled total suspended sediment (TSS) concentrations greater than 12 mg/L were spatially constrained to within a 1.2 km radius around the dredging footprint. During spoil disposal, TSS concentrations are not likely to exceed 10 mg/L above ambient levels greater than 3 km from the disposal location as 99% of the spoil sediment is likely to settle onto the seabed within 14 hours of disposal. As a precautionary monitoring measure, Coffey (2017; table 8) has proposed real-time turbidity plume monitoring near several management area boundaries to ensure actual turbidity levels from an project dredging and disposal plumes do not exceed acceptable threshold levels.

As discussed earlier in this section, any effects of increased turbidity from dredging activities will be limited in their spatial extent and displace only a small portion of the fish population (i.e. individual fish) temporarily from sites of the proposed activity or areas affected by the plume. Overall, any indirect effects of turbidity plumes from dredging activities are not expected to have any detrimental or long-term flow-on effects to local marine mammals in the region, and therefore will be *nil* to *de minimis*.

This conclusion is based on the following factors:

- resulting turbidity plumes from dredging or disposal activities are expected to settle out relatively quickly and are not expected to adversely affect nearby habitats
- short term displacement of only individual prey as a result of the small spatial scale of disturbance
- it is unlikely that whales would be affected by, or intentionally avoid, any localised turbidity plumes as they regularly migrate through highly turbid coastal waters around New Zealand each year.

3.3. Recommended avoidance, remediation and mitigation measures

Sections of Policy 11 of the New Zealand Coastal Policy Statement (NZCPS) relevant to the potential effects to marine mammals from the proposal are:

> (a) avoid adverse effects of activities on:
>
> (i) indigenous taxa that are listed as threatened or at risk in the New Zealand Threat Classification System (NZTCS) lists;
>
> (ii) taxa that are listed by the International Union for Conservation of Nature and Natural Resources (IUCN)
>
> (b) avoid significant adverse effects and avoid, remedy or mitigate other adverse effects of activities on:
>
> (ii) habitats in the coastal environment that are important during the vulnerable life stages of indigenous species;
>
> (iv) habitats, including areas and routes, important to migratory species.

Species' status under the NZTCS and IUCN systems are listed in Clement and Elvines (2015), and were considered when assessing the consequence of potential effects on the relevant species (i.e. bottlenose dolphins, orca, Bryde's and southern right whales). Any potential adverse effects to threatened marine mammals species

from the proposal, in relation to 11(a) of the NZCPS[9], have been assessed as *de minimis* if the recommended mitigation plans are followed. In regards to 11(b) of the NZCPS[10], Whangarei Harbour and nearby Bream Bay waters are not considered to be of ecological significance in terms of feeding, resting or breeding habitats. They represent a small fraction of similar habitats available along the north-eastern coastal region (Clement & Elvines 2015 and Section 2.2). Neither the Harbour nor Bream Bay is considered an ecologically important migration corridor as most whales generally pass by the area further offshore. Finally, any associated effects of climate change on marine mammals within this region[11] will be a gradual drift in their overall distribution range to the south over several decades. The only remaining effects of this proposal at that stage will be fewer (but more heavily laden) oil tankers using the harbour entrance and occasional maintenance dredging.

Overall, any adverse effects from dredging activities on local and visiting marine mammals are assessed as *de minimis* when considering the types of effects, their spatial scales and durations, likelihood, and potential consequences (Table 2). However, given that some of the possible consequences of rare events (i.e. vessel collision or entanglement) could have population level effects (i.e. injury or death of an endangered animal), several best management practices (BMPs) are recommended as mitigation actions in relation to marine mammals and dredging in Whangarei Harbour entrance (Table 4 and Appendix 3). Importantly, BMPs are recommended even where the likelihood is assessed as *low* given the concerns that Tangata Whenua o Whangarei Te Rerenga Paraoa have about maintaining and protecting the continued presence of these species in the region.

To ensure that the most appropriate measures are in place, it is suggested that a marine wildlife management plan (MWMP; Appendix 3) is finalised in consultation with DOC before commencing operations. The plan should detail the procedures referred to in Table 4, and may also include timelines for any on-going monitoring and / or any implemented procedures that will need to be reviewed for effectiveness during operations (Appendix 4).

In regards to vessel strike, researchers have found that when given a chance, most marine mammal species will exhibit avoidance behaviours when approached by a vessel moving at speed, a vessel producing rapidly changing noises and / or when a vessel directly approaches the animal (Richardson 1995). There will be few occasions when the dredge could be operating at the same time as commercial vessels are entering or leaving the harbour, given the narrow entrance channel and shallow depths associated with this particular section of the project area (e.g. Tonkin & Taylor

[9] As well as considering the tiered protection provided for in Policy 4.4.1 of the Northland's Regional Policy Statement (NRPS).
[10] Including Objective 9.2.3 of Northland's RCP.
[11] In regards to Section 7(i) of the RMA that requires Council to have particular regard to the effects of climate change.

2016; Appendix A, section 9.6). This reduces any potential cumulative effects from multiple vessel presence (and any associated masking effects on noise) leading to possible vessel strike.The adoption and use of simple and commonsense boating behaviour guidelines around marine mammals by the dredge vessel (as proposed in the MWMP; Appendix 3), particularly around baleen whales and any calves, are expected to reduce the already *low* risk of collision to near zero (see Table 2 and Table 4 for further details). In addition, it is recommend that real-time / recent sighting information is obtained from DOC (or other project vessels), in order to anticipate and mitigate potential interactions with any whale species sighted in and near the project area.

In the case of underwater noise effects, we recommend adopting the best practicable option (BPO) in terms of Part 1 Interpretation and application, section 2(1) of the Resource Management Act 1991 (the Act), which states:

> **best practicable option**, in relation to a discharge of a contaminant or an emission of noise, means the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to -
>
> a) the nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and
> b) the financial implications, and the effects on the environment, of that option when compared with other options; and
> c) the current state of technical knowledge and the likelihood that the option can be successfully applied.

For this proposal, the most effective options for minimising underwater noise in the first instance would be the selection of the smallest practical dredge vessel[12] and the least acoustically invasive pile-driving technique[13] practically suited for the conditions, as well as ensuring both the dredge and pile driver are regularly maintained to a high standard. However, as per (b) above, the BPO must also consider financial and other environmental implications, such as the use of a smaller dredge vessel will likely lengthen the overall duration of the project (and potentially other effects). Using the BPO at all times will ensure noise emissions are minimised to the lowest practicable level, thereby minimising any subsequent underwater noise effects to marine mammals.

[12]Also see comment in Pine and Styles 2016: “The use of smaller dredgers may reduce the broadband noise levels however, smaller dredgers will likely have a different source spectra that for some marine mammals, might contain more acoustic energy in certain frequencies that they are more sensitive to. In this case, smaller and older dredgers may have impact zones commensurate with the larger TSHDs and CSD modelled in this report. After the commencement of dredging, in-field measurements of the actual plant should be undertaken and compared to the modelled impact zones presented in [Pine & Styles 2016], and mitigation strategies or monitoring could be updated accordingly.”

[13] Although the proposal suggest using either traditional or vibro-driving techniques, additional considerations for pile-driving techniques and pile types are listed in the underwater noise management section (1.3.3) of the MWMP.

It is recommended that the actual noise levels produced from dredging activities be confirmed by measuring the associated underwater noises of these activities as soon as practical once the project has begun (see MWMP; Appendix 3 - 1.3.1). Using these measurements, spatial acoustic modelling should be completed or confirmed to understand the scale of any actual TTS effects before any further dredging activities take place.

In this case, acoustic modelling suggests that the chance of any auditory effects on marine mammal hearing (i.e. TTS) is extremely small based on how close an animal must approach (i.e. 1–10 m) an operating dredge vessel, and that the degree of any TTS effects is also dependent on how long the animal remains within close proximity to the dredge vessel. As discussed in Section 3.1.2, the likelihood of this overlap occurring is extremely *low* for this proposal. As such, intensive 24-hour monitoring is not warranted in terms of expense or practicality. Instead, and as an additional precaution only, we recommend the establishment of a precautionary safety zone (enforced by a marine-mammal observer) around an active dredge vessel during daylight hours, which would be sufficient to reduce this effect to effectively zero (*nil*) for a large portion of the project. If a marine mammal is sighted within or entering the precautionary zone, active sediment extraction (which generates the highest noise levels) would temporarily cease until the animal has exited the zone. Cessation of sediment extraction in this case refers to (for example): lifting the draghead from seafloor and ramping down the suction pump (TSHD); or cessation of on-going removal (BHD) or cutting (CSD) of the seabed.

Although no guidelines exist for pile driving within New Zealand, the government of South Australia has developed *Underwater Piling Noise Guidelines* (DPTI 2012) that provide excellent context and guidance on appropriate mitigation measures for the potential effects of pile driving activities on marine mammals. As mitigation actions for pile-driving noise we recommend the standard operational procedures and noise exposure thresholds from the DPTI guidelines (Appendix 3 - 1.3.2) are followed. These include, but are not limited to, soft-starts and a safety / shut-down zone around the work area to further minimise any risk of hearing impairment or injury to marine mammals from the proposed modifications to navigation aids. The key mitigation considerations are briefly described below:

- The **preferred method** of pile driving for this proposal is vibro-driving, due to the lower level of sound produced using this technique compared to impact-driving.
- **Soft-start / ramp-up** procedures in which the pile drive slowly increases the energy of the emitted sound giving any animals in the area time to move a safe distance away (Richardson et al. 1995).
- **Marine mammal observer and safety zone**. This involves a dedicated observer scanning a defined radius of the water's surface and coastal shoreline around the construction area for the presence of fur seals, dolphins or whales prior to commencement of pile-driving activities. If present, ramp-up procedures should

only commence once they have moved out of the zone. The size of the zone will be dependent on the technique used for pile driving, with vibro-driving having a smaller safety zone (100 m) than impact driving (300 m; DPTI 2012).

Table 4. Proposed mitigation goals and practices to mitigate or minimise the risk of any adverse effects of dredging activities on marine mammals in Whangarei Harbour and Bream Bay.

Potential effects	Mitigation goal	Best Management Practice	Reporting and monitoring (see Section 3.4, Appendix 3 and Appendix 4 for more detail)
Marine mammal / vessel strike due to increased vessel activity	1. Minimise the risk of dredge vessel collisions with any marine mammal and aim for zero injury/mortality.	1a. Adoption of best boating guidelines for marine mammals, including speed limits, to reduce any chances of mortality from vessel strikes (see Appendix 3). 1b. Liaise with the Department of Conservation (DOC) over the project period for real-time/recent sighting information, in order to anticipate and mitigate potential interactions with any whale species sighted in and near the project area.	• Record all vessel strike incidents or near incidents regardless of outcome (e.g. injury or mortality). • In case of a fatal marine mammal incident, carcass(es) recovered (if possible) and given to DOC, and further steps taken in consultation with DOC to reduce the risk of future incidences. Tangata Whenua notified.
Increase in underwater sound from dredging / disposal or pile-driving activities	2. Minimise the avoidance (attraction) or potential for injury of marine mammals due to dredging or pile-driving activities.	<u>Dredging</u> 2a. Use BPO to minimise underwater noise effects. 2b. Regular maintenance and proper up-keep of all dredging equipment and the vessel (e.g. lubrication and repair of winches, generators). 2b. Establish a designated observer on the dredge vessel and maintain a watch for marine mammals during any dredging and disposal activities over daylight hours. 2c. Establish a designated 'precautionary' safety zone (50 m) that marine mammal observers can enforce temporary cessation of active dredge operations when marine mammals are present (over daylight hours only), until any marine mammal leaves the zone. <u>Pile driving</u> 2d. Adoption of standard operating procedures, including the establishment of safety and observation zones, enforced by a dedicated marine mammal observer. 2e. Choose plant/techniques on the basis of minimisation of underwater noise levels (e.g. vibro-driving preferred over impact-driving).	• Measure actual underwater noise levels from dredging, and adjust modelling results and monitoring zones based on these data, if necessary (Appendix 4). • Record and report the type and frequency of any marine mammal sighted (or acoustically recorded) before, during or after transiting to or from the dredging/disposal site and pile-driving activities. Include behavioural data if possible. • Project sightings from 2b and 2d should be reported to DOC for input to database. • Passive acoustic monitoring of marine mammals' presence near dredging activities (see Section 3.4)

Potential effects	Mitigation goal	Best Management Practice	Reporting and monitoring (see Section 3.4, Appendix 3 and Appendix 4 for more detail)
Marine mammal entangle-ment in operational gear and / or debris	3. Minimise entanglement and aim for zero injury/mortality	3a. Avoid loose rope and other lines (keep them taut). 3b. Ensure that all dredging, support vessels and other project activities have waste management plans in place before the commencement of works.	• Record all entanglement incidents or near incidents regardless of outcome (e.g. injury or mortality). • In case of a fatal marine mammal incident, carcass(es) recovered and given to DOC, and further steps taken in consultation with DOC to reduce the risk of future incidences. Tangata Whenua notified.
Contaminant effects on marine mammals from maintenance dredging activities	4. Minimise or lower the risk of exposure to any contaminated sediments	4a. Test spoil sediments before maintenance dredging (sediment testing has already been undertaken for this proposal for capital dredge spoil).	

3.4. Recommended monitoring

Given the generally *low* likelihood and *de minimis* effect levels in this case, informative, rather than impact monitoring, is recommended for capital dredging as systematic marine mammal surveys to assess cause-effect relationships are not warranted or practical for this proposal[14]. Our recommendations are considered a more realistic monitoring option (scientifically and economically) because the programme will be focused on simple and answerable questions related to specific effects of the dredging, such as recording actual behavioural responses of local and visiting marine mammals. In this regard, monitoring is not intended to statistically assess the impact of dredging on local marine mammal populations in relation to pre-determined indicators or thresholds. Instead, the monitoring programme has been designed to help validate any potential assumptions of the AEE (e.g. underwater noise levels of dredge vessels given the lack of New Zealand data available) and further fine-tune mitigation options.

[14] There are inherent problems associated with implementing comprehensive monitoring programmes for marine mammals around cause-effect relationships. This is due to their mobility and flexible behaviour, highly variable population dynamics, and low sample sizes, with the manifestation of impacts from dredging likely to be very small relative to other stressors (and consequently lost in the 'noise' of background variability). As such, even with an established baseline dataset (such as exists for orca) and a high level of long-term effort, it would be highly unlikely that any statistically-valid conclusion could be reached in terms of a dredging effect on the population.

Informative monitoring questions should include:

- What are marine mammal behavioural reactions to the presence of dredge vessels during active versus non-active operations? For example, if present before dredging start-up, do animals immediately leave at start up?
- What are marine mammal behavioural reactions to spoil disposal? For example, if they are present before disposal, do animals immediately leave once disposal begins? If so, what is the mean time it takes them to return (if at all)?
- Are marine mammals visiting/passing through the dredging or spoil area in between dredging/disposals?
- What are the actual noise levels and frequencies produced from dredging and disposal activities within the Harbour entrance and at the disposal sites?
- How many delayed starts or shutdowns occurred due to marine mammal presence (and what species were these) during a single daylight period during pile driving?

Industry and DOC can use the information gained through the proposed capital dredge monitoring plan to further understand any actual effects of dredging activities on marine mammals and, if necessary, help reduce the risk of similar incidences with any future maintenance dredging.

3.4.1. Capital dredging

Pre- and post-dredging and disposal monitoring

Recommended monitoring involves the collection of opportunistic visual sightings and passive underwater acoustic monitoring before, and after capital dredging has ceased over a relatively short time period (approximately one month for each, depending on time of year). These data sources together will confirm which species are present in the proposal areas prior to the start of any dredging activities and assess marine mammals continued presence in the area once dredging has ceased. The recommended monitoring protocol is also described in Appendix 4.

Collection of sighting data

Any sightings collected before capital dredging will confirm which species may be currently using habitats in the vicinity of the project as discussed in the Phase 1 assessment. Post-dredge sightings (and acoustic monitoring) will mainly be used to assess the continued presence of any marine mammals within the project area after capital dredging activities have stopped. Opportunistic sightings have already been recorded by vessels collecting preliminary information for the project in the vicinity of the proposal and other nearby regions (i.e. benthic sampling in channel and proposed spoil disposal areas; Appendix 5). For instance, opportunistic sightings gathered by other consultants and the general public since March 2015 have helped reaffirm the limited presence of baleen whales in the Harbour region, as predicted based on the earlier Phase 1 literature and DOC national databases review.

Similar sources would be sufficient to collect opportunistic sightings on species' presence in the proposal areas for at least a month before and after any capital dredging activity. Any regular (non-project) users of the Whangarei Harbour entrance (e.g. tug boats) could also be encouraged to record and report opportunistic marine mammal sightings. Sighting data gained through the project should be exchanged with DOC for collation to the national database.

Passive acoustic monitoring

Passive acoustic recorders (i.e. moored underwater acoustic recorders) automatically listen and record any underwater sound at frequencies likely to be from marine mammal vocalisations. These recordings (also known as detections) are downloaded at a later date and used to assess whether marine mammals may have been present in a particular area. Pine and Styles (2015; Appendix 1) recorded marine mammal clicks and whistles (characteristic of dolphins) at four passive acoustic moorings over a single ~10-day period while undertaking preliminary ambient sound recordings around the Whangarei Harbour entrance. Although acoustic recorders are limited in range (usually within a few hundred metres of the device), and cannot assess if marine mammals are truly absent (versus present but not vocalising or echo-locating), the advantage of using passive acoustic moorings is that they can 'listen' for the presence of any marine mammals both day and night and when sea conditions are not favourable for visual sightings, thus helping to supplement and confirm sighting data. We recommend placing a limited number of passive acoustic moorings (~4) near the Harbour entrance, disposal area and near the 120 dB underwater noise boundary to record marine mammal detections over the same time period that opportunistic sighting data are collected (for one month before capital dredging, and for one month after).

3.4.2. Monitoring during dredging and disposal

The recommended monitoring during dredging and disposal activities also includes collecting general information on species presence within the project vicinity while assessing specific questions related to the actual versus potential responses of local and visiting marine mammals to dredging and disposal activities. This includes a marine mammal observer on board the dredge vessel and passive underwater acoustic monitoring for both marine mammal presence in the project area and dredge noise.

Marine mammal observer

A designated marine mammal observer should maintain a watch on the dredge vessel whenever dredging or disposal activities are underway (including transiting) over daylight hours only (Appendix 3). The observer does not need to be a qualified marine mammal observer (e.g. an existing crew member can be inducted and designated to fill the role of the observer).

The primary objective would be to enforce a precautionary safety zone of 50 m around dredging operations to avoid any TTS effects. The presence of any marine mammal within the zone would result in cessation of active dredging (i.e. cease suction, cutting or digging—depending on the dredge type being used at the time), until the animal leaves the pre-determined zone. An additional advantage of such observation is that it will allow for the effectiveness of any mitigation measures (e.g. boating behaviour guidelines) put in place to be reported and amended, if necessary, while dredging operations are underway.

While the observer is primarily recommended for implementing mitigation measures (i.e. shut-down of sediment extraction when marine mammals are in the vicinity), there will also be information-gathering benefits. The secondary objective would therefore be for the observer to record opportunistic sightings and observation data (e.g. behavioural information) on marine mammals in the general area, with an emphasis on those nearest to the dredging and disposal sites.

In addition, a central contact point should be established (e.g. with DOC and other project staff) to obtain up-to-date regional sighting information, so the observer onboard the dredge vessel can anticipate the presence of any marine mammals previously sighted in or near the area.

Passive underwater acoustic monitoring

Given the use of onboard observers, passive acoustic monitoring is necessary to assess whether marine mammals are passing through project areas when the dredge vessel is absent (i.e. transiting to/from spoil disposal site or during rough weather). This monitoring is not intended to assess species frequency or intensity of use but rather simply determine whether any marine mammals are present within project areas during different cycles and noise levels of the capital dredging project. Hence, only two separate monitoring periods of approximately 14 days each are necessary within the estimated six-month project duration to sufficiently detect the potential presence of marine mammals across several dredging cycles.

Measuring underwater noise produced from dredging works.

Actual dredging noise levels should be monitored periodically throughout different work phases. The monitoring periods should represent variation in dredging noise, for example noise associated with dredging different sediment types and different parts of the dredging cycle; and transiting vs. extraction vs. disposal.

Both datasets should be used to validate some of the assumptions made in this assessment. Of particular interest are marine mammal observations near the operating dredge vessel (i.e. out to 300 m), as these could provide some context around the underwater noise effects when coupled with actual acoustic data taken from the dredging operation (for example, ‘when starting to dredge sediment and the noise levels were approximately ‘x’ dB, the animals approached/avoided the vessel’).

Sighting data (from the observer, acoustic monitoring or that reported from other vessels or the public) would ideally be reviewed with the predicted TTS, auditory masking or behavioural spatial ranges (as determined in Pine and Styles 2016) to refine the assumptions of the acoustic modelling and any associated effects (as outlined in this report) prior to maintenance dredging.

3.4.3. Maintenance dredging

The consideration of possible monitoring options for capital dredging and spoil disposal also applies to any ongoing maintenance dredging, but more so in relation to operational practices in proximity to sighted marine mammals. The assumed smaller-scale aspects of maintenance dredging and disposal, along with smaller dredge vessel size, will likely require less extensive monitoring than that proposed for the capital dredging. At a minimum, best management practices should still be adopted (i.e. as part of the Marine Wildlife Management Plan). A designated marine mammal observer should also maintain a watch on the dredge vessel whenever dredging or disposal activities are underway (including transiting) over daylight hours only. The purpose of this observer would be to record opportunistic sightings and observation data (e.g. behavioural information) on marine mammals in the general area, with an emphasis on those nearest to the dredging and disposal sites; and secondarily, to avoid vessel strike / marine mammal interactions. As with capital dredging activities, a central contact point should be established (e.g. with DOC and other project staff) to obtain up-to-date regional sighting information, so the observer onboard the dredge vessel can anticipate the presence of any marine mammals previously sighted in or near the area.

The information compiled via direct observation and passive acoustic monitoring during the capital dredging project can be used to inform aspects of any program for maintenance dredging; especially regarding marine mammal response to dredging and spoil disposal operations and seasonal use of the area by individual species. Any additional monitoring practices, if required, will be determined after analysis of the capital dredging project data.

3.4.4. Pile driving

The recommended monitoring during pile-driving activities includes a marine mammal observer on board the pile-driving vessel (i.e. additional to the observer on-board the dredge vessel) and / or a separate support vessel in order to monitor for marine mammal presence within the observation zone and safety zone, if the size of these zones is not able to be surveyed effectively from a fixed platform.

Marine mammal observer

A designated marine mammal observer should maintain a watch on the pile-driving vessel whenever pile driving is underway (constrained to daylight hours; see Appendix 3 for more details). The observer does not need to be a qualified marine mammal

observer (e.g. an existing crew member can be inducted and designated to fill the role of the observer).

The primary objective would be to enforce a safety zone around pile-driving activities to reduce the risk of any TTS/PTS. The presence of any marine mammal within the zone would result in cessation of pile driving until the animal leaves the pre-determined zone. The size of the zone would be determined as part of the underwater noise management plan (Appendix 3, Section 1.3). In addition, the observer onboard the pile-driving vessel should be kept up to date with regional sighting information (as exchanged with DOC, Section 3.4.2), so they can anticipate the presence of any marine mammals previously sighted in or near the area.

4. PRE-SUBMISSION CONSULTATION

Consultation has been undertaken with the general public (via open days) and with all relevant stakeholders (at least attempted in some cases) throughout the writing of the Phase 1 report (Clement & Elvines 2015) and this Phase 2 marine mammal report . Specific concerns are highlighted and discussed further in this section.

4.1. Issues raised in the Tangata Whenua O Whangarei Te Rerenga Paraoa draft cultural effects assessment

The cultural assessment highlights that tangata whenua are concerned that some of the potential effects on marine mammals from the RNZ capital dredging proposal are considered 'low probability' but 'high impact'. In fact, the cultural assessment cites a statement from this report that refers to "some of the possible consequences of rare events (i.e. vessel collision or entanglement) could have population level effects" (see Section 3.3, p. 23). This means that effects with a very low or rare likelihood of occurring could have a severe consequence if they were to occur. In the case of marine mammals, the extreme example of this would be a death of an endangered female, as loss of her breeding potential could have serious repercussions on the future reproductive capabilities for the population as a whole. Tangata whenua feel that the existence of these rare events is an unacceptable adverse effect. Their conclusion is that such events cannot be mitigated and instead, must be avoided.

This report specifically addressed these concerns in detail, and concluded that implementing the appropriate mitigation actions could lower the overall chances of these rare events occurring to as near to zero as possible while increasing the animal's chances of survival in the extremely unlikely event that one did occur. I discuss these report findings further below using the mitigation of vessel strikes as an example.

4.1.1. Vessel strikes

It is important to emphasise that any vessel that is on the water in areas that marine mammals reside or travel has the exact same chance of striking an animal, regardless of type (commercial or recreational). This is due to the fact that marine mammals spend the majority of their time underwater and are usually only visible as they are surfacing. Their surfacing intervals, and subsequent reaction to a nearby vessel once surfaced, are at times completely random and often unpredictable. The only difference between a small recreational boat striking a marine mammal and a container ship is the potential outcome to the animal.

Most reported incidences of vessel strikes have been with mysticete (baleen) whales (see Section 3.1.1). Whale occurrences in Bream Bay (and Whangarei Harbour) are

seasonal with sightings restricted mainly to winter months, and individuals remain in the greater region for only a few days. As the proposed timeline for the capital dredging project is approximately six months, there is the possibility that the dredging will occur completely outside the whale migration period, overlap partially or occur throughout the entire migration period. However, it is important to note here that while vessel traffic will temporarily increase over the course of the capital dredging project, it will decrease over the longer term as fewer, but more heavily laden, oil tankers will be used in the future.

In order to place the likelihood of a vessel strike occurring in the context of this proposal, I have estimated a possible 'worst-case' scenario. I estimated the maximum number of whales that could occur in the larger coastal region[15] in one year at 5 individuals, based on the DOC sighting and stranding database. Out of the 112 reported sightings of baleen whales [16] in this same area, only 22 of these animals (or 19%) have passed through inshore waters between Bream Bay and Hen and Chicken Islands (to just north of Bream Head and Mangawhai Heads to the south). Based on these previous data, only 1 of 5 whales would be predicted to occur in Bream Bay waters near the proposal area.

The proposal area over which the vessel will be working is approximately 10 km^2 (including all channel areas and disposal sites; Tonkin & Taylor 2016), around 2% of the total Bream Bay area[17]. The average distance between the channel and disposal sites in which the dredge vessel must travel is between 3 and 7 km. This distance equates to around 60 to 90 mins of vessel transiting for each complete dredge cycle, or 12–13 hrs of transiting over a 24 hr period of uninterrupted dredging in perfect conditions.

Finally, I assumed that this hypothetical animal remained in this same Bream Bay area for up to three days[18]. Without any mitigation, the overall chances of this whale being struck by the dredge vessel are dependent on this one animal wandering through the specific transiting area (< 2% of Bream Bay) within a three-day period at the same time the dredge vessel is traveling to or from the disposal site (i.e. a potential collision window of 39 hrs out of an estimated 1800 hrs of transit time over a conservative five months for project completion). In other words, the likelihood of a whale being struck by the dredge vessel in this worst-case example is extremely low, but as pointed out in this report, can never be presumed to be zero.

[15] The coastal and more offshore waters between Tukukaka to the north and Omaha Bay and Great Barrier Island to the south.
[16] Note that several of these sightings will be re-sightings of the same animal on the same day and / or over different days as they travelled up the coast.
[17] Defined as ~432 km^2 from a line just north of Bream Head to the Hen and Chicken Islands to the east, to Mangawhai Head to the south and Bream Bay coastline to the west.
[18] Whales have only been resighted in the same location off this region over 1-2 days, but in other locations around NZ can occur up to a few weeks.

As discussed in this assessment, the likelihood of a vessel strike and the risk that it will result in serious injury or death increases above speeds of 10–14 knots (see references in Section 3.1.1). As demonstrated above, for approximately half of the dredging cycle, the dredge vessel will be of little concern to nearby whales as it will be relatively stationary while dredging (i.e. 1–3 knots) and disposing of dredged sediment. When travelling to the disposal site, the normal operating speed of a dredging vessel is estimated to be around 7.5 knots with a loaded hopper and up to 15 knots empty, depending on TSHD used (Tonkin & Taylor 2016). The generally slower speeds of dredge vessels likely explain why they have been involved in only one out of the 134 worldwide collisions with whales (in which the vessel type was known) reported between 1975 and 2002.

To further reduce the likelihood of a strike and avoid any risk of a mortality, we have recommended several mitigation actions (see Table 4 and Appendices 3-4). These actions include the adoption of best boating behaviour guidelines around marine mammals by the dredge vessel as part of a Marine Wildlife Management Plan, which importantly includes vessel speed limits. In addition, it is recommend that real-time / recent sighting information is obtained from DOC (or other project vessels) throughout the duration of the project, in order to anticipate and mitigate potential interactions with any whale species sighted in and near the project area. Finally, as part of the proposed informative monitoring programme, a designated marine mammal observer will also be maintaining a watch for marine mammals on the dredge vessel whenever dredging or disposal activities are underway (including transiting) over daylight hours.

Together, these mitigations actions will ensure that all available information is being used to help locate, further reduce and avoid any interactions between the dredge vessel and any visiting marine mammals (e.g. vessel collision, entanglement or otherwise) that may occur within the proposal area during the course of this project.

4.2. Issues raised by Forest & Bird

At a meeting in Wellington on 29 June 2017, Forest & Bird's marine representative raised several points of concern in relation to the capital dredging proposal and more specifically, the resulting oil tanker traffic once the project was completed. The main issues are outlined and discussed further below.

4.2.1. Underwater noise issues

Forest & Bird's main concern is that this report and the underwater noise assessment (Pine & Styles 2016) have used NOAA's previously recommended behavioural noise threshold of 120 dB, developed in 1998, for assessing the spatial extent of any behavioural effects. Unlike NOAA's recent recommendations for TTS and PTS thresholds (2016), there is currently no agreed-upon behavioural noise threshold for marine mammals in the United States or worldwide. This is due to the fact that

understanding behavioural responses to varying noise levels is complex and complicated by differences in species, age groups, current behavioural state and even individual tolerances.

Forest & Bird is worried that use of 120 dB threshold for behavioural reactions, without further explanation, will set an unwarranted precedent for future resource consents of a similar nature (e.g. marine construction). As a result it was suggested, and we have agreed, that further explanation around the use of this threshold and our approach as being specific only to this application was included (see footnote 6 p.12 and further discussion in Appendix 2). We have also included spatial figures for the 120 dB threshold for behavioural reactions as single, un-weighted models in Appendix 2 (Figure A2.1), as requested by Forest & Bird to be used in combination with proposed acoustic monitoring to determine the efficacy of the 120 dB behavioural threshold in this particular case (see below for more detail).

4.2.2. Lack of proposed marine mammal surveys

Forest & Bird were curious why there was no systematic marine mammal surveys of the proposal area and nearby waters undertaken or recommended as part of the monitoring programme in this report. Given the general lack of information available on marine mammals in New Zealand and no current government initiatives to fund research, they feel that this is one of the only ways to gain more knowledge.

We discussed the lack of any resident species in the proposal area and the amount of data that could be realistically gathered over the course of this project, in particular, the 6 months while capital dredging was occurring. Through the discussion, it was pointed out that in a case such as this, several months or even years of surveys only accumulate a small sample size, too small for statistical testing to see whether there are any significant behavioural effects on marine mammals. As a result, such surveys would be collecting ‘data for data’s sake’ and not necessarily providing any useful data for mammal experts or answering any useful questions in context of the proposal. Instead, we have carefully framed the monitoring to actually get some useable data on marine mammal reactions to dredging and disposal; and the representative agreed that they were happy with that part of the monitoring programme.

Forest & Bird noted an interest in finding out more about some of the offshore species (particularly beaked whales), as Northland in general seems to be a high density region for these species. They noted that beaked whales can be extremely sensitive to underwater noise and overseas research has found that impulsive sound levels (i.e. military sonar and seismic surveys) as low as 80 dB can have behavioural effects on these species.

Our Phase 1 report (Clement & Elvines 2015) identified the presence of beaked whales as possible offshore residents of the Northland region and suggested the theory that they may move inshore during summer and autumn months as evident by increase in strandings during that time, as well as noting their increased acoustic sensitivity. At the meeting, we all agreed that there is no evidence that beaked whales would venture into waters as shallow as the proposal areas, but they still remain a potential species of interest.

It was suggested, and we agreed, that one of the passive acoustic recorders for monitoring could be placed along the 120 dB sound contour during the capital dredging work to monitor any evidence of offshore species presence and possibly their acoustic reactions to the various dredging cycles and noises levels (see Appendix 2). These results would be correlative, not causative but still useful from the perspective of trying to understanding underwater noise effects of dredging on such species and may provide some empirical evidence in terms of the 120 dB threshold for behavioural reactions. However, the actual placement of a recorder will be dependent on practicality (e.g. exposure to commercial fishing, distance offshore) and local environmental conditions (e.g. depth and currents).

4.2.3. Resulting shipping issues

Forest & Bird are concerned that the heavier oil tankers used once the capital dredging was completed would sit deeper in water and therefore, more underwater noise would be generated from the greater surface area of ship underwater. The speeds of the tankers in the channel and harbour were also queried, noting that there is a preference for 10 knots or less based on research for the avoidance of ship strike.

In response, it was noted that the current oil tankers will only be adding 10% more cargo and this will result in it sitting only 3 m deeper than currently. Jon Styles (Styles Group, acoustic and vibration consultants) noted that underwater noise comes primarily from the propeller and engine, not hull and that the extra draft would only increase the noise levels by a very small amount. Navigatus' (2016; section 4.7) risk assessment and the RHDHV (2016; section 2.2.5) report confirm that the tankers will do less than 10 knots, typically 6-8 knots in the channel, slowing as they near the berth.

4.2.4. Other issues

It was noted that it might be possible for some marine mammals to swim into the harbour while the dredge was transiting or disposing of dredge sediment, and then be 'trapped' in the harbor by the dredge noise once it started working in channel again. As discussed in Section 4.1, the THSD dredging cycle was estimated to be approximately 110–180 minutes and the transfer and disposal would be approximately half of that length (RHDHV 2016). Hence, if animals did enter the harbour and were not willing to pass by a working dredge, they would not be trapped for long. The

proposed passive acoustic monitoring stations located near the Harbour entrance will be able to provide actual data into whether this issue is occurring and information on any subsequent responses.

Note, there is the possibility of both the THSD (in the channel) and BHD (at the jetty) barges working at the same time during daylight hours. In this case, the break in active dredging is likely to be shorter but still adequate for any animals to exit the Harbour within a few hours of entering.

5. CONCLUSIONS

The purpose of this report is to describe the existing environment in terms of the local and visiting marine mammals that utilise and / or are influenced by the Whangarei Harbour and associated Bream Bay ecosystem. In particular, information on the various species was reviewed for any life-history dynamics that make them more vulnerable to dredging and disposal activities or where proposal sites may overlap with any ecologically significant feeding, resting or breeding habitats (which include prey resources). This, in turn, enabled the potential effects associated with the capital and maintenance dredging and disposal components on marine mammals to be assessed.

The marine mammals most likely to be affected by the proposed project include those species that frequent the Whangarei Harbour and Bream Bay regions year-round or on a semi-regular basis. These species are bottlenose dolphins, orca, Bryde's whales, and common dolphins. Other species including NZ fur seals, pilot whales, beaked whales, southern right whales, humpback whales, sperm whales and pygmy sperm whales were considered in this assessment because of their records of occurrence in the area and their known vulnerabilities to particular anthropogenic impacts (i.e. vessel collision); species-specific sensitivities (i.e. underwater noise); and / or special concern to local iwi Tangata Whenua o Whangarei Te Rerenga Paraoa.

The coastal waters of Whangarei Harbour and Bream Bay are not considered significant habitats for any marine mammal species. Instead, these waters represent only a small fraction of similar habitats available to these marine mammals throughout the larger north-eastern region.

Based on the direct and indirect potential effects highlighted in this report, the overall effects of the capital and maintenance dredging and the disposal and pile-driving components on marine mammal species within Whangarei waters are assessed as *de minimis* when considered with the recommended avoidance / mitigation actions. This conclusion is based in part on information from other consultancy reports including the expected levels of underwater noise due to dredging (Pine & Styles 2016) and pile-driving activities, concentrations of contaminants in dredging materials and expected effects on local benthos and fish communities (Coffey 2017), and modelled and predicted turbidity plume dynamics (MSL 2016).

Informative monitoring is recommended and based around a combination of recording visual sightings of marine mammals (both opportunistic and from dedicated observers on the project vessels) with simultaneous passive underwater acoustic monitoring. Given the *low* likelihood and *de minimis* effects of the proposal, the recommended monitoring plan for capital dredging and pile driving is based on collection of information to improve understanding of how marine mammals respond to these activities, rather than testing of specific predictions of effect (Section 3.4.1,

Appendix 4). Such a programme will serve the dual purpose of collecting important data on the actual effects of dredging and pile driving on New Zealand marine mammals while assessing the effectiveness of any mitigation measures put in place. These measures can then be amended, if necessary, while operations are underway, for later maintenance dredging projects.

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7. APPENDICES

Appendix 1. Short-term passive underwater acoustic survey of Whangarei Harbour entrance and Marsden Point: preliminary investigation by Pine and Styles 2015.

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Prepared for: **Chancery Green on behalf of Refining New Zealand**

Date: **13th November 2015**

Title: **Short-term Passive Underwater Acoustic Survey of Whangarei Harbour Entrance and Marsden Point: Preliminary Investigation**

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Reviewed by:

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Executive Summary

Styles Group has been engaged by Refining New Zealand (RNZ) to undertake a passive acoustic survey of the ambient underwater soundscape within and around Calliope Bay at the entrance to Whangarei Harbour as part of an investigative phase 1 study. This survey addressed three separate objectives: the first was to establish the temporal and spatial variability of background sound levels over the two week study period; the second was to determine the received sound pressure levels from several vessels, particularly a suezmax vessel, entering and departing the Marsden Point Oil Refinery; and the third was to confirm the presence of marine mammals over the study period.

Up to eight passive acoustic loggers were deployed within Calliope Bay and Bream Bay at four separate survey sites (Lort Point, Mair Bank, Busby Head and Bream Bay). Ambient sound levels varied within each survey site with spectral analyses revealing variances up to 47 dB for frequencies below 10 kHz. Measured sound levels were highest within the Lort Point survey site (average 119 ± 0.08 dB_{rms} re 1 µPa) and decreased with increasing distance from the Marsden Point industrial area (averages of 113 ± 0.07 dB_{rms} re 1 µPa, 108 ±, 0.46 dB_{rms} re 1 µPa, and 105 ± 0.10 dB_{rms} re 1 µPa from within the Mair Bank, Busby Head and Bream Bay survey sites, respectively). Between survey sites, the ambient soundscape was largely characterised by frequencies below 2 kHz. Unique within the Lort Point survey site (within the boundary of a Marine 1 (Protection) Management Area) was a consistent low frequency signal (103 - 121 dB_{rms} re 1 µPa between 0.1 and 1 kHz) of various harmonics. This low frequency signal did not demonstrate any biological characteristics and appeared typical of an already existing mechanical source. In the absence of any operating vessels, the broadband sound levels within the Whangarei Harbour entrance were comparable with many other nearshore environments around New Zealand and the soundscape within Calliope Bay was spectrally similar to other busy harbours where vessels are common (as spectral analyses reveal peaks in spectral density below 1 kHz).

Received broadband sound levels from vessels showed considerable variation depending on the type of vessel as well as being a function of speed and distance. The highest broadband (0.05 - 70 kHz) received level measured from any vessel was 150 dB_{rms} re 1 µPa (Torea, IMO 9274082); a considerable increase from the lowest measured level of 128 dB_{rms} re 1 µPa (Anatoki, IMO 8864153). There was no apparent relationship between the tonnage of a vessel and the received broadband sound levels as the largest suezmax vessel (Jag Lagshita, IMO 9208057) had a received broadband level of 135 dB_{rms} re 1 µPa; a phenomenon previously measured by Styles Group at other locations.

Dolphins (species unidentified) were detected within all survey sites, with most detections occurring outside Calliope Bay. No whales were detected during the survey period. In total, dolphins were detected on 13 separate occasions between all four survey sites and vocalisations were mostly detectable for approximately 30 minutes a time. The longest duration

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for which vocalisations were detected during a single occurrence was 1.5 hours. These data provide evidence that dolphins do frequent this area, however care should be taken when inferring any conclusions regarding their abundance or habitat use because the data is limited in sample size and methodology.

The data from this survey shows the ambient sound levels within and around Calliope Bay are comparable with other nearshore environments around New Zealand, however average and median levels were lower compared to very busy harbours such as the Waitemata Harbour and inner Hauraki Gulf.

DRAFT

Table of Contents

Executive Summary.....ii
Introduction 1
Materials and Methods 1
Survey Sites..... 1
Underwater Recording Systems..... 3
Calibration..... 3
Data analysis 4
Survey Results and Discussion 4
Objective 1: Background sound levels 5
Objective 2: Vessel noise..... 12
Objective 3: Marine mammal detection 15
Conclusion 17
References..... 18
Appendix A..... 19

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Introduction

Styles Group has been engaged by Refining New Zealand (RNZ) to undertake a passive acoustic survey of the ambient underwater soundscape within and around Calliope Bay at the entrance to Whangarei Harbour to accompany an application to deepen the channel at Whangarei Heads to allow suezmax vessels to operate at a higher capacity than at present, as well as ease the navigational difficulty during the channel approach. Currently, these large ships carry cargo to and from the oil refinery but are under-loaded so as to successfully navigate the channel between Whangarei Heads and Marsden Point.

The overall aim of the survey was to investigate the ambient underwater soundscape and achieve the three following objectives:

1. To establish background sound levels;
2. To determine the received levels from several vessels, particularly oil tankers, entering and departing the Marsden Point Oil Refinery;
3. To confirm any presence of marine mammals over the survey period.

This report will outline the survey methodology and results for each of the above three objectives. Potential impacts on marine life from undersea dredging or any acoustic modelling of undersea dredging noise have not been undertaken as part of this report.

Materials and Methods

Survey Sites

In order to establish background underwater sound levels within the Whangarei Harbour entrance, Styles Group was asked to design a suitable survey methodology. It was identified that potential underwater noise arising from the proposed dredging activity may propagate into four separate Marine 1 (Protected) Management Area zones in accordance with NRC Map C13 (Figure 1). Thus, eight calibrated SoundTrap (ST) acoustic loggers were deployed to assess the current background sound levels within Calliope Bay and Bream Bay; including within the Marine 1 (Protected) Management Area Lort Point and next to Mair Bank. The four survey sites (each with two individual acoustic loggers) were (1) Lort Point (S 35° 49.856' E 174° 30.223'); (2) Mair Bank (S 35° 51.091' E 174° 31.125'); (3) Busby Head (S 35° 52.449' E 174° 32.757'); and (4) Bream Bay (S 35° 53.147' E 174° 31.326'). A map showing the location of each survey site is provided in Figure 2. The location of each site was selected based on field-accessibility, depth, currents and the purpose of that particular ST logger in the scheme of the overall survey.

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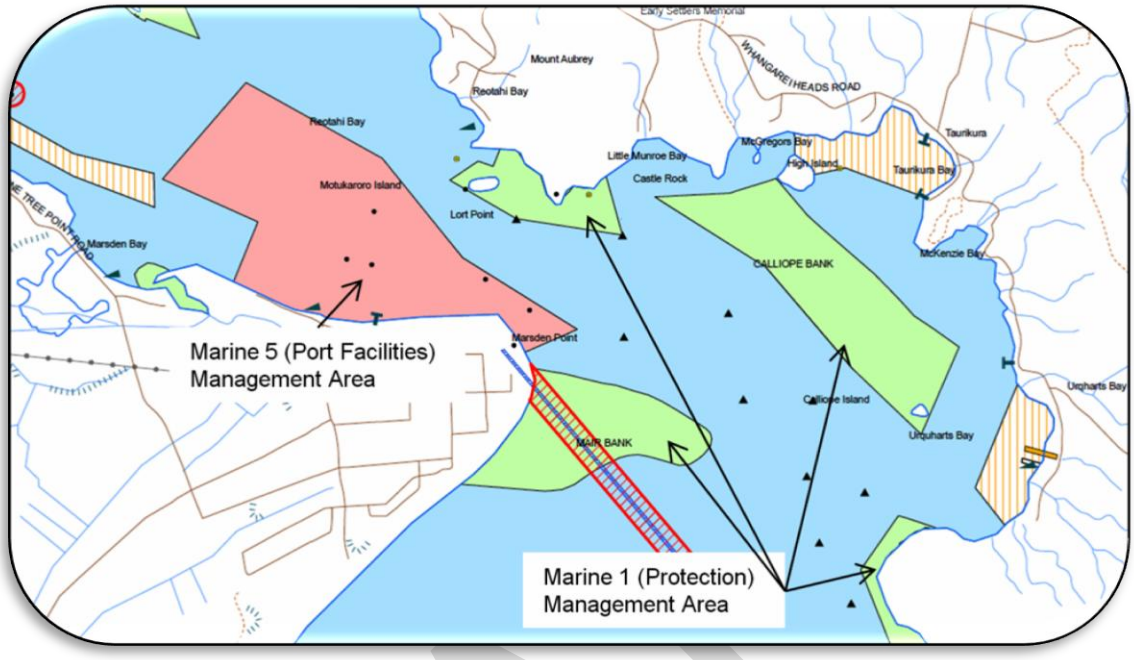

Figure 1: NRC C13 Map. Arrows show main Marine Management Areas.

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Figure 2: GPS location of each survey site where SoundTrap loggers were deployed.

Underwater Recording Systems

Ambient sound recordings were made using SoundTrap (ST) 201 (288 kHz sampling rate), 202 (288 kHz sampling rate), and 202HF (576 kHz sampling rate) laboratory grade underwater acoustic loggers secured between 1 m and 2 m off the seabed and at a depth between 6 m and 20 m at MLWS. See Appendix A for a schematic diagram of the deployment apparatus. Two loggers were deployed at each survey site and set on alternating duty cycles to conserve memory and battery life during the survey. Acoustic data were obtained between the 26th March and 6th of April 2015.

Calibration

The hydrophone component of the ST acoustic logger was calibrated by the manufacturer and field-calibration checks before and after deployment were undertaken using a calibrated pistonphone (GRASS Type 42AA, SPL 114 dB re 20 µPa, nominal frequency 250 kHz), a calibrated (using a Brüel & Kjaer Type 4231 Sound Calibrator) sound level meter (Brüel & Kjaer 2250 Type 1 SLM with a Brüel & Kjaer 1/2 inch Condenser Microphone Type 4189) and specialist acoustic software. Electronic calibration of the recorder component was done at the

start of each 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 and verified using the pistonphone. The calibrated range of the hydrophones was 20 Hz to 144 kHz (ST 201, 202 recorders) or up to 200 kHz (ST202HF recorders) before sensitivity begins to decrease. The distances at which an animal would need to be before being detected is highly variable and depends on the vocalisation amplitude and frequency. Consequently, we are unable to identify a scientifically defined range for which marine mammals may be detected.

Data analysis

Each sound recording was examined for extraneous noise contamination from wind, waves, or precipitation to ensure accurate calculation of ambient pressure levels, as well as received levels from commercial vessels. Recordings which did contain considerable contamination were not analysed.

A descriptive statistical analysis was undertaken on 1200 thirty-minute recordings made between the 26th March and 6th April over the four survey sites. Power spectra, third-octave band levels, the spectral probability density (SPD) and broadband sound pressure level (SPL) for each survey site over the deployment period were calculated. Note the 1200 recordings were made up of systematically selected 30min recordings which did not contain extraneous noise contamination (from weather). Selection was based on every hour or half-hour period depending on the degree of contamination, if any.

Ship arrival and departure times at the oil refinery during the survey period were provided by North Tugz Limited and were used to identify passing ships in the acoustic data. Broadband received levels of each passing ship were calculated and plotted against time, along with the corresponding power spectra.

Acoustic data were analysed to determine the presence or absence of marine mammals using automated acoustic detectors and confirmed by visual inspection of the corresponding spectrogram. Vocalisations were not characterised or specifically analysed as this type of analysis was outside the survey's scope.

Survey Results and Discussion

Due to the high tidal currents within Calliope Bay, a single ST logger at Lort Point was physically compromised by mud and contained too much extraneous noise contamination to be used. The second ST logger at Lort Point that was closer to the surface was not affected. Therefore, analysis was carried out on the remaining seven acoustic loggers.

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Objective 1: Background sound levels

Broadband (50 Hz - 48 kHz) ambient SPLs measured passively over a 24 hour period (28th March 2015) are shown in Figure 3, while percentile plots of both power spectra and third-octaves over the entire survey period are given in Figure 4 and Figure 5, respectively. The 28th March 2015 was selected because the least number of ships were logged coming in or out of Marsden Point on that day and therefore provided the best opportunity to obtain a representative measure with minimal noise contamination. Simple descriptive statistics of the broadband SPLs over the survey period are provided in Table 1.

Ambient sound levels varied within each survey site with spectral analyses revealing variances up to 47 dB for frequencies below 10 kHz (due to consistent vessel activity). Consistent between survey sites was the soundscape being characterised by frequencies below 2 kHz; indicated by the power spectra (Figure 4) and third-octave (Figure 5) percentile plots. Sound levels measured from the Lort Point survey site were largely controlled by large vessels arriving and departing Marsden Point (characterised by a greater noise-floor at frequencies below 2 kHz compared to Busby Head and Bream Bay where sound levels below 200 Hz are >10 dB less). With the exception of the Lort Point survey site, in the absence of any vessels the ambient soundscape could be considered similar to other nearshore environments, such as the outer Hauraki Gulf (~109 - 118 dB re 1 µPa[1]), Rotoroa Island (~112 - 117 dB re 1 µPa[2]) or the Kaipara Harbour (~114 - 118 dB re 1 µPa, respectively (Pine et al. 2015)). However, at the Lort Point survey site only, a continuous low frequency signal (~103 - 121 dB_{rms} re 1 µPa between 0.1 and 1 kHz) of various harmonics was recorded below 1 kHz (Figure 6) on most days. Peak frequencies and SPLs of the signal did vary in time, although showed no consistent pattern (Figure 7). The source of this low frequency signal is not biological but appears mechanical. Notwithstanding this, average background sound levels (broadband) from all four survey sites were lower compared to the inner Hauraki Gulf where average sound levels measured from within the Waitemata Harbour, Rangitoto Channel and Waiheke Channel range between 116 and 127 dB re 1 µPa[3]. The gradual increases in sound energy residing in frequencies above 10 kHz were controlled by snapping shrimp, which are the most ubiquitous species within New Zealand's temperate habitats (Pine et al. 2015; Radford et al. 2008; Radford et al. 2010), such as those around Whangarei Heads and within Calliope Bay.

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[1] Pine, MK. Unpublished data, August 2011. Leigh Marine Laboratory, Institute of Marine Science.
[2] Pine, MK, Styles JR. Unpublished data from passive acoustic survey, July - October 2014. Styles Group Acoustics and Vibration Consultants.
[3] Pine MK., Styles JR. Unpublished data from passive and active surveys between May 2013 and October 2014. Styles Group Acoustics and Vibration Consultants.

Survey Site	Mean ± SE (dB_{rms} re 1 µPa)	Median (dB_{rms} re 1 µPa)	Max (dB_{rms} re 1 µPa)	Min (dB_{rms} re 1 µPa)	Range (dB_{rms} re 1 µPa)
Lort Point	119 ± 0.08	117	147	111	36
Mair Bank	113 ± 0.07	111	146	108	38
Busby Head	108 ± 0.46	107	142	98	44
Bream Bay	105 ± 0.10	104	132	96	36

Table 1: Basic statistics for ambient broadband sound (50 Hz - 48 kHz) measured at each survey site between 26th March and 6th April 2015 based on 7,043 randomly selected 60-sec samples per site.

Despite the lower broadband sound levels, the soundscape within the Whangarei Harbour entrance was spectrally similar to other harbours where vessel activity is high as the root mean squared and 5th percentile spectrum was characterised by frequencies below 1 kHz, while the outermost survey site, Bream Bay, demonstrated spectra closer resembling those of soft sediment habitats.

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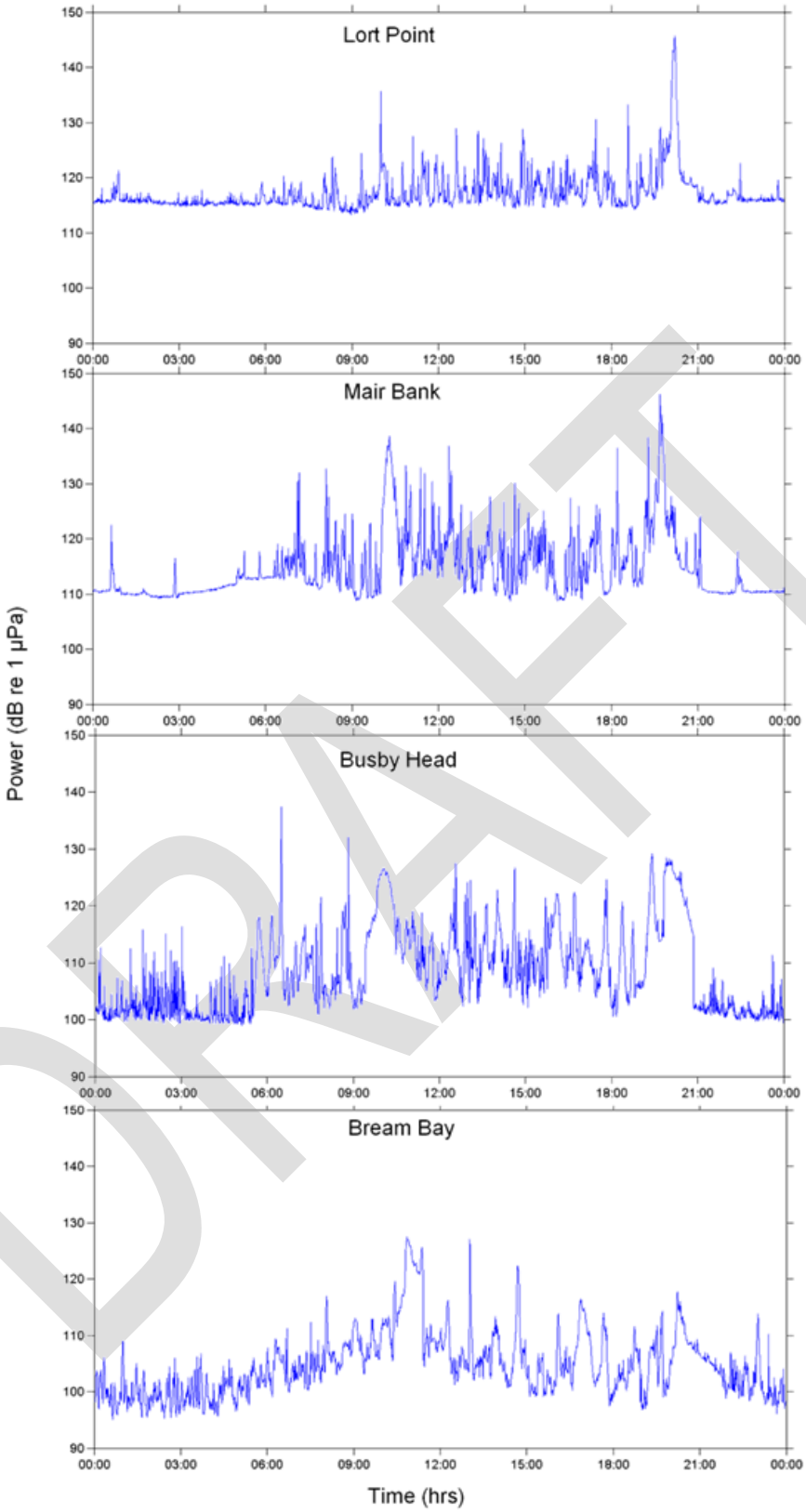

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Figure 3: Broadband (50Hz - 48kHz) ambient SPLs measured over a 24 hour period (28th March 2015) at each survey site (n=2161).

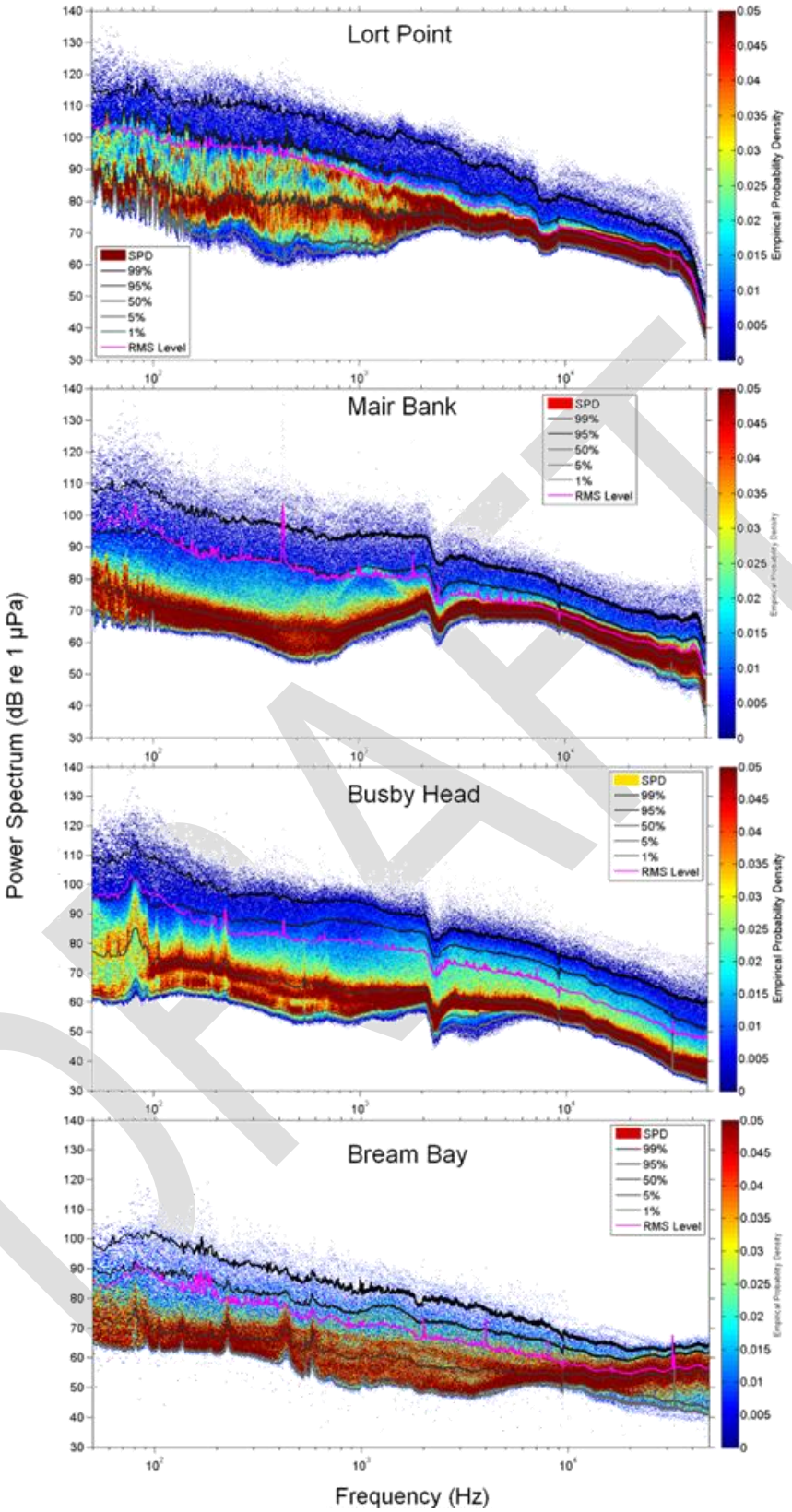

Figure 4: Power spectra plots showing RMS spectrum, percentiles and SPD measured over the survey period.

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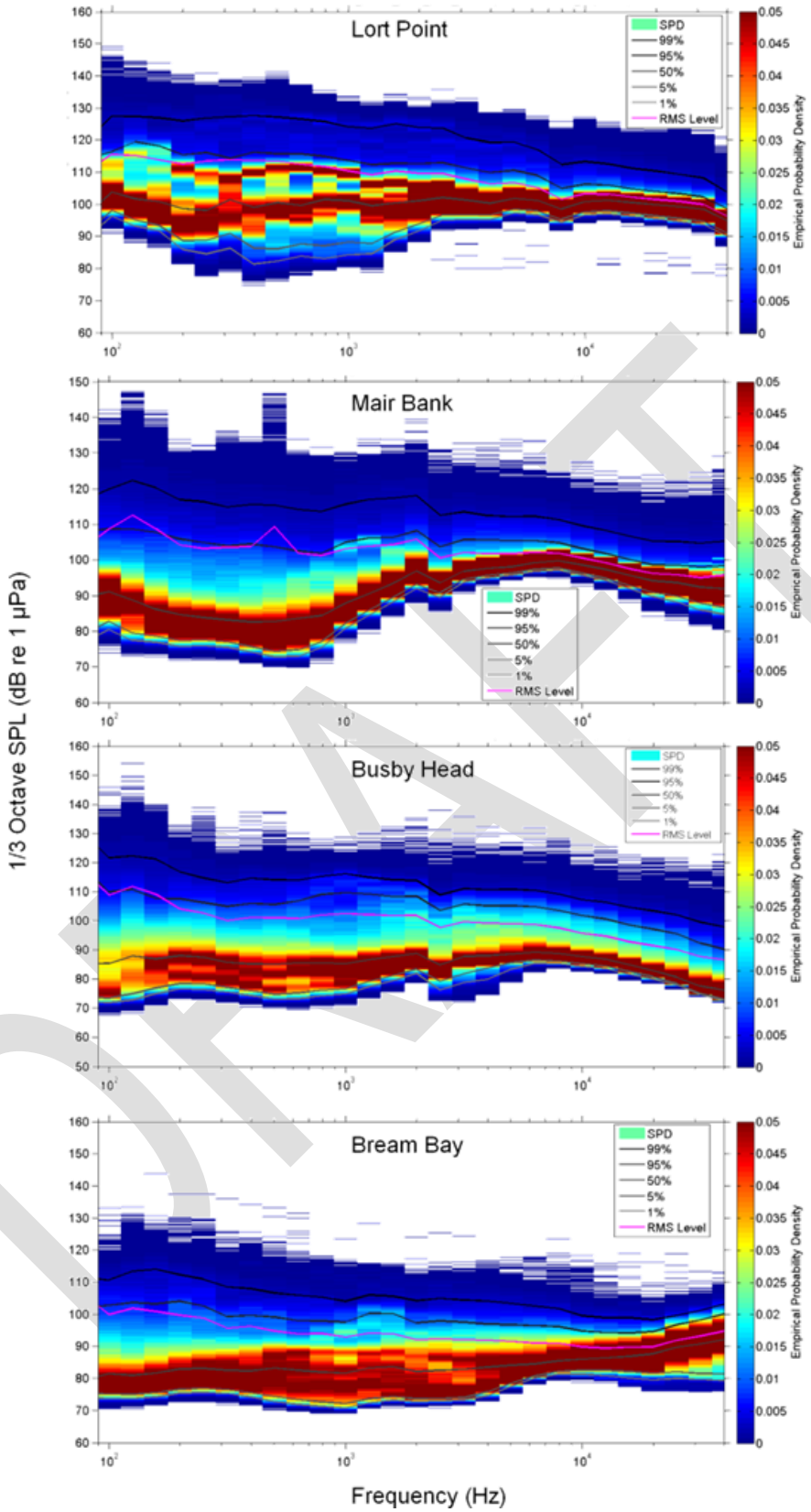

Figure 5: Third octave band plots showing RMS spectrum, percentiles and SPD measured over the survey period.

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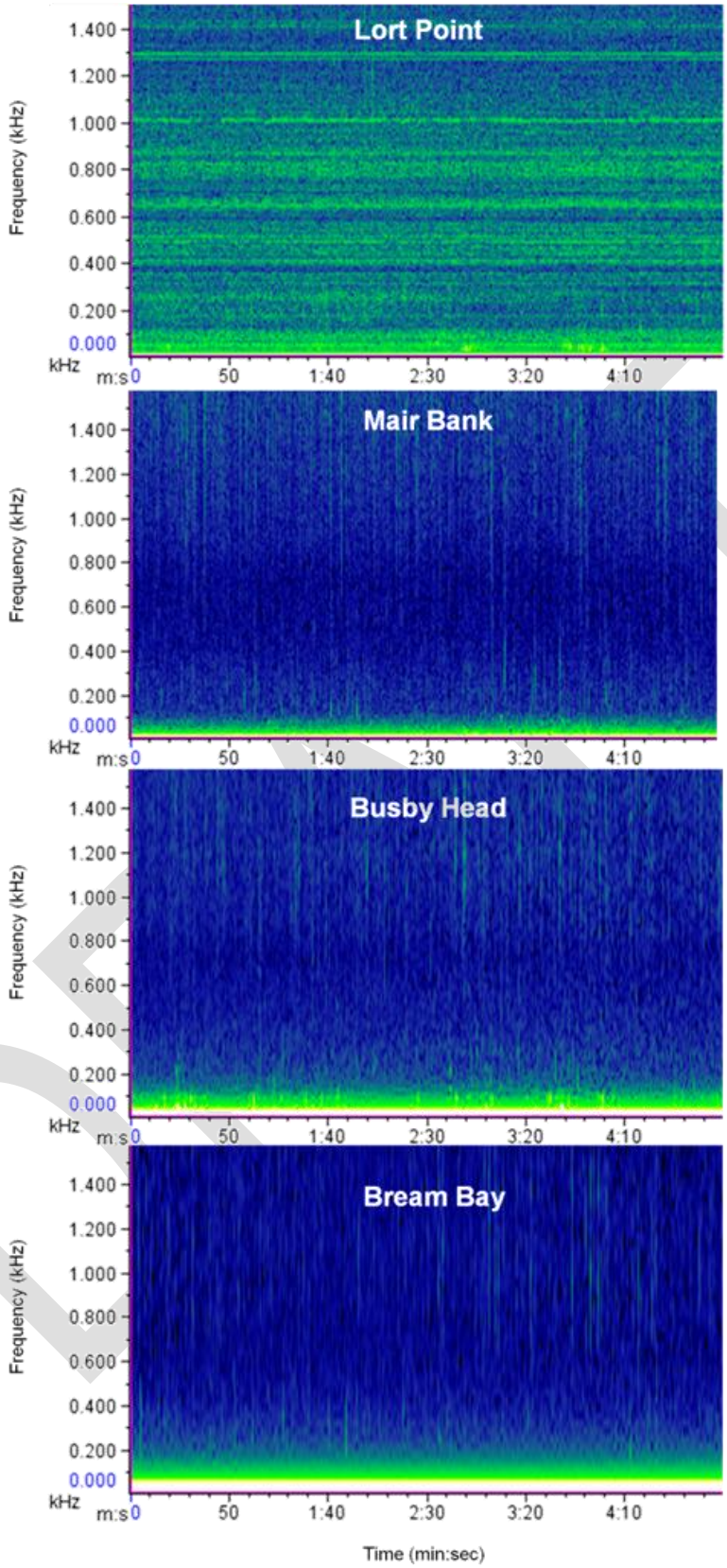

Figure 6: Acoustic spectrograms showing the low frequency signal composed of several harmonics within the Lort Point site only. Spectrograms based on five minute sample at 01:00hrs 26th March 2015.

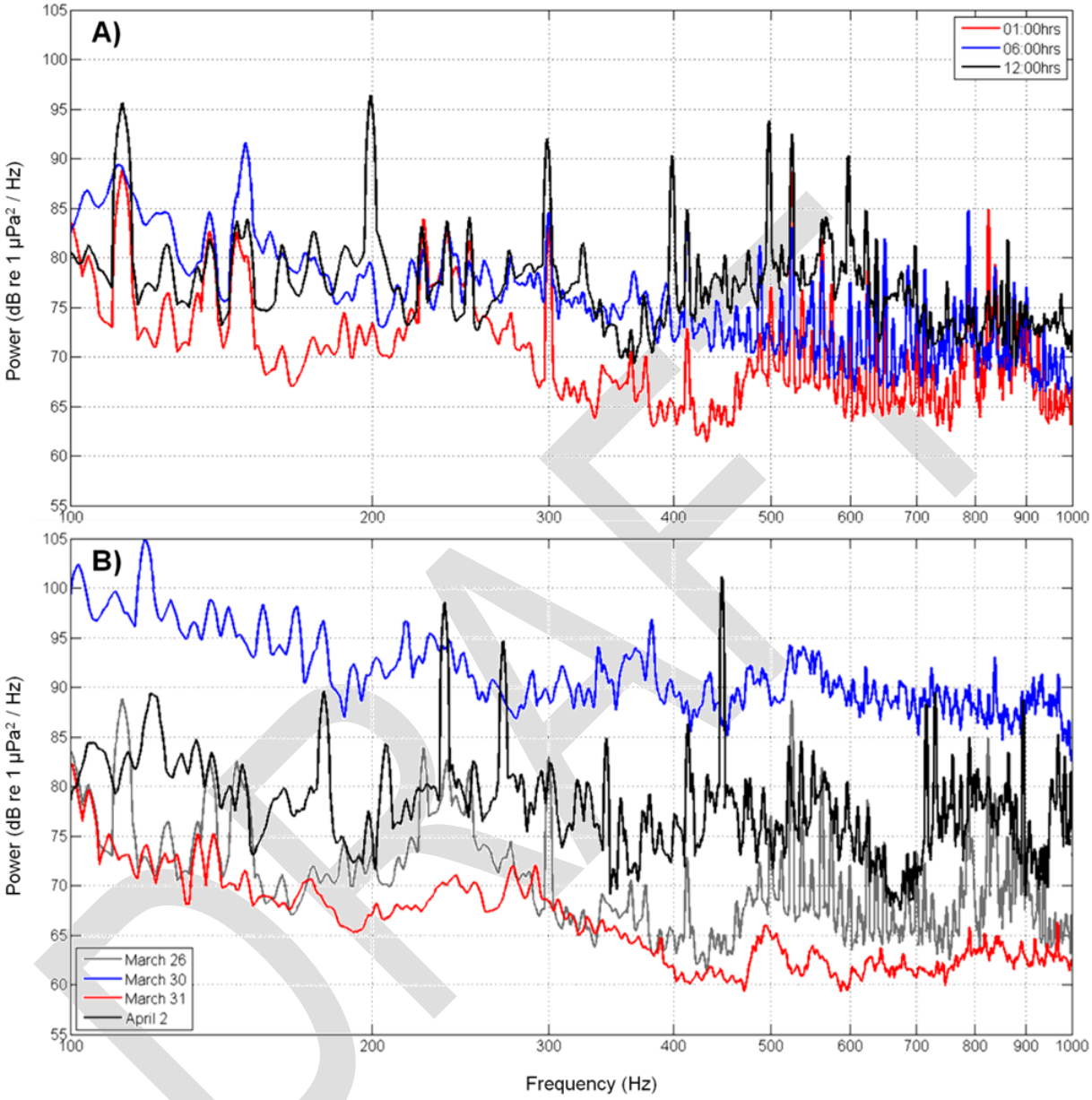

Figure 7: Power spectra plots of continuous low frequency signals within the Lort Point survey site: (A) 26th March 2015 at 01:00hrs, 06:00hrs and 12:00hrs; and (B) plots showing temporal variability in peak frequencies and SPL below 1 kHz between the 26th March and 2nd April. Samples were taken between 01:00hrs and 02:30hrs where no vessel noise (commercial and recreational) was present. Power spectra was calculated using a randomly selected 10min recording. The continuous low frequency harmonics suggest source is mechanical.

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Objective 2: Vessel noise

A total of 15 identifiable vessels were recorded both arriving and departing Marsden Point. Of those 15 vessels, five were oil tankers (four out of the five were smaller coastal product vessels). Details of all 15 vessels, including the received SPLs are given in Table 2. Broadband SPL plots of each oil tanker passing through the Mair Bank or Lort Point survey site (identified in Table 2) and the corresponding spectral plots are provided in Figure 8.

Vessel Name	IMO Number	Type	Speed (km h^{-1})	Distance (m)	Received SPL (dB_{rms} re 1 µPa)	Survey Site
Awanuia	9458042	Bunker Tanker (Coastal)	17	257	143	Mair Bank
Maritime Victory	9550292	Log	17	287	141	Mair Bank
Ningpo	9134658	Veneer	NA*	NA*	136	Mair Bank
Pacific Princess	7806271	Fishing	NA*	NA*	142	Mair Bank
Amsel	9076387	Log	15	300	141	Mair Bank
Jag Lagshita	9208057	Suezmax	12	277	135	Mair Bank
Kakariki	9158305	Coastal Tanker	19	248	137	Mair Bank
Anatoki	8864153	Cement	20	314	143	Mair Bank
Yangtze Grace	9584231	Log	19	293	142	Mair Bank
Matsumae	9401336	Triboard	17	270	136	Mair Bank
Baltic Hare	9397236	Log	18	249	143	Mair Bank
Southern Trader 3	9167459	Cement	23	286	141	Mair Bank
Torea	9274082	Coastal Tanker	22	313	150	Mair Bank
High Endurance	9272929	Small Tanker	10	508	133	Lort Point
Maritime Fidelity	9528861	Log	16	284	143	Mair Bank

*Data unavailable.

Table 2: Details of each commercial vessel arriving/departing the oil refinery and the received broadband SPLs (50 Hz - 70 kHz).

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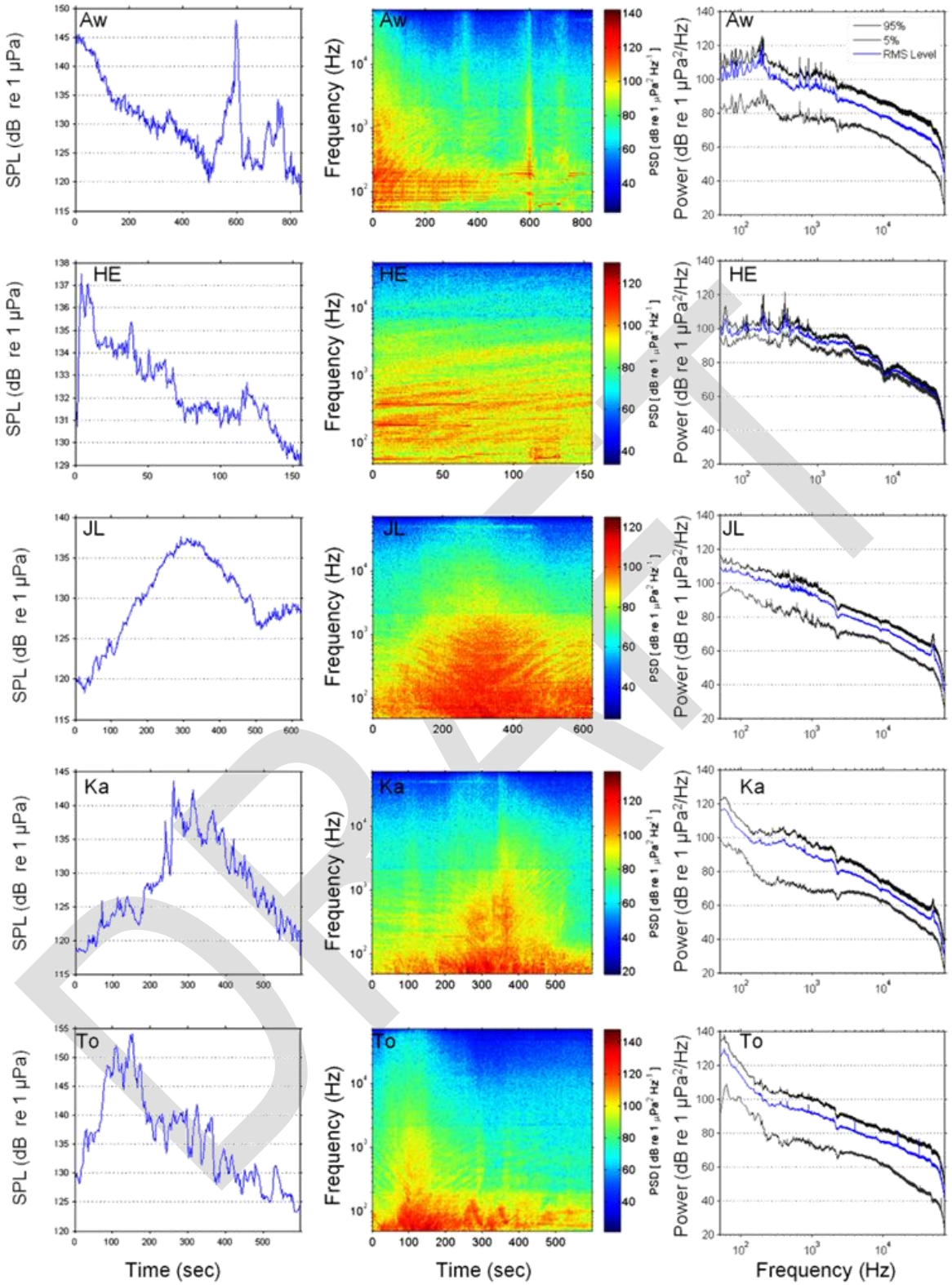

Figure 8: Broadband SPLs (left column) and corresponding acoustic spectra for five oil tankers arriving or departing the Marsden Point oil refinery (Aw=Awanuia; HE=High Endurance; JL=Jag Lagshita; Ka=Kakariki; To=Torea).

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The broadband SPL of the larger suezmax tanker is not the highest, with many of the smaller coastal tankers showing greater received SPLs. It is important to note, however, that this difference may be caused from reduced speed, differing distances or engine configurations and the relationship between vessel speed and received SPLs are plotted in Figure 9.

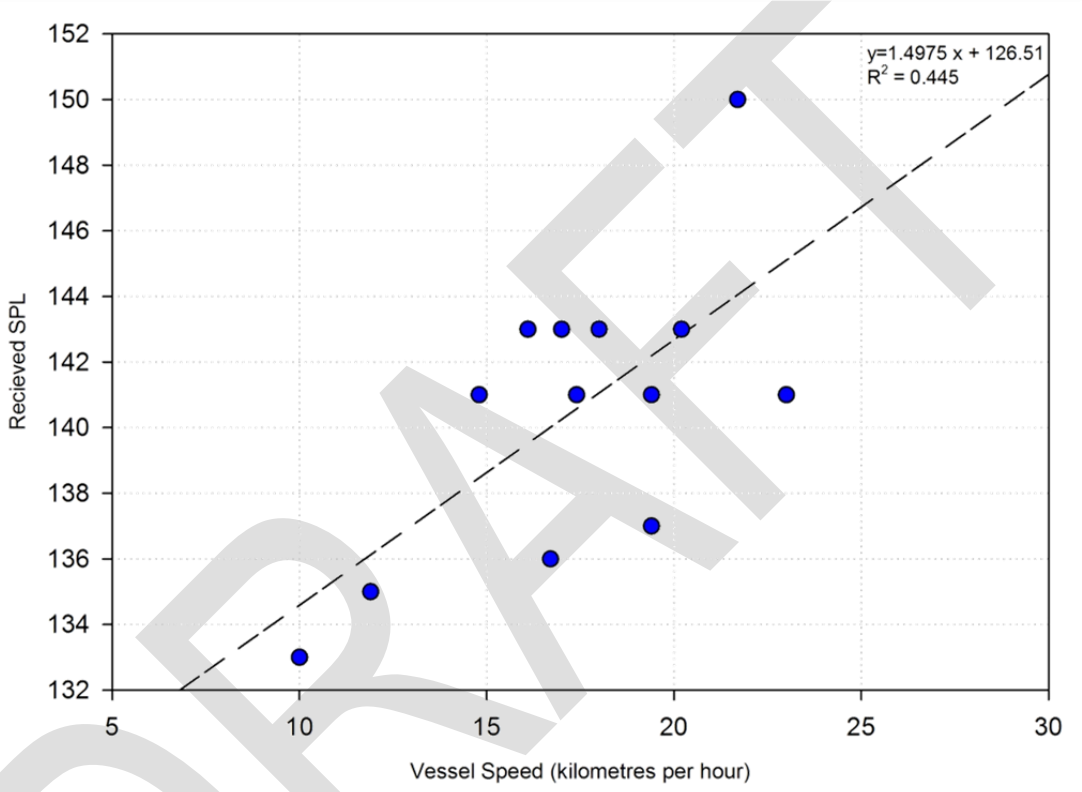

Figure 9: Relationship between received SPL (dB re 1 µPa) and vessel speed (km h^{-1}). Dotted line represents the regression line showing a statistically significant positive relationship (y = 1.4975x + 126.51; R^2 = 0.445; Regression ANOVA $F_{1,12}$ = 8.833, P = 0.013). ANOVA was performed after confirming the data met the assumptions for normality and homogeneity. Note these are based on received SPLs and have not been controlled for distances or spectral variability between vessels' acoustic outputs.

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Objective 3: Marine mammal detection

Marine mammals were identified on several occasions during the survey. In total, marine mammals were detected 13 separate times between all four survey sites. Both echolocation clicks and whistles were detected and a typical example is shown in Figure 10. On most occasions, vocalisations were detectable for approximately 30 minutes at a time, with the longest occurrence lasting was approximately 1.5 hours.

Recorded whistles were consistently between 6 kHz and 20 kHz and clicks were broadband between 20 kHz and 100 kHz (characteristic of some dolphins). Due to the limited number of samples, identification of species was not possible. Whales and narrow-band high frequency cetaceans were not detected during the survey. The highest number of dolphin detections were within the Busby Head (6 separate detections) and Bream Bay (5 separate detections) survey site, followed by Mair Bank (2 separate detections) and Lort Point (1 detection). On one occasion, a group of dolphins were clearly detected during the passing of the ship Anatoki (IMO 8864153), at Mair Bank, as shown in Figure 11.

It is important to note that this survey does not serve as an accurate estimate of abundance or diversity, or the degree of affinity to a particular habitat or area. Dolphins vary their vocalisations depending on their behaviour and they are only detectable when they vocalise in proximity to the hydrophone, at sufficient levels to be detected over the background noise floor. Notwithstanding that, however, the results from this survey show that dolphins do frequent the general area. It is therefore our opinion that a noise management plan including passive acoustic monitoring may be required. This is, however, a matter that will be revisited in the future during the Phase 2 work.

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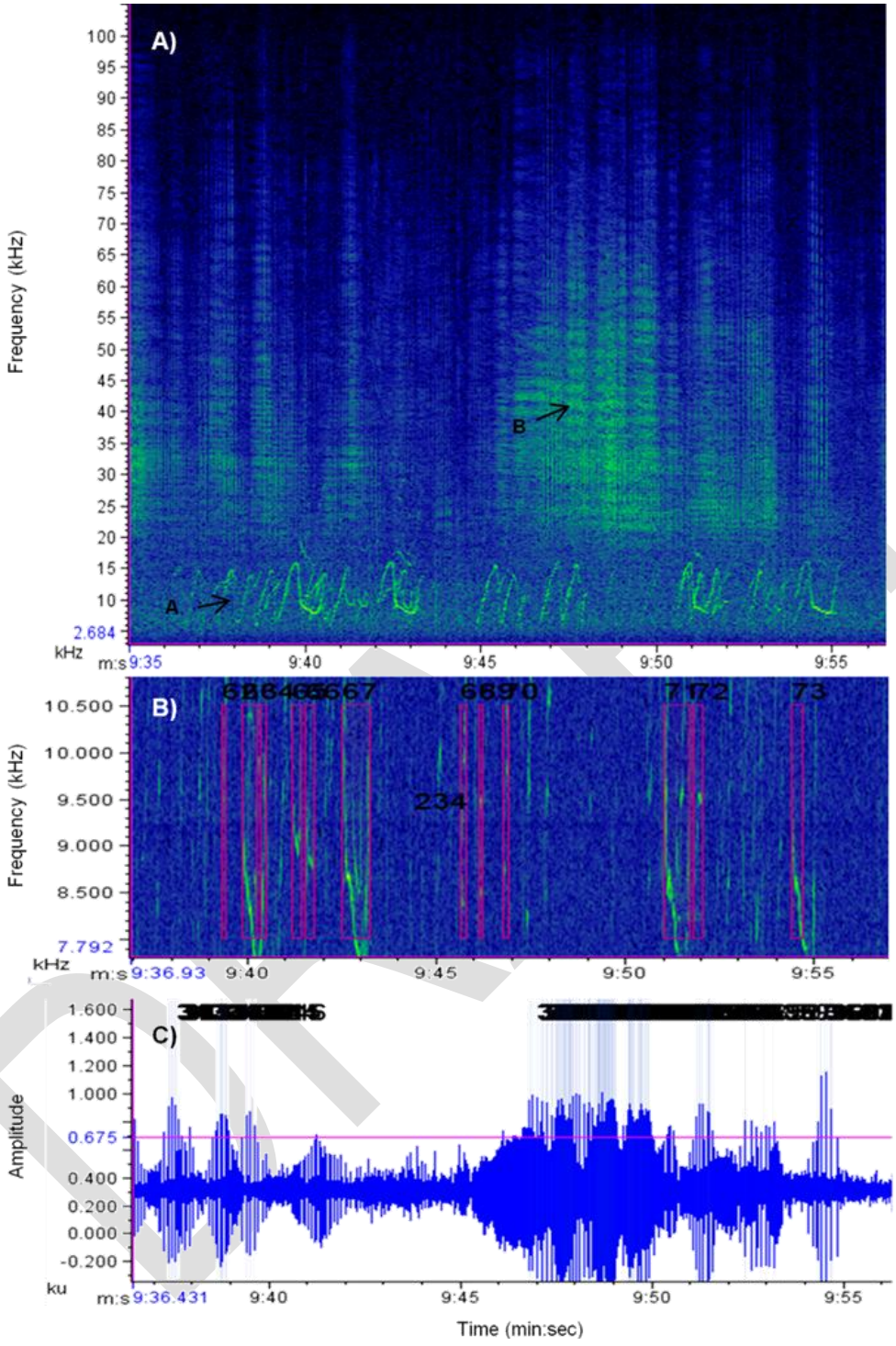

Figure 10: Acoustic spectrograms and waveform of dolphin vocalisations: (A) Echolocation clicks (shown by the arrow labelled B) and whistles (shown by arrow labelled A); (B) magnified section of whistles showing the auto-detection; and (C) waveform of vocalisations showing the amplitude auto-detection.

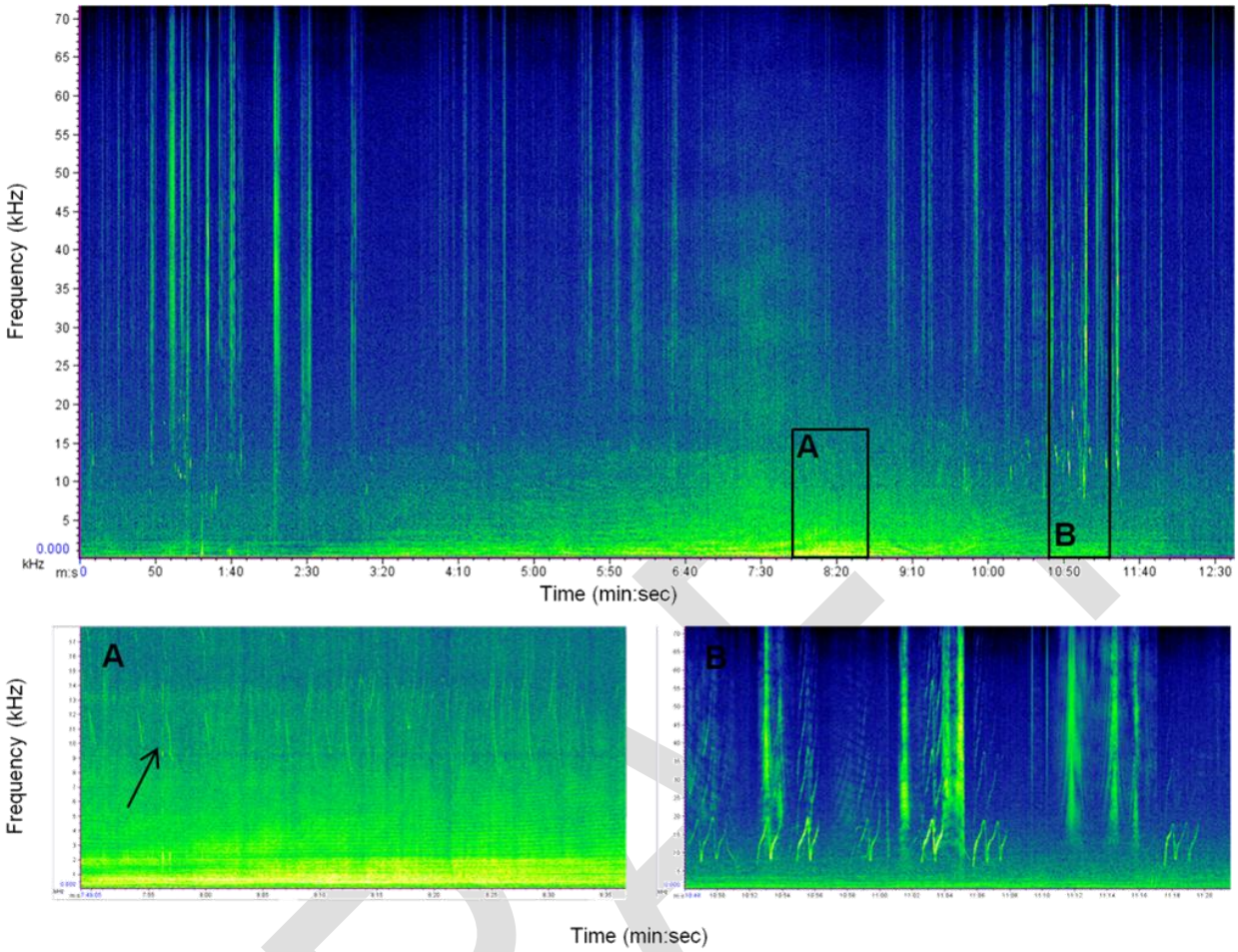

Figure 11: Acoustic spectrogram of the Anatoki (IMO 8864153) and dolphins at Mair Bank. The smaller windows labelled A and B are magnified sections corresponding to the boxes in the main spectrogram. The arrow identifies dolphin whistles over the top of the passing vessel noise.

Conclusion

Styles Group has been engaged by RNZ to undertake a passive acoustic survey of the ambient underwater soundscape within and around Calliope Bay at the entrance to Whangarei Harbour to accompany an application to deepen the channel at Whangarei Heads to allow suezmax vessels to operate at a higher capacity than at present. Currently, these large ships carry cargo to and from the oil refinery but are under-loaded so to successfully navigate the channel between Whangarei Heads and Marsden Point.

Background sound levels varied considerably between survey sites. The highest background sound levels were measured from Lort Point (average 119 ± 0.08 dB_{rms} re 1 µPa) followed by

Mair Bank (113 ± 0.07 dB_{rms} re 1 µPa), Bubsy Head (108 ± 0.46 dB_{rms} re 1 µPa) and Bream Bay (105 ± 0.10 dB_{rms} re 1 µPa). When compared to other New Zealand harbours, for example the Waitemata Harbour and around the inner Hauraki Gulf, the broadband background sound levels measured within the Whangarei Harbour entrance were lower. However, in the absence of any operating vessels, the ambient soundscape within the Whangarei Harbour entrance was comparable with many other nearshore environments around the New Zealand coastline, for example the outer Hauraki Gulf and Kaipara Harbour. Spectrally, the soundscape within the Whangarei Harbour entrance was similar to other harbours where vessel activity is high as the root mean squared and 5th percentile spectrum was characterised by frequencies below 1 kHz, while the outermost survey site, Bream Bay, demonstrated spectra closer resembling those of soft sediment habitats.

Received noise levels from vessels also varied considerably and ranged from 128 dB_{rms} re 1 µPa (Anatoki, IMO 8864153) to 150 dB_{rms} re 1 µPa (Torea, IMO 9274082). The received SPLs from the larger suezmax tanker was less than many of the smaller coastal tankers. However, the lower SPL from the suezmax may be because of her lower speed and differing distances from the receiving hydrophone.

Dolphins were detected at all survey sites, with most detections occurring outside Calliope Bay (Busby Head and Bream Bay). However, dolphins were detected within Calliope Bay on three separate occasions; once being detected as far as Lort Point. While these findings clearly show evidence that dolphins do frequent the general area, much care should taken when inferring any conclusions regarding their abundance or habitat use because the data is limited in sample size.

References

Pine, M.K., Radford, C.A., Jeffs, A.G. (2015). Eavesdropping on the Kaipara Harbour: characterising underwater soundscapes within a seagrass bed and a subtidal mudflat. *New Zealand Journal of Marine and Freshwater Research* 49(2): 247-258.

Radford, C.A., Jeffs, A.G., Tindle, C.T., Montgomery, J.C. (2008). Temporal patterns in ambient noise of biological origin from a shallow water temperate reef. *Oecologia* 156: 921-929.

Radford, C.A., Stanley, J.A., Tindle, C.T., Montgomery, J.C., Jeffs, A.G. (2010). Localised coastal habitats have distinct underwater sound signatures. *Marine Ecology Progress Series* 401: 21-29.

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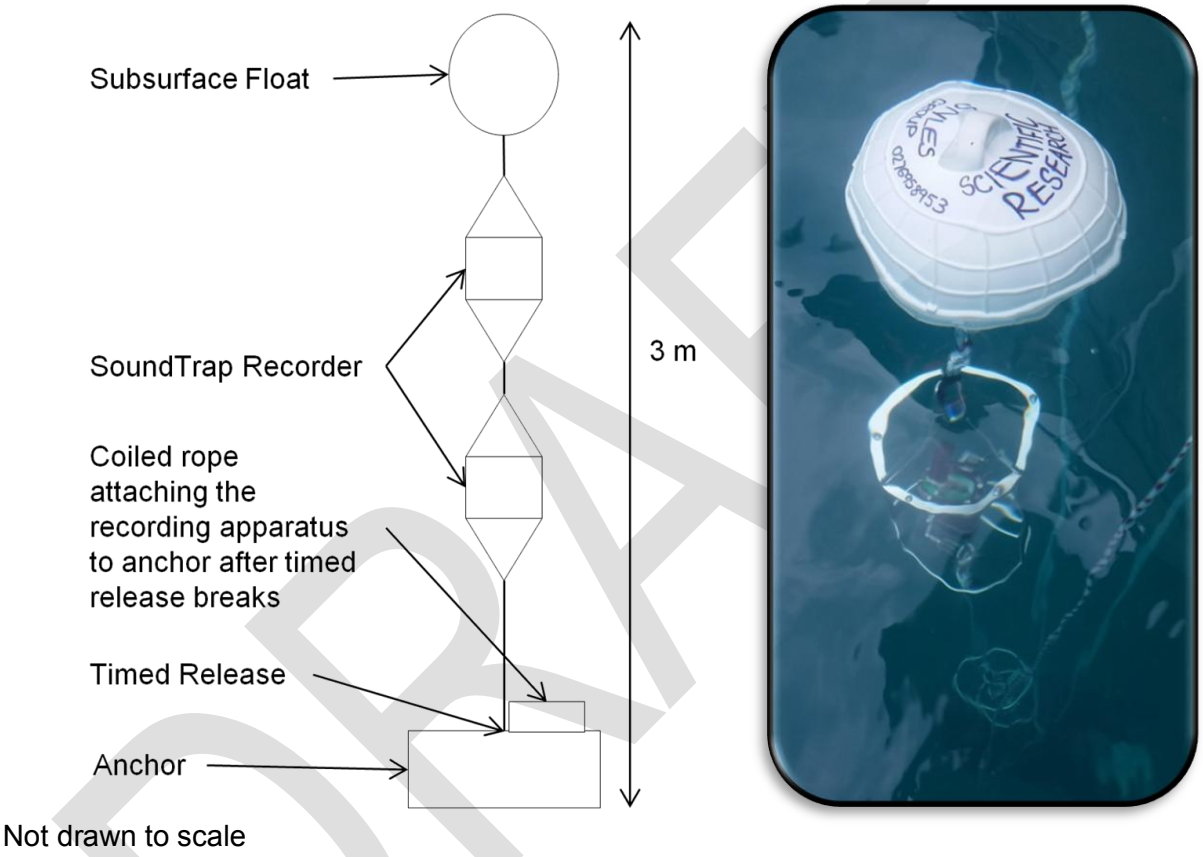
Appendix A

Schematic diagram of the SoundTrap acoustic logger apparatus and photograph of the apparatus being lowered during deployment.



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Appendix 2. Theoretical zones of auditory influence and sound threshold criteria.

Theoretical 'zones of auditory influence', originally proposed by Richardson et al. (1995), are mainly based around the distance between the source and receiver, and the idea that underwater sound intensity, and its potential impact, decreases with increasing distance. These zones include detection, behavioural responses, auditory masking and possible auditory injury (also see Pine and Styles 2016 and, in particular, figure 10).

Southall et al. (2007) used a number of studies that examined the potential onset of temporary auditory threshold shifts (TTS; in humans this is often described as the muffled effect your hearing might have after a loud concert) and more permanent threshold shifts (PTS) in captive marine mammals, and extrapolated these to set some initial thresholds for assessing potential auditory damage. More recently, the USA National Oceanic and Atmospheric Administration (NOAA) has researched, and suggested functional hearing specific sound thresholds for, the sound levels likely to cause injury (NOAA 2016), or behavioural responses (NOAA 2011). These threshold criteria are summarised in Table A2.1.

The sound levels at which significant behavioural disturbance for marine mammals can occur are still under discussion (NOAA 2016). Interim sound threshold guidelines (previously known as Level B harassment) are defined in the context of the Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA) and other United States statutes (NOAA 2011; also see Southall et al. 2007). These behavioural disturbance thresholds range between 120 and 160 dB *re*1µPa rms (including both non-pulse and pulse noise) and are defined as having …*the potential to disturb a marine mammal or marine mammal stock in the wild by causing meaningful disruption of biologically significant activities, including, but not limited to, migration, breeding, care of young, predator avoidance or defense, and feeding.* (see Table A2.1).

In the absence of any new behavioural guidelines, this report and Pine and Styles (2016) have used the 120 dB re.1µPa rms non-pulse noise threshold. We have chosen to weight this threshold in combination with the main species functional hearing group weightings proposed by NOAA (2016) to give a better estimate as to what the animals are actually receiving. We have also modelled the unweighted spatial extent of the 120 dB re.1µPa rms threshold (Figure A2.1). If practical, we will monitor this theoretical behavioural boundary for the possible presence of offshore species (i.e. beaked whales, pilot whales) to empirically test any subsequent behavioural responses to the dredging noise at the time and determine whether this noise threshold is an effective mitigation tool for protecting these species.

It is important to emphasises that Pine and Styles (2016) have used topography and oceanographic data specific to the proposal location to model the spatial extent of capital dredging noise within Whangarei Harbour and Bream Bay waters. Hence, the

underwater noise approach and findings reported in Pine and Styles (2016) and this report are not applicable to other regions or similar dredging proposals.

Table A2.1. Proposed acoustic injury criteria for individual marine mammals exposed to 'discrete' noise events (multiple exposures within a 24-h period) from NOAA (2016) (and NOAA [2011] for behavioural threshold for non-pulse noise levels).

Mammal Group	Effect	Measurement	Threshold
Cetaceans (LF)*	PTS onset	Exposure Level†	199 dB re.1μPa^2/s SEL_{cum} weighted
	TTS onset	Exposure Level	179 dB re.1μPa^2/s SEL_{cum}
	Behavioural	Non-pulse noise	120 dB re.1μPa rms
Cetaceans (MF)**	PTS onset	Exposure Level†	198 dB re.1μPa^2/s SEL_{cum} weighted
	TTS onset	Exposure Level	178 dB re.1μPa^2/s SEL_{cum}
	Behavioural	Non-pulse noise	120 dB re.1μPa rms
Otariid pinnipeds (in water)	PTS onset	Exposure Level†	219 dB re 1μPa^2/s SEL_{cum} weighted
	TTS onset	Exposure Level	199 dB re 1μPa^2/s SEL_{cum}
	Behavioural	Non-pulse noise	120 dB re.1μPa rms

* Applies to low-frequency cetaceans – 7 Hz-35 kHz, all baleen whales;
**Applies to mid-frequency cetaceans – 150 Hz-160 kHz, all toothed cetaceans except those listed in high-frequency category (high-frequency cetaceans - 275 Hz-160 kHz, true porpoises, *Kogia*, river dolphins, cephalorhynchid (Hector's dolphin), *Lagenorhynchus cruciger, L. australis)*.
†Non-impulsive sounds only.

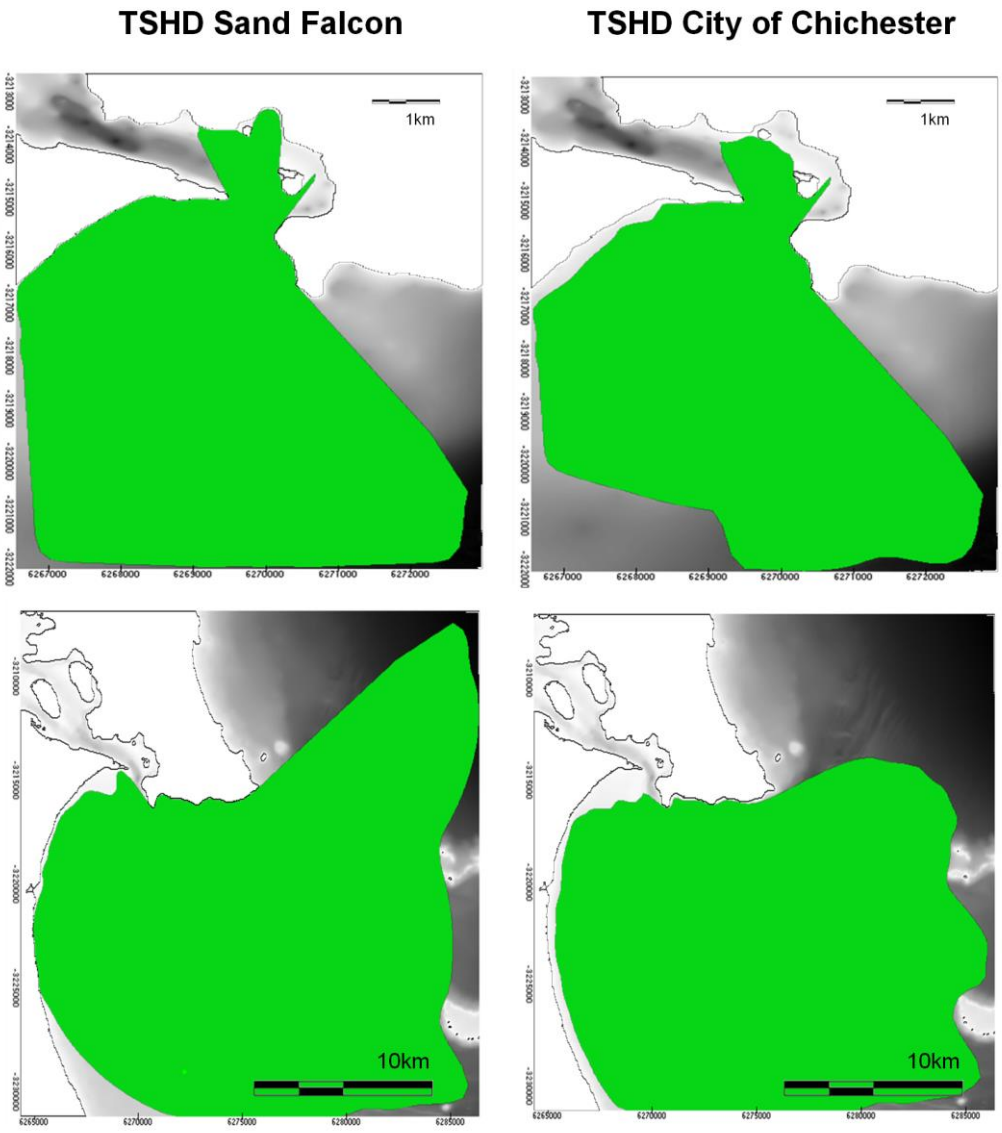

Figure A2.1. Modelled impact zone for the potential onset of behavioural responses at the 120 dB contour for unweighted noise levels for the larger TSHD Sand Falcon (left column) and smaller TSHD City of Chichester (right column) under full dredging conditions within the inner channel (top row) and outer channel (bottom row). Full dredging conditions is draghead down, pumps running and dredging vessel underway.

Appendix 3. Marine Wildlife Management Plan for the proposed capital dredging and pile driving.

1. MARINE WILDLIFE MANAGEMENT PLAN

1.1. Best boating guidelines

The overall risk of a vessel strike between dredge vessels and marine mammals is low. In the unlikely case that a vessel should encounter a marine mammal while working, implementing the following 'best practice' boating behaviours (used worldwide) around marine mammals shall reduce any chance of collision.

1.1.1. General practice

If a whale or dolphin is sighted, but not directly in the path of the vessel:

- Keep boat speed constant and / or slow down while maintaining current direction
- Avoid any abrupt or erratic changes in direction
- Maintain or resume normal operating speeds once well way from animals.

1.1.2. Large baleen whales—such as Bryde's or southern right whales

If a whale is sighted directly in the path of the vessel:

- If the whale is far enough ahead of the vessel (e.g. > 500 m) and can be avoided, slow to 'no-wake' if necessary and maintain a straight course away from the immediate sighting area (where practicable)
- If the whale is too close to the vessel and cannot be avoided, immediately place the engine in neutral and allow the boat to drift to one side of the sighting area where practicable (do not assume the whale will move out of the way)
- Avoid any abrupt or erratic changes in direction while at speed
- Once the whale has been re-sighted away from the vessel, slowly increase speed back to normal operation levels.

If a cow / calf pair is sighted within 500 m of an underway vessel:

- Gradually slow boat while maintaining a course away from the immediate sighting area (where practicable)
- Allow the pair to pass
- Once the pair has been re-sighted away from the vessel (> 500 m), slowly increase speed back to normal operation levels
- Avoid any abrupt or erratic changes in direction while at speed.

If a whale and / or cow / calf pair approaches a stationary vessel:

- Keep the engine in neutral, and allow the animal to pass
- Maintain or resume normal operating speeds once well way from animals (> 500 m).

1.1.3. Small to medium whales and dolphins —— such as bottlenose dolphin or orca

If a dolphin(s) is sighted directly in the path of the vessel:

- Keep boat speed constant and / or slow down while maintaining a course slightly to one side of the group, do not drive through the middle of a pod
- Avoid any abrupt or erratic changes in direction
- Maintain or resume normal operating speeds once well way from animals.

If a dolphin(s) approach an underway vessel to bow-ride or ride the stern wave:

- Keep boat speed constant and / or slow down while maintaining course
- Avoid any abrupt or erratic changes in direction
- Do not drive through the middle of a pod
- Maintain or resume normal operating speeds once well way from animals (> 500 m).

1.2. Debris management guidelines

To avoid the risk of entanglement to marine mammals, all dredging, support vessels and other project activities shall have waste management plans in place prior to the commencement of works. Debris and waste management shall, at a minimum, include:

- Avoiding use of continuous looping lines.
- Slack or free-floating lines should be avoided where practicable.
- Any lines to be kept under tension.
- Proper disposal, and secure storage of plastics and other wastes, especially in higher wind conditions.

1.3. Underwater noise management

Foremost, all dredging and pile-driving equipment and vessels will be regularly maintained with proper upkeep (e.g. lubrication and repair of winches, generators) to reduce the production of underwater noise.

1.3.1. Dredging noise level measurements

Acoustic monitoring shall be undertaken at the earliest possible date once the dredge vessels has arrived to confirm that the actual noise levels associated with dredging activities are as expected for dredging (Pine & Styles 2016). This monitoring shall include, as a minimum, underwater noise measurements, taken during good weather conditions and at varying distances and bearings from the vessels, during the following operational conditions/production cycles:

- During the sediment extraction phase (for all dredge types), from when the bucket/draghead/cutterhead enters the water and sediment is being loaded into the hopper/barge
- During disposal of sediment.

Noise emissions from the loaded/unloaded transit of the dredged material can be assessed and monitored from the passive acoustic moorings and AIS data from the area during dredging. Underwater recordings of each production phase identified above should be taken from the dredge vessel itself (if possible) and a range of log distances (such as, but not limited to, 50 m, 100 m, 200 m, 500 m, 1000 m, 2000 m). Recordings should be of a duration that allows for at least three representative production cycles to be sampled in good weather over the same day. RMS parameters will be measured to compare with the behavioural criteria for ground truthing the underwater noise propagation modelling in Pine and Styles (2016).

Results will be reviewed with parameters used for acoustic modelling in Pine and Styles 2016, and if necessary, spatial modelling results adjusted for use in later maintenance dredging planning. The designated 'precautionary' safety zone of 50 m for avoiding TTS effects (discussed in Section 1.1.2) is highly conservative and robust enough to accommodate any final adjustments based on actual dredging sound data.

1.3.2. Standard operational procedures for pile-driving activities (from DPTI 2012)

Standard operation procedures that must be undertaken by contractors during piling activities include pre-start, soft start, normal operation, stand-by operation, and shut-down procedures. The marine mammal observer (Appendix 4, Section 1.1.3) associated with the pile-driving works will be familiar with the SOP, and will document the process.

Pre-start procedure – The presence of marine mammals should be visually monitored by a suitably trained crew member for at least 30 minutes before the commencement of the soft start procedure. Particular focus should be put on the shut-down zone but the observation zone [which can be up to 2 km radius depending on pile-driving type and noise propagation] should be inspected as well, for the full extent where visibility allows. Observations should be made from the piling rig or a better vantage point if possible [i.e. in the absence of a high vantage point, a large observation zone may require an additional vessel as sufficient observation platform].

Soft start procedure – If marine mammals have not been sighted within or are likely to enter the shut-down zone during the pre-start procedure, the soft start procedure may commence in which the piling impact energy is gradually increased over a 10 minute time period. The soft start procedure should also be used after long breaks of more than 30 minutes in piling activity. Visual observations of marine mammals within the safety zones should be maintained by trained crew throughout soft starts. The soft

start procedure may alert marine mammals to the presence of the piling rig and enable animals to move away to distances where injury is unlikely.

Normal operation procedure – If marine mammals have not been sighted within or are not likely to enter the shut down or observation zone during the soft start procedure, piling may start at full impact energy. Trained crew should continuously undertake visual observations during piling activities and shut-down periods. After long breaks in piling activity or when visual observations ceased or were hampered by poor visibility, the pre-start procedure should be used. Night-time or low visibility operations may proceed provided that no more than 3 shut-downs occurred during the preceding 24 hour period.

Stand-by operations procedure – If a marine mammal is sighted within the observation zone during the soft start or normal operation procedures, the operator of the piling rig should be placed on stand-by to shut-down the piling rig. The trained crew member should continuously monitor the marine mammal in sight.

Shut-down procedure – If a marine mammal is sighted within or about to enter the shut-down zone, the piling activity should be stopped immediately. If a shut-down procedure occurred and marine mammals have been observed to move outside the shut-down zone, or 30 minutes have lapsed since the last marine mammal sighting, then piling activities should recommence using the soft start procedure. If marine mammals are detected in the shut-down zone during poor visibility, operations should stop until visibility improves.

In addition, it is recommended that a record is be kept of all sightings (as per the sighting data form in the marine mammal monitoring plan), delayed start-up or enforced shut-downs due to presence of marine mammals.

Zone sizes

The size of the safety zone and observation zone will be based on the chosen driving technique, noise exposure thresholds and subsequent safety zone distances as provided by the Australia DPTI guidelines and listed in the following table.

Species	Noise exposure threshold	Observation zone	Shutdown zone	Zone of behavioural response
Impact piling	**SEL in db(M*) re 1 µPa²s for single impact**			
All species / all functional groups	≤150 db(M_{xx}) at 100 m	1 km	100 m	≤ 150 m
	≤150 db(M_{xx}) at 300 m	1.5 km	300 m	≤ 500 m
	>150 db(M_{xx}) at 300 m	2 km	1 km	≤ 3 km
Vibro-driving	**SPL in dB re 1 µPa for single impact**			
Cetaceans	≤180 db at 10 m	500 m	10 m**	≤ 5 km
	>180 db at 10 m	1 km	100 m**	≤ 10 m
Pinnipeds	≤190 db at 10 m	500 m	10 m**	≤ 5 km
	>190 db at 10 m	1 km	100 m**	≤ 10 m

*M-weightings should be used for the species functional hearing groups for impact driving noise exposure threshold. For example, for LF cetaceans, the first noise exposure threshold would be ≤150 db(M_{lf}) at 100 m.

** when no avoidance.

1.3.3. Additional measures

Given the shallow location, soft sandy sediments and extremely short-term duration of the proposed pile-driving activity, no additional or further noise minimising options are considered necessary. The following measures are listed as additional considerations when determining the BPO for pile-driving techniques, depending on the practicality and appropriateness specific to this proposal.

Considerations for the BPO for pile driving

- Suction piling (directly from DPTI [2012]) – Suction piling uses tubular piles that are driven into the seabed, or dropped a few metres into a soft seabed, after which air and water are sucked out the top of the tubular pile thereby sinking the pile into the ground. Suction piles are often used to secure offshore floating platforms, in both shallow and deep waters. Although noise levels have not been reported, they are expected to be low as the only source of noise is the pump.
- If practicable, to reduce impact noise use a non-metallic dolly for concrete and steel piles.

1.4. Department of Conservation liaison procedures

A two-way liaison with the Department of Conservation shall be established for exchange of marine mammal sighting data throughout the capital dredging project.

The Department of Conservation shall be contacted regularly [INSERT FREQUENCY; TBC in liaison with DOC] over the project period to obtain real-time/recent sighting information. Information will be shared with officers on board all project vessels, including the designated observer on-board the dredge vessel. This will allow project vessels to anticipate and mitigate potential interactions with any whale species sighted in and near the project area.

In addition, RNZ shall collate and regularly [INSERT FREQUENCY; TBC in liaison with DOC] share any opportunistic or on-board observer sighting data (Appendix 4, Section 1.1) with DOC.

1.4.1. Contact persons and contact details

Contact person (DOC): [INSERT NAME AND CONTACT DETAILS]
Contact person (RNZ): [INSERT NAME AND CONTACT DETAILS]

1.5. Incident reporting (vessel strike and entanglement)

Incidents involving the injury or mortality of a marine mammal shall be reported to the Department of Conservation's contact person as soon as is practicable but not more than six hours. In the case of a fatality, tangata whenua's representative shall also be notified within 24 hours of the incident occurring.

Incident details shall include as much information as possible relating to incident (e.g. date, time, weather conditions [visibility, sea state, etc], vessel location, speed, activity, etc). Any details of the marine mammal (e.g. species, group size) and its behaviour before, during and after the incident shall also be recorded. If practicable, video or photos could be taken. Information will be used to inform how future incidences could be avoided.

Any incident that results in marine mammal injury or fatality will be documented using the incident reporting form (Section 1.5.2 below).

1.5.1. Contact persons and contact details

Department of Conservation: [INSERT NAME AND CONTACT DETAILS]
Tangata Whenua representative: [INSERT NAME AND CONTACT DETAILS]

1.5.2. Incident reporting form

Project vessels shall record any incidents in which a marine mammal physically contacts any project gear with this plan using the incident reporting form shown below. Incident reporting forms will be shared with DOC and Tangata Whenua within 24 hours of the incident occurring. [Final form content TBC in liaison with DOC and Tangata Whenua]

INCIDENT REPORTING FORM

Date	Time	Incident Location on Vessel (description; port, bow, propeller,..)	Vessel Position		Vessel type, activity, and speed at time of incident and any subsequent responses*	Species ¥	No. of animals involved	Animal(s) activity before incident and after #	Description of any injury or mortality	Observer/ reporter	Additional comments (e.g. weather and sea conditions)
			Latitude (northing	Longitude (easting)							

* TSHD, CSD, BHD; in transit, dredging, discharging spoil, etc

¥ Using a species guide such as IFAW and AHP (2005).

Feeding, resting, travelling, socialising, breaching, bowriding etc (e.g. see IFAW and AHP (2005]).

Appendix 4. Description of the recommended marine mammal monitoring for the proposed capital dredging.

1. MARINE MAMMAL MONITORING PLAN

1.1. Visual sighting data collection

The general public and other (non-project related) vessels working in vicinity of the project should be encouraged to report opportunistic marine mammal sightings to RNZ or DOC over the specified monitoring and project timeframes (Section 1.1.1 below). Project vessels shall record and report opportunistic sightings in accordance with this plan and sighting data shall be collected by the on-board observer when on watch (Section 1.1.2).

1.1.1. Opportunistic sighting data collection

Opportunistic sighting data shall be recorded in and around Whangarei Harbour and Bream Bay area for approximately[19]:

- One month before capital dredging.
  Aim - The resulting data will be used (in conjunction with passive acoustic monitoring data) to verify the predicted visitation/presence of marine mammals as described in the Phase 1 and Phase 2 reports.
- The entire ~6 month period when capital dredging is underway.
  Aim - The resulting data will be used (in conjunction with passive acoustic monitoring data) to determine use of the project area by marine mammals during active dredging operations (e.g. are marine mammals still coming into the project area even though dredging is underway?).
- One month following the completion of capital dredging.
  Aim - The resulting data will be used (in conjunction with passive acoustic monitoring data) to determine the continued presence, or return, of marine mammals in the project area following the completion of capital dredging.

1.1.2. On-board observer (dredging)

An observer will be on board the dredge vessel during daylight hours over the duration of capital dredging. The observer will be on watch whenever dredging or disposal activities are underway (including transiting). The observer has two general duties; (1) to enforce the shut-down of sediment extraction when marine mammals are within the precautionary exclusion zone (50 m; see 'shut downs') and (2) to record sighting data (Section 1.1.4), with an emphasis on marine mammals within 300 m of

[19] The necessity and timing of the collection of opportunistic sightings for maintenance dredge monitoring will be reviewed and revised, if necessary, based on capital dredge monitoring results.

the dredge vessel. The observer does not need to be a qualified marine mammal observer (e.g. an existing crew member can be inducted and designated to fill the role of the observer).

Shut-downs

If a marine mammal comes within 50 m of an active dredge vessel (i.e. undertaking sediment extraction), a 'shut-down' should be initiated. This is to further reduce the risk of TTS onset (see Section 3.1.2 of main report, Assessment of Actual and Potential Effects).

A 'shut-down' in this case refers to cessation of sediment extraction. This might involve lifting the draghead from seafloor and ramping down the suction pump (TSHD) or cessation of ongoing removal (BHD) or cutting (CSD) of the seabed[20]. Once the mammal has left the 50 m radius, operations can be resumed. Details of any shut-down event should be captured on an incident reporting form.

The on-board observer will communicate to the [INSERT CREW POSITION] when a marine mammal is within 50 m of the dredge vessel. The [INSERT CREW POSITION] will then cease sediment extraction. Once the marine mammals has left the 50 m radius, the observer will advise the [INSERT CREW POSITION] that operations can be resumed.

1.1.3. Onboard observer (pile driving)

The observer/s associated with pile-driving works has two general duties; (1) to detect and record the presence of marine mammals and (2) to ensure standard operating procedures are followed including documenting any enforcements (if necessary). Specifically, these are detailed in Appendix 3 (Section 1.3.2). The observer does not need to be a qualified marine mammal observer (e.g. an existing crew member can be inducted and designated to fill the role of the observer).

1.1.4. Sighting data form

All sighting data collected should be collated into a tabulated format as shown below, for ease of database input.

[20] TSHD: Trailer suction hopper dredge, BHD: Back-hoe dredge, CSD: cutter suction dredge.

SIGHTING FORM

Date	Time (of first sight)	Sighting duration	Location (description including minimum distance from vessel if applicable)	Position (at first sight)		Species*	No. of animals	Animal activity ¥	Vessel type and activity of vessel #	Observer/ reporter	Additional comments (e.g. weather and sea conditions)
				Latitude (northing	Longitude (easting)						

* Using a species guide such as IFAW and AHP (2005).

¥ Feeding, resting, travelling, socialising, breaching, bowriding etc (e.g. see IFAW and AHP 2005).

TSHD, CSD, BHD; in transit, dredging, discharging spoil, etc

1.2. Acoustic data collection

1.2.1. Passive acoustic monitoring for presence of marine mammals

Passive acoustic monitoring for the presence of marine mammals shall be undertaken for approximately:

- One month before capital dredging.

  Aim - The resulting data will be used (in conjunction with sighting data) to verify the predicted visitation/presence of marine mammals as described in the Phase 1 and Phase 2 reports.

- Two separate fortnightly monitoring periods while capital dredging is underway (~6 months). These timeframes will be sufficient to capture several dredging cycles.

  Aim - The resulting data will be used (in conjunction with sighting data) to determine use of the project area by marine mammals during active dredging operations (e.g. are marine mammals still coming into the project area even though dredging is underway?).

- One month following the completion of capital dredging.

  Aim - The resulting data will be used (in conjunction with sighting data) to determine the continued presence, or return, of marine mammals in the project area following the completion of capital dredging.

During each of these periods, passive acoustic moorings would be placed in at least four locations, including around the Harbour entrance to record any animals entering or leaving the Harbour, near the disposal area in Bream Bay and along the 120 dB contour (see Figure A4.1 for some general site locations).



Figure A4.1. Suggested site locations for passive acoustic monitoring moorings. Figure originally from Pine and Styles (2015).

Appendix 5. Reported occurrences of marine mammals in the Whangarei coastal region and Harbour since March 2015.

Date	Start time	Finish time	Location Description	longitude (easting)	latitude (northing)	Species	Number observed	Activites around animals	Observer_reporter	Comments
13/03/2015	9:00		off Whangerai Harbour			bottlenose dolphin	3 to 4 (multiple groups in area)	socializing, fast travel, chasing (prey?), bow and stern riding	Simon West	Bioresearches - Simon West while doing benthic sampling on project; photos confirm bottlenose and one animal with distinct 1 tooth rake patch on top of dorsal, left side and maybe some other good shots
26/03/2015	4:30	5:00	Bream Bay			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
26/03/2015	7:30	8:00	Bream Bay			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
28/03/2015	3:00	3:26	Busby Head			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
29/03/2015	14:00	14:30	Bream Bay			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
30/03/2015	4:30	5:35	Busby Head			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
30/03/2015	5:30	7:00	Mairs Bank			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
30/03/2015	7:30	8:00	Busby Head			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
30/03/2015	17:30	18:00	Bream Bay			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
30/03/2015	18:30	19:00	Bream Bay			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
31/03/2015	6:30	7:00	Busby Head			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
31/03/2015	9:30	10:00	Busby Head			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
2/04/2015	11:30	12:15	Mairs Bank			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
2/04/2015	14:00	14:30	Lort Point			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
2/04/2015	18:30	19:00	Busby Head			unknown dolphin			Styles Group data - acoustic logger	Styles Group data - acoustic logs of dolphin species in pre-assessment field work
3/08/2015	10:30	13:00	went up Whangerai Harbour (reported Tamaterau and furthest pt was Kissing Point)			bottlenose dolphin	10	fast travel swimming up harbour, maybe in response to orca outside of heads	Northern Advocate news article	Northern Advocate news article - Lindy Laird, orca also sighted in Parau Bay
3/08/2015	10:00		off Parau Bay			orca			Floppy Halliday with Whale Watch hotline	Northern Advocate news article - Lindy Laird,
15/08/2015	15:00	17:00	Smugglers Cove (Whangarei Heads near Busby Head)			Southern right whale	1	resting in shallows	Andrea Robinson and friends	Northern Advocate news article - Mike Dinsdale, watched for about 1.5 to 2 hrs in same general area, resting in shallow ssame whale seen in Auckland's Mechanics Bay a few days earlier (not sure if ID confirmed or not); Ingrid Visser reported same animal in Sandy Bay (further north) on following Tuesday (18 Aug) and again off Bland Bay campground (Puriri Bay, Whangaruru Harbour) on the Friday 21 Aug 2015.
16/09/2015	14:00		entered Whangerai Harbour - Snake Bank sandbar (between McLeod's Bay and One Tree Point)			orca	3 +	feeding on eagle rays and stingrays	Northern Advocate news article	Northern Advocate news article - Lindy Laird, went on boat with Ingrid Visser; Good shot of orca in front of RNZ jetty and ship - Michael Cunningham Northern Advocate
22/11/2015	9:00		Managawhai estuary (south of Bream Bay); few hundred metres south of the Tara Creek mouth			bottlenose dolphin	6		Daren Grover-Project Jonah	Northern Advocate news article - Lindy Laird, stranded up creek with low tide, all released
9/03/2016	9:00		Ruakaka Beach	1731815	6023433.9	Gray's beaked whale	3	STRANDING	Clive Stone, Juliane Cheltham, Ingrid Visser; Marie Jordan - DOC	DOC stranding report and photos attached
21/04/2016			Bream Bay near proposed spoil grounds	35 54.954'S	174 31.740'E	bottlenose dolphin	5	5 included cow/calf pair	Alice Morrison - independent	Refining NZ benthic field work for ??
23/04/2016			Bream Bay near proposed spoil grounds	35 57.531'S	174 33.046'E	bottlenose dolphin	5	possibly same group both days	Alice Morrison - independent	Refining NZ benthic field work for ??
3/05/2016	a.m		north of RNZ jetty			bottlenose dolphin	2 to 3 (?)	chasing kahawhai and following small rubber boat	Joshua Roberts - RNZ staff	chasing and catching kahawhai on way to work in morning
19/06/2016	14:00		Prob 5 miles out off Ruakaka, middle of Bream Bay			Bryde's whale	2	traveling north to south	Steve Tyson - RNZ staff	mum with calf; sighted while sailing boat from Auckland; video at (https://youtu.be/3wpIPJ9XhWI); same pair may have been seen again on 15 June in harbour
2/07/2016	9:00	10:00	Whangarei Harbour just west of the Port			Humpback whale	2	rolling around in shallows with lots of flippers out of water	Riaan Elliot - RNZ staff	Whale on side with fin in the air. Fin was white and serrated along one edge. Also Northern Advocate article that showed 2 whales and confirmed humpback
13/07/2016			Kerikeri- far north beach			blue whale	1	dead stranding	Northern Advocate news article	Northern Advocate news article - Mike Dinsdale, dead blue whale washed up on private kerikeri beach. No obvious causes of death
8/09/2016	7:45		Reotahi and Darch Point			Orca	3	Travelling	Steve Tyson, RNZ, via Riaan Elliot - RNZ staff	Reotahi and Darch Point. "I talked to Ingird Visser, the male with the wobbly dorsal fin is called Funky Monkey and is 18 yrs old". Caught on video at 0745am.
3/09/2016			Onerahi			Orca			Friend of Riaan Elliot - RNA	
22-24 Oct 2016			Bream Bay			Unknown dolphin	50-100	Large pod of dolphins	Staff members sailing in the Coastal classic (via Riaan Elliot, RNZ)	Staff members sailing in the Coastal classic over labour weekend sighted a large pod of dolphins in Bream Bay. Pod size was somewhere between 50 and 100.

Annexure Two: Technical Reports

j) **AEE Report – Coastal Birds – Final. Bioresearches Group Limited. Graham Don. Dated 09 August 2017**

Bioresearches
A Babbage Company

REFINING NZ
CRUDE SHIPPING PROJECT

AEE REPORT
COASTAL BIRDS

FINAL

FOR: **REFINING NZ**

BY: **BIORESEARCHES GROUP LIMITED**
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CONTENTS

1. EXECUTIVE SUMMARY 1

2. INTRODUCTION 3

3. FIELD INVESTIGATIONS 7
- 3.1 Introduction 7
- 3.2 Methodology 8
- 3.3 Specific Area Surveys 10
  - 3.3.1 Bream Bay Beach 10
  - 3.3.2 Mair Bank 11
  - 3.3.3 Refinery Jetty to Northport 12
  - 3.3.4 One Tree Point 14
  - 3.3.5 Snake Bank 15
  - 3.3.6 Reotahi Bay 17
  - 3.3.7 Taurikura Bay 18
  - 3.3.8 McKenzie Bay 19
  - 3.3.9 Urquharts Bay 19
  - 3.3.10 Comparative Population Composition and Habitat Use 20
- 3.4 Pelagic Birds 21
- 3.5 Breeding Season Surveys 23
  - 3.5.1 Mair Road to Northport 23
  - 3.5.2 Marsden Point to Refinery Jetty 23
  - 3.5.3 Refinery Jetty to Northport 23
  - 3.5.4 Darch Point to Home Point 23
- 3.6 Harbour Penguin Surveys 24

4. AVIFAUNAL VALUES AND HABITAT SIGNIFICANCE 26
- 4.1 Introduction 26
- 4.2 Bream Bay Beach 29
- 4.3 Mair Bank 29
- 4.4 Refinery Jetty to Northport 30
- 4.5 One Tree Point 30
- 4.6 Snake Bank 30
- 4.7 Reotahi Bay 31
- 4.8 Taurikura Bay 31
- 4.9 McKenzie Bay 31
- 4.10 Urquharts Bay 31
- 4.11 Pelagic Birds 32
- 4.12 Breeding 32

5. AVIFAUNAL EFFECTS 35
- 5.1 Discounted Effects 35
- 5.2 Potential Issues 36
  - 5.2.1 Turbidity Increase 36
  - 5.2.2 Resuspended Sediment Deposition 45
  - 5.2.3 Vessel Movements 45
  - 5.2.4 Vessel Lighting 46
  - 5.2.5 Noise 49

5.2.6 Cumulative Effects 50

6. CONSULTATION AND REVIEW 51

7. RECOMMENDATIONS AND MITIGATION 52
7.1 Little Penguin 52
7.2 Vessel Lighting 53
7.3 Grey-faced Petrel 53

8. MONITORING 55
8.1 Monitoring 55
8.1.1 Coastal Birds 55
8.1.2 Little Penguin 56

9. CONCLUSION 57

10. REFERENCES 58

1. EXECUTIVE SUMMARY

A description of the coastal and pelagic birds observed utilising or recorded previously within the broad Project area is presented; that is the result of literature searches, information from a local bird watcher and specific field investigations completed in 2015 and 2016. High value bird habitats in a national context were identified at Mair Bank and Bream Bay. Northport to One Tree Point and Urquharts Bay areas were identified as being of high value in the context of the Outer Harbour.

Breeding within the Harbour was recorded or strongly inferred for variable oystercatcher, reef heron and little penguin; specific breeding sites used by threatened and at risk species are of national importance during the breeding season.

The potential risk of Project-generated effects on shorebird habitats was considered high at Mair Bank and low-moderate at Reotahi Bay as a result of their proximity to the works. The risk at the other habitats was judged to be low.

Potential issues regarding coastal and pelagic birds were identified as climate change, turbidity increases, deposition of resuspended sediment, vessel movements, vessel lighting, underwater noise and cumulative effects. There is no concern regarding permanent decrease in feeding habitat, a loss of roosting or breeding habitat, sediment contaminants, maintenance dredging, or the erection and maintenance of navigational aids. An analysis of potential effects was completed. The species most susceptible to a turbidity increase in the dredging area is considered to be little penguin; the concern is disruption of its passage between shoreline nesting areas, specifically those within the Harbour and the nearby open water. However the confined sediment plume, limited dredging area within Busby Head, temporary nature of the works, Project turbidity thresholds and ranges in ambient turbidity, indicate that adverse effects will likely be avoided and will not be contrary to NZCPS Policy 11 (a) (i) and Policy 11 (b) (ii). The probability of an adverse turbidity effect at the disposal site is considered remote and not likely to be contrary to NZCPS Policy 11 (a) (i) or 11 (b) (ii). Similarly there would be no effect on coastal or pelagic birds from the deposition of any resuspended sediments. The issue of increased vessel movements is assessed

relative to the current baseline; because the Project area is frequently used by a wide variety of vessels the effect has been judged less than minor.

Vessel lighting is a known attraction to pelagic species especially shearwaters and petrels that nest on the Hen and Chickens Islands, but especially grey-faced petrel that nests locally and is being actively encouraged within the immediately adjacent Bream Scenic Reserve. Although the objective of NZCPS Policy 11 (a) (i) would be maintained, mitigation is proposed via the provision of nesting boxes in the Reserve. The issue of noise regarding diving and swimming birds is considered negligible and to be consistent with NZCPS Policies.

Recommendations are the provision of nesting boxes for little penguin (possible turbidity effect) and grey-faced petrel (possible lighting effect), and a lighting audit of the Project's vessels to minimise the light attraction of seabirds. Monitoring of the post-dredging state-of-the-environment is proposed to cover little penguin specifically and coastal birds.

In summary the overall impact on coastal and pelagic birds is considered to be low. The Project would be consistent with NZCPS Policy 11 (a) (i) and Policy 11 (b) (ii).

2. INTRODUCTION

Assessments of the coastal bird populations in the area from a line between One Tree Point and Darch Point through to Home Point and the northern end of Bream Bay Beach were completed in February-March 2015, November 2015 and February-March 2016. The February-March 2015 and 2016 surveys aimed at documenting coastal bird abundance, diversity and habitat use while the November 2015 surveys recorded breeding activities in the context of the planned application by Refining NZ for the Crude Shipping Project.

The aim of the surveys was to gain an understanding of the characteristics and significance of bird populations in areas in the vicinity of the Project and to update information that had been reviewed in a literature review completed by Bioresearches in 2015. That literature review identified that a total of ten nationally threatened and sixteen nationally at risk coastal and pelagic species had been recorded in the outer Harbour (east of One Tree Point) and Bream Bay habitats. With non-resident native and non-threatened birds the total diversity was 34 species. Breeding in Harbour and Bream Bay edge habitat was reported for both threatened and at risk species comprising a wide range of bird groups – waders, gulls, terns, penguin, shags and shearwaters.

The two broad groups of birds present are coastal birds that utilise intertidal and nearshore habitats, and pelagic birds that generally utilise open water offshore habitats (eg shearwaters, petrels) but can occur close to shore on occasions. In this investigation the coastal birds were assessed via field surveys while information on pelagic species relied on the literature, together with observations and reports provided by Margaret Hicks, a local resident and experienced bird watcher.

While the surveys completed for this Project were completed in a two year period, a longer term benchmark is provided by the data collected at Marsden Bay by the Ornithological Society of NZ (now Birds NZ) and reported by Dickie 1984, from 1975 to 1984 inclusive; and from 2009 to 2015 inclusive by Bioresearches for the Marsden Cove Development. Those data indicate a relative stability in at least the wading bird population in this part of the Harbour over that period.

The coastal and pelagic species referred to in this report and their current (May 2017) national conservation ratings are shown in Tables 1 and 2.

The assessment of effects recognises the New Zealand Coastal Policy Statement (NZCPS) (2010), particularly Policy 11 Indigenous Biological Diversity (biodiversity) (a) which states "avoid adverse effects of activities on: (i) indigenous taxa that are listed or threatened or at risk in the New Zealand Threat Classification System lists."A total of 27 such species have been recorded in the outer Harbour survey area and Bream Bay.

Policy 11(a)(ii) is also relevant but birds listed by the International Union for Conservation of Nature and Natural Resources (IUCN) are understood to have been captured by Policy 11(a)(i). Policy 11(a)(v) is relevant to this assessment i.e. "areas containing nationally significant examples of indigenous community types" insofar as it relates to communities of coastal birds. That has been summarised in Figure 11 of this report.

Finally this evaluation recognises Policy 11(b): "avoid significant adverse effects and avoid, remedy or mitigate other adverse effects of activities on: (ii) habitats in the coastal environment that are important during the vulnerable life stages of indigenous species". Areas of known (literature review, field investigations) habitat used for bird nesting and juvenile rearing have been identified in this assessment.

TABLE 1 - List of Coastal birds, recorded during the surveys and their current conservation status (Robertson et al, 2017*)	
COMMON NAMES	**CONSERVATION STATUS ***
black-backed gull; karoro	not threatened
caspian tern; taranui	threatened – nationally vulnerable
eastern bar-tailed godwit; kuaka	at risk - declining
eastern curlew	non-resident native
kingfisher; kotare	not threatened
lesser knot, huahou	threatened – nationally vulnerable
little shag; kawaupaka	not threatened
mallard	not threatened
NZ dotterel; tuturiwhatu	at risk - recovering
paradise shelduck; pūtangitangi	not threatened
pied shag; karuhiruhi	at risk - recovering
pied stilt; poaka	not threatened
red-billed gull; tarapunga	at risk - declining
reef heron; matuku-moana	threatened – nationally endangered
South Island pied oystercatcher; torea	at risk - declining
spur-winged plover	not threatened
variable oystercatcher; toreapango	at risk - recovering
white-faced heron	not threatened
white-fronted tern; tara	at risk - declining

* Robertson, HA; Baird K; Dowding JE; Elliott, GP; Hitchmough, RA; Miskelly CM; McArthur N; O'Donnell CFJ; Sagar, PM; Scofield RP; Taylor GA May 2017. Conservation Status of New Zealand birds, 2016. NZ Threat Classification Series 19. Dept of Conservation. 23 pp.

TABLE 2 - List of pelagic birds, recorded in the literature as utilising the wider Bream Bay area and their current conservation status (Robertson et al, 2017*)	
COMMON NAMES	**CONSERVATION STATUS ***
australasian gannet; takapu	not threatened
arctic skua	non-resident native
black-winged petrel	not threatened
Buller's shearwater	at risk; naturally uncommon
fairy prion, titi wainui	at risk – relict
flesh-footed shearwater; toanui	threatened – nationally vulnerable
fluttering shearwater, pakaha	at risk – relict
giant petrel (northern); pangurunguru	at risk - recovering
grey-faced petrel; oi; titi	not threatened
Indian Ocean yellow-nosed mollymawk	non-resident coloniser
little penguin; korora	at risk – declining
little shearwater	at risk - recovering
northern diving petrel; kuaka	at risk - relict
Pycroft's petrel	at risk - recovering
shy mollymawk	at risk - declining
sooty shearwater; titi; muttonbird	at risk - declining
white-faced (NZ) storm petrel; takahikare-moana	at risk – relict

3. FIELD INVESTIGATIONS

3.1 INTRODUCTION

Over the 2015-16 period there were three groups of surveys as follows:-

(i) February – March 2015: coastal bird surveys at five locations

- Bream Bay Beach (at Mair Road)
- Taurikura Bay
- McKenzie Bay
- Urquharts Bay

(ii) November 2015 – breeding activity surveys:

- Mair Road to Northport inspection
- Marsden Point to Northport habitat use
- Darch Point to Home Point habitat use

(iii) February – March 2016:- coastal bird surveys at eight locations

- Mair Bank (as 2015)
- Refinery Jetty to Northport
- Marsden Bay west to One Tree Point
- Part of Snake Bank
- Reotahi Bay
- Taurikura Bay
- McKenzie Bay
- Urquharts Bay

The above areas are shown on Figures 1 to 8.

The only 2015 survey area that was not surveyed in 2016 was Bream Bay Beach on the basis that it supported a low diversity and relatively low numbers of coastal birds and no significant high tide roosting.

For clarity a summary of the coastal bird count surveys is as follows:

Area of coast	Date	No. hourly counts
Bream Bay Beach	23.3.15	9
Mair Bank	25.2.15	9
	3.3.15	9
	9.2.16	9
Refinery Jetty to Northport	8.3.16	9
Marsden Bay West to One Tree Point	16.2.16	8
Part Snake Bank	16.2.16	8
Reotahi Bay	9.3.16	9
Taurikura Bay	18.3.15	9
	9.3.16	9
McKenzie Bay	18.3.15	9
	9.3.16	9
Urquharts Bay	18.3.15	9
	9.3.16	9

Bird use of nine sections of coastline was recorded via a total of 124 hourly counts. Mair Bank received additional emphasis regarding both the coastal bird surveys and breeding season surveys because of its proximity to the proposed works, its significance as a coastal bird habitat in a national context [NZCPS 11(a)(v)]and its current condition that includes a decrease in the pipi population (Williams JR & Hume TM 2014; Pawley, 2016) and an apparent increase in green-lipped mussels (Pawley 2016) that may change the attractiveness of Mair Bank as a feeding area for coastal birds, especially variable oystercatcher.

3.2 METHODOLOGY

The methodology for the bird surveys of the nine sections of coastline was reviewed by NIWA on behalf of Northland Regional Council. It is the same methodology that has

been used to monitor the bird populations using Marsden Bay, to the west of Northport, over the 2003 to 2015 period with approval of Northland Regional Council and the Department of Conservation.

At each site hourly counts were completed to cover a range of tidal conditions and habitat use activities recorded using Leupold BX-2 Cascades 10 x 42 binoculars and a Kowa TSN-883 Prominar spotting scope (25-60 times wide zoom eye piece). Before each count the air temperature was measured (quartz digi-thermo -10 to +110°C thermometer) with wind speed, barometric pressure (Silva Alba Windwatch) and general weather conditions recorded. Field data were entered on pre-prepared, waterproof record sheets.

As well as recording bird abundance and diversity, bird habitat use was recorded using an activity code as follows:

FI	:	feeding in the intertidal area
FW	:	feeding in or over the water
REI	:	resting in the intertidal area
REW	:	resting on the water
ROI	:	roosting (waders only) in the intertidal area *
ROP	:	resting/roosting on stakes, poles, rock walls, trees

* Roosting (ROI) over the high tide period is a category applied only to wading birds in this assessment, because the presence of a high tide wading bird roost is generally considered a notable coastal feature. The ROI category applies to the period of high tide itself and one hour either side of it to provide a comparative standard. Roosting by waders can be related to “staging” i.e. birds form groups at mid to upper shore levels prior to moving up to above the high tide level to roost over the high tide period or alternatively, flying elsewhere to roost. Whether birds are resting or roosting at the time of staging can be variable and debatable, and “roosting” has therefore been standardised. In contrast, resting/roosting by non-wading birds tends to be more random in terms of both the location used and tidal stage.

For the breeding season surveys the Mair Road to Northport area was inspected on foot and using a spotting scope and binoculars. The Marsden Point to Refinery Jetty

area was monitored for a total of six hours to record breeding season activities. The coastline from Darch Point to Home Point was inspected mostly on foot (Darch Point to Little Munro Bay; Urquharts Bay to Home Point) or via a combination of specific point inspections and spotting scope observations (Little Munro Bay to Urquharts Bay).

3.3 SPECIFIC AREA SURVEYS

3.3.1 Bream Bay Beach

The section of Bream Bay Beach surveyed (Figure 1) extended from near the end of Rama Road to just south of Marsden Point proper, a distance of c.2350m.



Figure 1. Bream Bay Beach Survey Area.

Species diversity was low and comprised australasian gannet, black-backed gull, caspian tern, red-billed gull, variable oystercatcher and white-fronted tern i.e. six species (note that "pelagic species" are discussed further in Section 2.4).

The highest maximum number was only 18 red-billed gull with the other species recording less than 8 individuals.

Similar maxima per kilometre were recorded in the same habitat north of Waipu River mouth but higher numbers were recorded at the Waipu River mouth and estuary in previous surveys.

The average number of birds (rounded) was 15 with red-billed gull the dominant species (53.3%) followed by black-backed gull (20.7%) and variable oystercatcher (13.3%). In total 74% of the population was gulls and the main habitat use was resting in the intertidal area (79.3% of records).

3.3.2 Mair Bank

The Mair Bank survey area (Figure 2) included the beach between Marsden Point proper and the Refinery Jetty, the inner bank adjacent to the Refinery mooring dolphins and the outer banks.



Figure 2. Mair Bank Survey Area.

The diversity of species was moderate with ten species over the three surveys – black-backed gull, caspian tern, little shag, NZ dotterel, pied shag, pied stilt, red-billed gull, South Island pied oystercatcher, variable oystercatcher and white-faced heron; one threatened and five at risk species.

The highest maximum was of black-backed gull (196) followed by 70 red-billed gull and 66 variable oystercatcher over the three surveys. The maximum number of individuals was 288 at low tide on 25.2.15 but 67.4% were black-backed gulls. Average numbers of birds (rounded) were 119, 76 and 120 over the three surveys with the highest numbers on the two lowest tides (0.5m).

Mair Bank was utilised for feeding mainly during a four hour period from about four hours after high tide, over the low tide period and to about two hours after low tide i.e. for about one third of a 12 hour tidal cycle.

There was no significant high tide wading bird roost but the beach was used for resting by up to about 100 black-backed gulls and the occasional caspian tern, red-billed gull and variable oystercatcher.

The dominant species was clearly black-backed gull followed about equally overall by red-billed gull and variable oystercatcher.

The predominant habitat use was resting in the intertidal (80.4% 2015; 70.7% 2016) with feeding in the intertidal habitats 14.9% in 2015 and 20.9% in 2016.

The two outer banks were the more important feeding habitats; the average percentages of feeding records over the surveys were: beach – 5.7%; inner bank – 19.9% and outer banks 74.4%. That probably reflects the presence of shellfish beds in the outer banks area that remain attractive to coastal birds.

3.3.3 Refinery Jetty to Northport

This area of habitat consists of a sandy intertidal area flanked by the Refinery Jetty and Northport (Figure 3).

A total of ten species were recorded comprising black-backed gull, caspian tern, NZ dotterel, pied shag, pied stilt, red-billed gull, South Island pied oystercatcher, spur-winged plover, variable oystercatcher and white-fronted tern; one threatened species and six at risk species.

South Island pied oystercatcher had the highest number of individuals (437) followed by red-billed gull (154) and variable oystercatcher (60) noting that a maximum of 66

variable oystercatcher was also recorded using Mair Bank in February 2016. The maxima of all the remaining species were less than 5. The average number of birds (rounded) was 298 which is high but reflects specific habitat use (refer below).

The key habitat feature of this piece of coastline was its use by the three dominant species and NZ dotterel for roosting at high water; numbers of wading birds were high from high tide to half tide falling but red-billed gull, that nests within the Refinery grounds, remained throughout the survey period and was most common with white-fronted tern over the low tide period following the departure of the oystercatchers.

South Island pied oystercatcher comprised 56.6% of the records, red-billed gull 30.4% and variable oystercatcher 8.0%; white-fronted tern occurred at 3.2% while the remaining species were less than 1%.

The clearly dominant habitat use was resting rather than feeding: resting in the intertidal – 61.1%; high tide roosting – 37.2%. The value of the habitat for feeding was low.

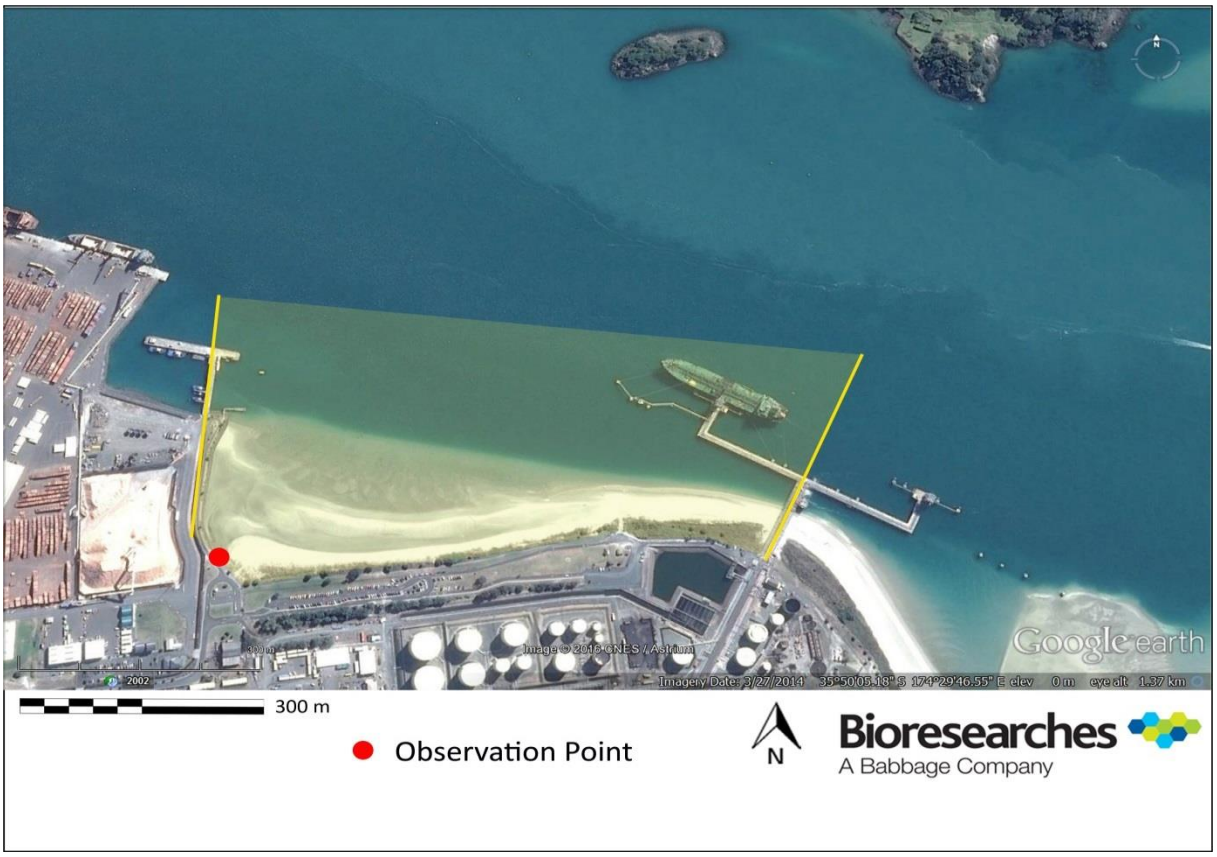

Figure 3. Refinery Jetty to Northport Survey Area.

3.3.4 One Tree Point

This area of habitat is contiguous with and similar to Marsden Bay, albeit with a narrower intertidal area and a lack of high tide roosting opportunity for wading birds (Figure 4).

Note: where there are multiple observation points, those locations were used on each hourly count to provide better coverage of the survey area (traversed by vehicle).

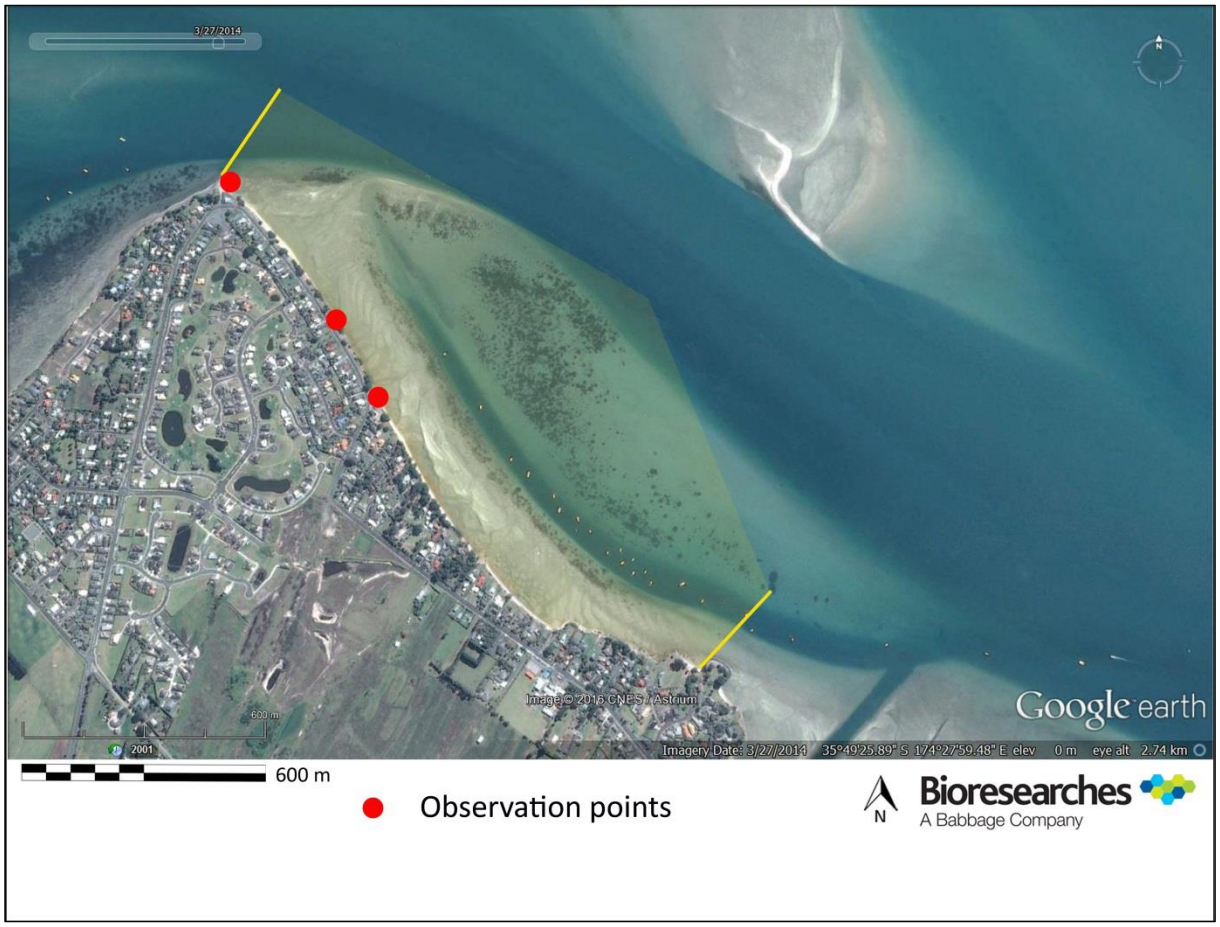

Figure 4. One Tree Point Survey Area.

A moderate – high total of 15 species was recorded – black-backed gull, caspian tern, eastern bar-tailed godwit, eastern curlew, lesser knot, little shag, mallard, NZ dotterel, paradise shelduck, pied stilt, red-billed gull, South Island pied oystercatcher, variable oystercatcher, white-faced heron and white-fronted tern.

The notable species were bar-tailed godwit, eastern curlew and lesser knot, all overseas migrants. A total of two threatened species and six at risk species was

recorded; bar-tailed godwit is at risk nationally but threatened overseas while lesser knot is threatened both nationally and overseas.

The highest maxima were black-backed gull (114), white-fronted tern (71), bar-tailed godwit (60), red-billed gull (58), variable oystercatcher (54) and lesser knot (37). In contrast to the maxima at Marsden Bay, (i.e. between Northpoint and the One Tree Point survey area) the maxima at One Tree Point that were lower were for bar-tailed godwit, lesser knot, NZ dotterel, South Island pied oystercatcher and variable oystercatcher noting that Marsden Bay is also utilised for high tide roosting. The only higher maxima at One Tree Point were for black-backed gull and white-fronted tern.

The average number of individuals was 168 (rounded) with the highest number over the low tide period to half tide rising after which only white-fronted tern was common, resting on an intertidal fence.

Over the entire survey period the dominant species were black-backed gull (25.2%), white-fronted tern (20.5%), red-billed gull (17.5%), bar-tailed godwit (13.9%) and variable oystercatcher (9.2%) while the remaining species occurred at less than 5%.

In contrast to the Refinery Jetty to Northport area and Marsden Bay (c.24% feeding, c.76% resting/roosting), the split at One Tree Point was 47.6% feeding and 52.4% resting with no high tide wading bird roost but a high proportion of resting by gulls and tern.

The predominant features were a lower diversity than Marsden Bay and a population containing relatively large numbers of black-backed gull and white-fronted tern.

3.3.5 Snake Bank

The southern end of Snake Bank was surveyed i.e. south of a line from about One Tree Point to Darch Point. The wider area of Snake Bank, and McDonald Bank to the east, where considered beyond the survey area for the purposes of this assessment

The diversity of species recorded (8) was relatively low but included one threatened and four at risk species. Birds recorded were black-backed gull, eastern bar-tailed

godwit, little shag, red-billed gull, South Island pied oystercatcher, variable oystercatcher, white-faced heron and white-fronted tern.

The highest maximum was for South Island pied oystercatcher (63) but maxima for the remaining species were all less than 12.



Figure 5. Snake Bank Survey Area. Observation points as shown in Figure 4.

The average number of individuals (rounded) was relatively low at c.39 but birds were only common over the low tide period, as recorded at Mair Bank, and no high tide roost is present.

Clearly dominant was South Island pied oystercatcher (75.8%) followed by black-backed gull (9.7%) and variable oystercatcher (6.5%) with the remainder incidental only. Feeding, mainly by South Island pied oystercatcher, was the predominant activity (63.5%). The Snake Bank population differed from that at Mair Bank in that black-backed and red-billed gull were not as prominent and South Island pied, rather than variable, was the more common oystercatcher species. Snake Bank is a relatively short commute for birds roosting at Marsden Bay over the high tide period and contains a notable population of cockles as a food source.

3.3.6 Reotahi Bay

Reotahi Bay (Figure 6) presents a small area of soft intertidal habitat amongst a rocky shoreline.

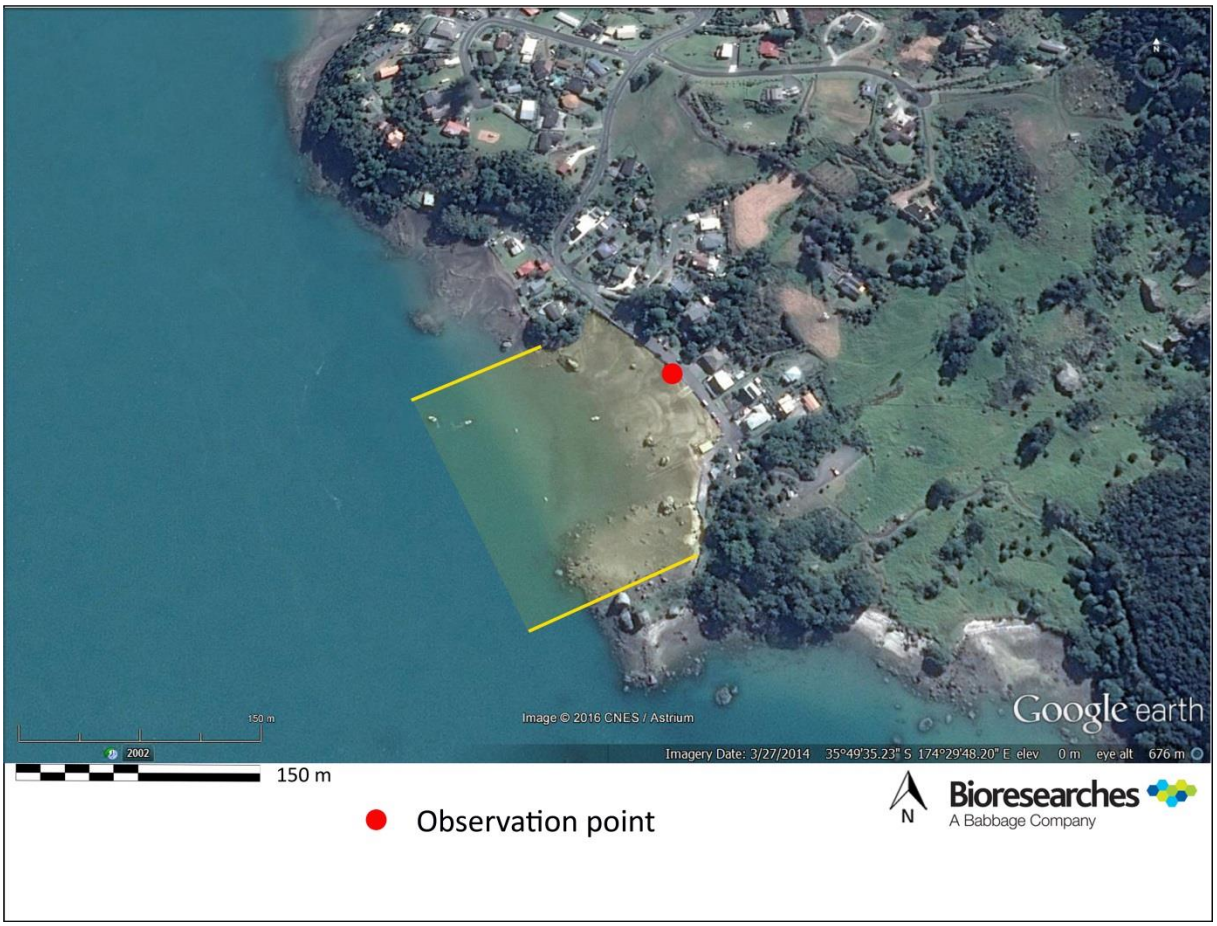

Figure 6. Survey Area at Reotahi Bay.

A total of six species were recorded – black-backed gull, caspian tern, red-billed gull, variable oystercatcher, white-faced heron and white-fronted tern. Of those species, one is threatened and three at risk.

Overall the maxima were low with the highest being of red-billed gull (26) followed by white-fronted tern (10) and the rest less than six. The overall average (rounded) was 24 individuals dominated by red-billed gull (77.6%) and white-fronted tern (10.0%) with the remaining species less than 7%.

The Bay was used almost exclusively for resting (in the intertidal area) or roosting on poles, boulders and trees, a combined total of 98.2%.

3.3.7 Taurikura Bay

The Bay (Figure 7) contains a combination of rocky and soft intertidal habitat.

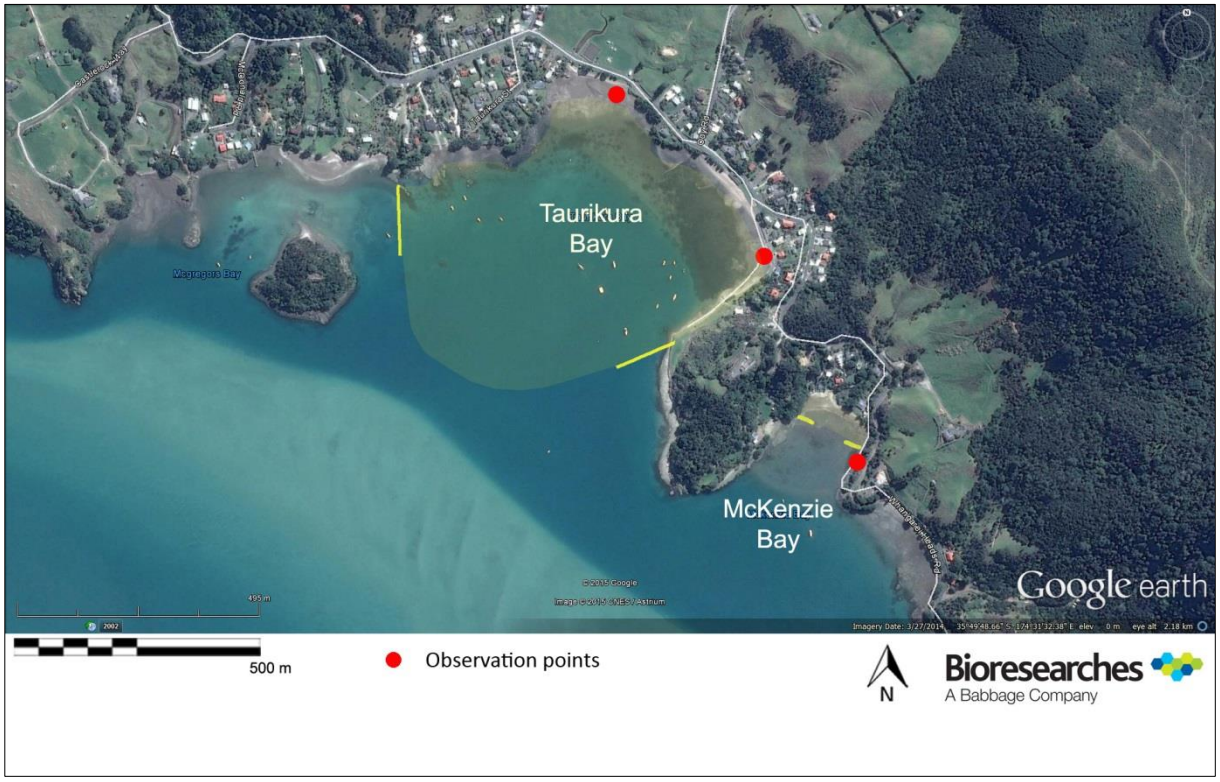

Figure 7. Taurikura Bay and McKenzie Bay Survey Areas.

Over the two (2015 and 2016) surveys a total of 11 species was recorded that included two threatened species and three at risk species. The species recorded were australasian gannet, black-backed gull, caspian tern, kingfisher, little shag, pied shag, red-billed gull, reef heron, spur-winged plover, variable oystercatcher and white-faced heron.

The maxima were low with the highest being for red-billed gull - 24 in 2015 and 29 in 2016; other species were less than 10 and 6 respectively.

The average numbers were 23 (2015) and 30 (2016) and dominated by red-billed gull at 71.9% and 80.3% of records respectively. The second most dominant species was variable oystercatcher with 8.1 and 7.7 respectively i.e. 8 individuals in each survey.

Habitat use was biased toward resting in both 2015 and 2016 with 75.9% and 82.4% resting respectively.

Overall the 2015 and 2016 results were similar inferring a consistency to bird use of Taurikura Bay in the March period.

3.3.8 McKenzie Bay

McKenzie Bay is a small, enclosed area of habitat that was utilised by low numbers and a low diversity of species.

Birds recorded were black-backed gull, caspian tern, red-billed gull, variable oystercatcher and white-faced heron that included one threatened and two at risk species.

The rounded average number of birds was 2 in 2015 and 3 in 2016; the dominant (consistent) species overall was variable oystercatcher and resting and roosting were the dominant habitat use activities at 96.9%.

3.3.9 Urquharts Bay

The Bay is relatively large and comprises both rocky and soft intertidal substrate dominated by the latter.

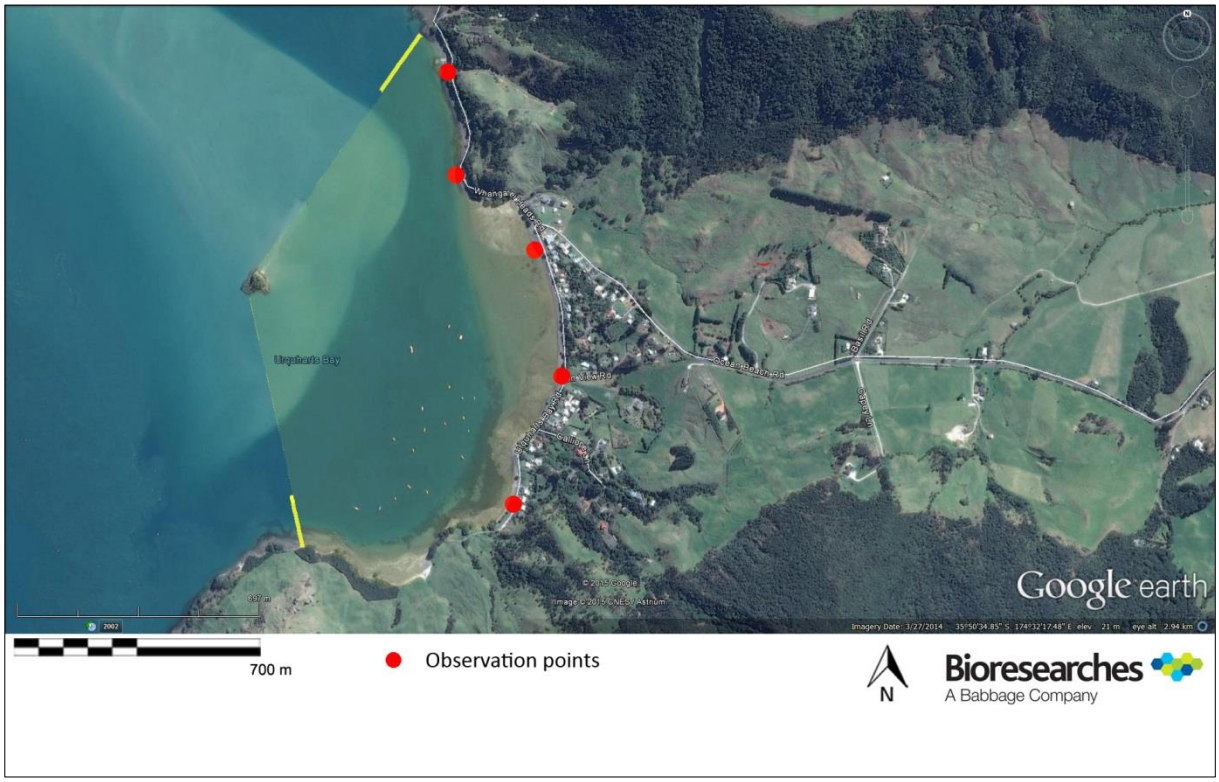

Figure 8. Urquharts Bay Survey Area.

A relatively high total of 12 species was recorded, considering the limited habitat, over the 2015 and 2016 surveys including two threatened and five at risk species.

The population recorded consisted of australasian gannet, black-backed gull, caspian tern, little shag, pied shag, red-billed gull, reef heron, South Island pied oystercatcher, spur-winged plover, variable oystercatcher, white-faced heron and white-fronted tern.

As at both Reotahi and Taurikura Bays, the highest maxima at Urquharts Bay were for red-billed gull (51 : 2015; 37 : 2016) with about equal maxima for black-backed gull and variable oystercatcher. Little shag was notably common overall.

The average number of individuals was 77 in 2015 and 50 in 2016. The dominant species were consistent in terms of percentage occurrence. Notably, 8.9% of records in 2016 were for little shag but only 2.4% in 2015; little shag commonly roosts on vessels in Urquharts Bay.

The total percentage occurrence of gulls illustrates the typical population in the Bay with 66.6% in 2015 and 69.7% in 2016 (red-billed plus black-backed gull). That is largely reflected in the habitat use data with resting and roosting the main activity – 70.1% : 2015; 74.4% : 2016. However the proportion of feeding (29.9% : 2015 and 25.6% : 2016) was relatively high. Marsden Bay, which contains both feeding and high tide roosting habitat, has c.24% feeding and c.76% resting and roosting activity.

3.3.10 Comparative Population Composition and Habitat Use

The following summarises the percentages of wading birds versus gulls in the survey area and the percentages of feeding versus resting/roosting. McKenzie Bay is excluded because of low numbers.

TABLE 1 – COMPARATIVE POPULATION COMPOSITION AND HABITAT USE

	Bream Bay Beach	Mair Bank	Refinery Jetty to Northport	One Tree Point	Snake Bank	Reotahi Bay	Taurikura Bay	Urquharts Bay
% feeding	11.8	18.0	1.5	47.6	63.5	1.8	20.9	23.3
% resting/ roosting	88.2	83.5	98.5	52.4	36.5	98.2	79.1	76.7
% wading birds	13.3	16.1	65.1	34.4	84.2	4.2	12.1	23.9
% gulls	74.0	82.9	31.0	42.3	12.9	84.4	81.1	68.2

Where several surveys have been completed, an overall percentage is presented. Table 1 presents an overall reference that is useful in the effects analysis below by identifying the areas where feeding was predominant with that activity likely to be the more susceptible to any habitat changes. The activity can be matched with the overall population composition. For example One Tree Point and Snake Bank stand out as key feeding habitats for reasonably high proportions of wading birds whereas the Refinery Jetty to Northport and Reotahi Bay are not notable feeding areas. Areas clearly dominated by gulls are Bream Bay Beach, Mair Bank, Reotahi Bay, Taurikura Bay and Urquharts Bay.

3.4 PELAGIC BIRDS

Pelagic species recorded in the outer Harbour and Bream Bay are also addressed in the Bioresearches literature review (2015). A total of 17 species had been recorded in the literature; of those species one is considered threatened (flesh-footed shearwater) and eleven at risk – little penguin, sooty shearwater, little shearwater, Pycroft's petrel, fairy prion, fluttering shearwater, northern diving petrel, white-faced storm petrel, Buller's shearwater, giant petrel and shy mollymawk.

Other, non-threatened species recorded are – australasian gannet, arctic skua, black-winged petrel, grey-faced petrel and eastern yellow-nosed mollymawk.

The literature indicates that Bream Bay is utilised for feeding by the above species either regularly or on a seasonal basis.

Observations of three pelagic species have been provided by Margaret Hicks as follows:

(i) From September onwards, large numbers of Australasian gannets feed in the vicinity of the Ruakaka Estuary mouth and an extensive area to the north of the mouth. Ms Hicks reports that advice from the Department of Conservation is that the gannets are from the Poor Knights Islands colony.

(ii) Little penguins, possibly mainly juveniles, are common in the northern part of Bream Bay especially in spring and summer; dead individuals are commonly found washed up on Bream Bay Beach. On 9 November 2015, between Mair Road and Northport, four dead little penguins and one dead fluttering shearwater were recorded. The observations are also endorsed by the results of regular surveys of beach wrecked birds undertaken by the Northland Region of the Ornithological Society of New Zealand and published in their newsletter Amokura. For example in February 2007 a notable beach wreck of 258 little penguin was recorded between Mair Road and Mangawhai (Amokura, 2007). Other commonly beach wrecked birds are flesh-footed shearwater, Buller's shearwater, sooty shearwater, fluttering shearwater, common diving petrel and australasian gannet, however numbers and species are both highly variable.

(iii) In April hundreds of fluttering shearwaters are typically observed in Bream Bay in the area off Bream Bay Beach between Sime Rd and Mair Rd and they also enter the Mair Bank and outer Harbour open water areas.

There is a high diversity of species that utilises Bream Bay's open water habitat; several of those species have been observed to occur in high numbers close to shore at various times.

3.5 BREEDING SEASON SURVEYS

The "breeding season" for shorebirds was considered to be from August/September to December/January acknowledging that some species exhibit breeding outside that period. The surveys described below were undertaken in November 2015 and results are shown on Figures 9 & 10.

3.5.1 Mair Road to Northport

The section of foreshore was inspected on foot on 9 November 2015. No nesting birds were present along the foreshore.

3.5.2 Marsden Point to Refinery Jetty

The use of this area by breeding birds was documented on 9 and 24 November 2015. The decision to survey this area was based on known breeding of NZ dotterel in particular within the RNZ grounds and the possibility that early nesting in the area may have occurred prior to 9 November.

This section of coastline was used by a pair of NZ dotterel for juvenile rearing with three juveniles present on 9 and 24 November. Secondly a maximum of four adults were recorded feeding along the intertidal habitat and returning to within the Refinery grounds.

The area was also utilised by variable oystercatcher for juvenile rearing and adult feeding with a total of four adults and two juveniles recorded.

3.5.3 Refinery Jetty to Northport

No juveniles of either NZ dotterel or variable oystercatcher were recorded and the feeding frequency of adults of both species was low. In comparison the adjacent Marsden Point to Refinery Jetty area had the greater "intensity of use" during the breeding season period surveyed.

3.5.4 Darch Point to Home Point

This area contained a high diversity of potential breeding habits – rocky outcrops, overhanging trees (especially pohutukawas), caves, rock platforms, Harbour edge scrub and sandy beach.

The following nesting was recorded:

Western end Reotahi Bay	• variable oystercatcher on rocky outcrop (1 pair)
Motukaroro Island	• little shag (dominant) and pied shag in pohutukawas (10-15 pairs) • variable oystercatcher on rock platform (1 pair) • reef heron probable outside a small cave
McKenzie Bay east	• variable oystercatcher in high tidal boulders (1 pair)
Calliope Island	• black-backed gull and variable oystercatcher on rock platform (1 pair of each)
Urquharts Bay South	• pair variable oystercatcher + 2 juveniles
Home Point	• little shag and pied shag in pohutukawas (10-15 pairs)

3.6 HARBOUR PENGUIN SURVEYS

Preliminary surveys in the November-December 2016 nesting period concluded that a population of little penguin is utilising the area between Busby Head and McLeods Bay. Nesting is considered highly probable on the mainland between McLeods Bay and Reotahi Bay, and on High, Callliope and Motukaroro Islands. A minimum population of 12 nesting pairs is estimated from the initial surveys (Bioresearches, December 2016).

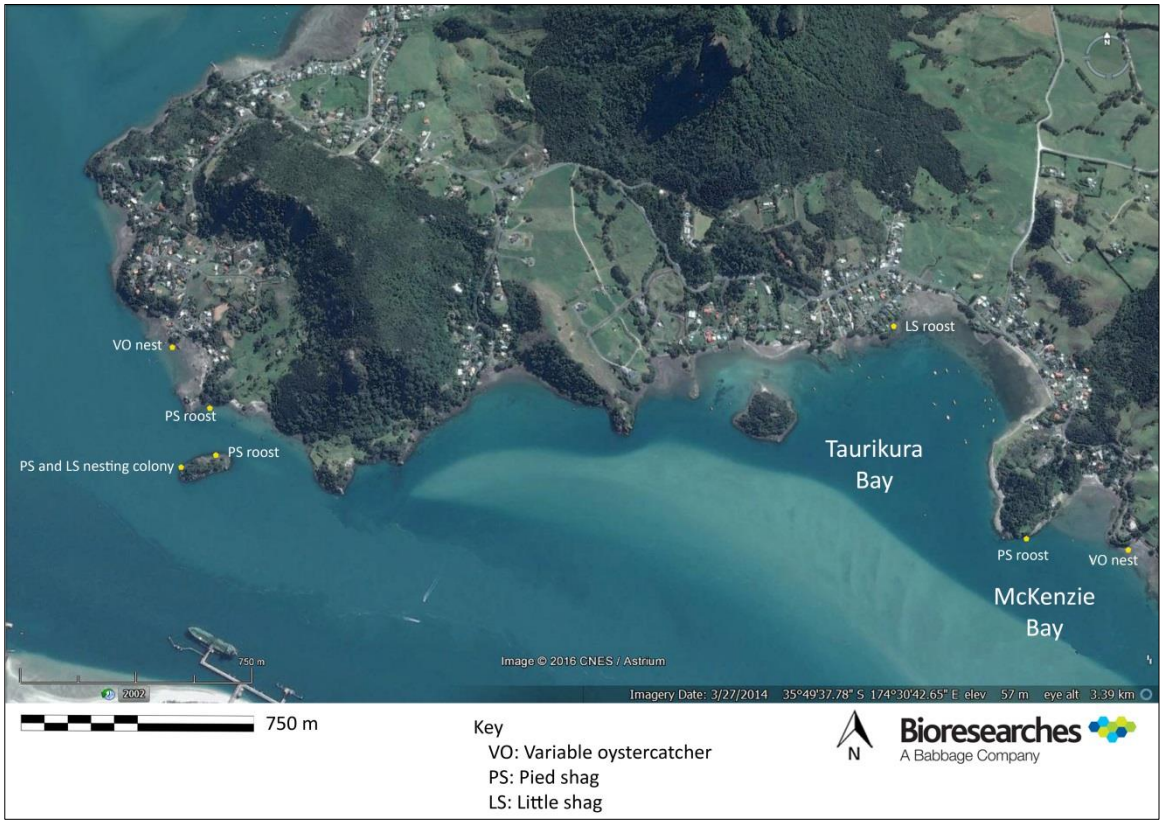

Figure 9. Breeding activity recorded from Reotahi Bay to McKenzie Bay

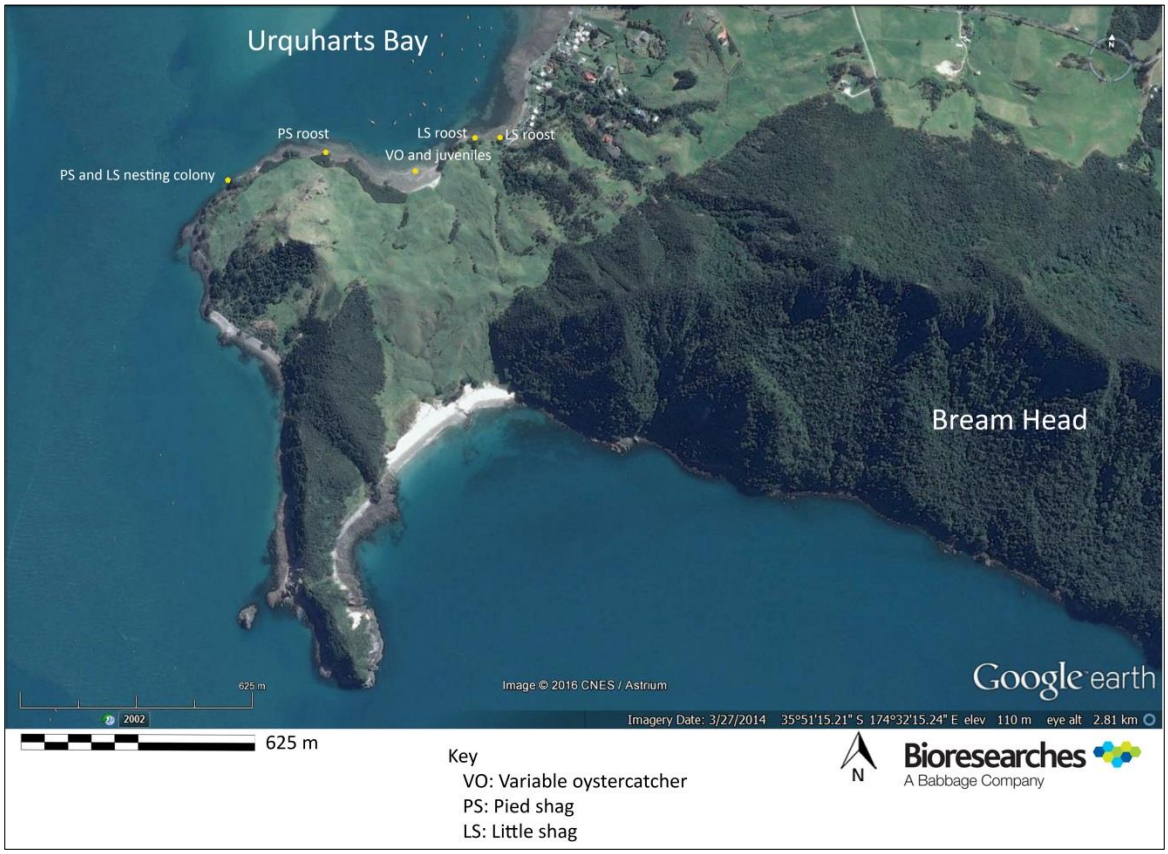

Figure 10. Breeding activity recorded from Urquharts Bay to Home Point.

4. AVIFAUNAL VALUES AND HABITAT SIGNIFICANCE

4.1 INTRODUCTION

The operative Regional Coastal Plan (RCP) for Northland refers at Section 9.2 to Habitats of Indigenous Fauna i.e. “all fauna associated with estuarine or marine habitats other than those known to be introduced by man. This includes resident and migratory birds, fish and marine mammals”.

Relevant to coastal birds, intertidal habitants include:

- sand flats and banks
- beaches
- rocky shores

Subtidal habitats also involve the full range of types (i.e. soft bottom open coasts to shallow and deep rocky reefs and flats) that are relevant to open water pelagic species.

A significant threat to habitats of indigenous fauna noted in the RCP is “dredging and dredge spoil disposal.”

A Policy (9.2.4.1) relevant to this assessment is “to identify habitats or habitat areas of indigenous fauna that have moderate, moderate high, high or outstanding value within Northland’s coastal marine area and protect these from adverse effects of subdivision, use and development.”

Method 9.25.2 of the RCP states that “assessments of significance should include the criteria listed within the appendices.” Appendix 9 – Criteria used to determine areas of important conservation value – lists 9 criteria including (3) Protected areas (4) Wetlands, Estuaries and Coastal Lagoons, (5) Marine Mammals and Birds and (6) Ecosystems, flora and fauna habitats. Specifically, Criterion 5(b) concerns “habitats of endangered, vulnerable, rare or threatened bird species” and Criterion 5(c) refers to “important roost sites, or feeding areas of wading birds”. The assessment of avifaunal values and habitat significance has considered the criteria and policies of both the RCP and NZCPS; in combination, both documents capture the features that need to be considered.

The draft Northland Regional Plan identifies significant bird areas in the Whangarei Harbour. Those within the survey area for this project are Snake Bank, Marsden Bay to One Tree Point; the Northern Coastline – Darch Point to Busby Head, Mair Bank – Marsden Point and the nearshore area of Bream Bay Beach and Mair Bank across to Busby Head and thence to Bream Head. (Note: the Plan's provisions are currently draft and have no legal effect).

Two habitats within the area of interest for this project that are not annotated as significant bird areas are (i) the wider Bream Bay pelagic habitat and (ii) the intertidal area between the Refinery Jetty and Northport.

The most recent Harbour – wide assessment of its avifauna is that of Pierce, 2005 for Northland Regional Council in the context of a proposed reclassification of a substantial part of the harbour as a Marine 1 (MM1) Area.

Key locations identified in Pierce 2015 were as follows:

(i) Tidal flats of Marsden Bay (including mangroves) and One Tree Point.

(ii) Mair Bank and Snake Bank

(iii) Northeastern Harbour beaches and headlands i.e. Darch Point to Home Point in this assessment.

(iv) Islands used for breeding: Motukaroro, High and Calliope.

In addition the area from Home Point to Busby Head, including Frenchman Island, was identified as a key location. Pierce, 2005 concluded that regarding the key areas, "habitat and avifaunal values are particularly high at these sites and they require ongoing protection via the RMA and other statutory means."

On the basis of the recent literature reviews, surveys specific to this project and surveys completed in Marsden Bay almost annually in the 2002-2015 period, the following values are assigned to the key locations identified in Pierce 2005.

(a) Tidal flats – Marsden Bay to One Tree Point: of regional significance and of high value in an outer Harbour context.

(b) Mair Bank : national significance and part of Snake Bank: regional significance and of high value in an outer Harbour context.

(c) Northeastern Harbour beaches and headlands: national significance in parts in the breeding season because of nesting by threatened and at risk species. Of local significance outside the breeding seasons and vary between low and high value in the context of the outer Harbour.

(d) Islands – Motukaroro; High and Calliope: significance as for (c) above. Frenchman Island, adjacent to Busby Head, would also be of national significance in the breeding season (as indicated on Figure 11).

The additional areas of significance identified in this survey are Bream Bay pelagic habitat and the upper intertidal habitat adjacent to Northport. The Bream Bay area is of national significance for seabirds being in close proximity to breeding habitats at the Bream Head Scenic Reserve and the Hen and Chicken Islands. The area of the Refinery Jetty to Northport shoreline that is used for high tide roosting is considered to be of regional significance during high tide periods only, but is otherwise of low coastal bird value based on the field investigations completed for this project.

The following assessment of values addresses each survey area and integrates the information from the Regional Coastal Plan, draft Northland Regional Plan, Pierce 2005 and the specific surveys undertaken for this project.

Sections 3.2 to 3.10 inclusive address the avifaunal values of the various surveyed areas that apply during most of the year i.e. their general values based on feeding, resting and roosting. Section 3.11 considers pelagic species including the close proximity of nationally important seabird breeding colonies. Section 3.12 addresses breeding activities as a separate consideration because, rather than any area supporting exceptionally large colonies, the breeding recorded occurred in discrete, relatively small areas and at isolated nesting sites. Those activities increase the values for the duration of the breeding season only eg scattered individual variable oystercatcher nests. A summary of avifaunal habitat values is shown as Figure 11.

4.2 BREAM BAY BEACH

The c.2450m section of Beach in the vicinity of Mair Road is open coastline habitat that was utilised by a low diversity and relatively low numbers of coastal birds. It did not contain a high tide roost for wading birds and was not used by significant numbers of birds for feeding either in its intertidal habitat or nearshore open water habitat. It is accepted however that pelagic species use the nearshore areas for feeding at times (refer 4.11 below).

The intertidal habitat is similar to that along about 30km of Bream Bay from Marsden Point to Bream Tail, has relatively low coastal bird values and is considered of local significance only. However, that assessment excludes both Ruakaka and Waipu River mouths and estuaries that have very high coastal bird values in a national context. The River mouth habitats were not surveyed because they were considered too remote from potential works areas. Based on the project description and proposed disposal areas (i.e. disposal areas 1, 2 and 3.2) the probability of the river mouths and estuaries being adversely affected is remote.

4.3 MAIR BANK

The three surveys indicated that Mair Bank complex was a notable high tide resting area for black-backed gull and a key low tide feeding habitat for variable oystercatcher as a result of its pipi beds. The surveys showed that the two outer banks (Figure 2) are the most utilised feeding habitats and are therefore the highest value areas within the context of the entire Bank. Mair Bank presents a habitat that is different from habitats of both Bream Bay Beach and inside the Harbour entrance. Mair Bank is a sand and shell ebb-tidal delta swept by strong currents and contains shellfish beds whereas Bream Bay Beach is an open, sandy surf beach. The Taurikura to Home Point area is relatively sheltered and contains a diversity of soft sediment and rocky habitats. Overall Mair Bank is considered a nationally significant coastal bird habitat. A key feature of Whangarei Harbour is that it is the third ranked wintering site in New Zealand for variable oystercatcher (Dowding and Moore 2006). The present surveys showed that Mair Bank is a key feeding area for variable oystercatcher and that raises the significance of the Bank. The potential risk of an adverse effect on Mair Bank is high because of its proximity to the works and its use for feeding.

4.4 Refinery Jetty to Northport

This area of coastline presents poor quality feeding habitat but is a notable high tidal roosting area and supports a significant portion of the outer Harbour's variable oystercatcher population at high tide. Other roosting and resting birds were South Island pied oystercatcher, red billed gull and white-fronted tern. The area is of significance in the context of the outer Harbour and functions as an alternative to the Marsden Bay high tide roosting areas. It is of regional significance during high tide periods as a roosting site for threatened and at risk species but is otherwise of local significance only. The potential risk is considered low-moderate because the area is used mainly for roosting and resting.

4.5 One Tree Point

The coastline from the western side of Marsden Bay to One Tree Point contrasts with the above (4.4) area in that it is a significant outer Harbour feeding and resting habitat in the context of the Harbour, but does not contain a high tide roosting area, the closest of which is in the contiguous Marsden Bay. Notable numbers of black-backed gull and white-fronted tern were recorded but the maxima of five typical wading species were lower than recorded in Marsden Bay. Both the Bay and the One Tree Point area are "stepping stone" habitats to Snake Bank in particular. The Marsden Bay – One Tree Point – Snake Bay complex is considered a regionally significant coastal bird habitat. The overall risk is considered low because it is removed from the works area.

4.6 Snake Bank

The southern part of Snake Bank supported a low species diversity but a high number of feeding South Island pied oystercatcher. The southern part of the Bank is a significant outer Harbour feeding area in the context of Whangarei Harbour especially in tandem with the Marsden Bay to One Tree Point habitats and in this survey, particularly for South Island pied oystercatcher. The Marsden Bay – One Tree Point – Snake Bank complex is considered a regionally significant coastal bird habitat – separating out individual areas is arbitrary and not appropriate in the context of a functioning habitat. The overall risk is considered low because it is removed from the works area.

4.7 REOTAHI BAY

Reotahi Bay supported a low number and low diversity of birds dominated by red-billed gull and is used mainly for resting and roosting. It is not a notable local feeding habitat and is not a significant coastal bird habitat in general relative to the NZCPS (i.e. for feeding, resting and roosting) outside of the breeding season the details of which are provided in Section 4.12 below. The risk is considered low-moderate because it is close to the works but is mainly used for resting.

4.8 TAURIKURA BAY

The results of Taurikura Bay (also dominated by red-billed gull) recorded in 2015 and 2016 were consistent and indicated that the Bay does not contain significant intertidal feeding habitats or a notable high tide roost. In the context of the northern shoreline and the NZCPS it is a low value coastal bird habitat. All the remaining northern Bays (McKenzie, Taurikura and Urquharts) are considered low risk areas because they are removed from the works area.

4.9 MCKENZIE BAY

The McKenzie Bay results were consistent in 2015 and 2016; it provides limited habitat that supports a low diversity and very small number of coastal birds. It is not a significant coastal bird habitat in the context of the northern shoreline and the NZCPS in general outside the breeding season, the details of which are provided in Section 4.12 below.

4.10 URQUHARTS BAY

The results for Urquharts Bay were also consistent in 2015 and 2016 and indicate that the Bay supports a relatively diverse avifauna although dominated by red-billed gull. It provides feeding habitat for variable oystercatcher and resting habitat for red-billed gull and is a favoured local area by little shag. It is in close proximity to Mair Bank feeding habitats and overall is a notable habitat for coastal birds but only in the context of the outer Harbour and the NZCPS outside the breeding season, the details of which are provided in Section 4.12 below.

4.11 PELAGIC BIRDS

Bream Bay supports a relatively high diversity of pelagic birds including threatened and at risk species, some of which can be present in high numbers eg little penguin, australasian gannet, fluttering shearwater. It is in close proximity to known seabird breeding colonies within Bream Bay Scenic Reserve and the Hen and Chickens Islands in particular, together with slightly more distant habitats at the Poor Knights and Mokohinau Islands. Whangarei Harbour and Bream Bay are within a wider area proposed as a New Zealand Pelagic Important Bird Area (IBA) (Gaskin, 2014). Overall Bream Bay is considered a significant habitat for pelagic birds in a national context i.e. it is of national significance relative to the NZCPS (Figure 11).

4.12 BREEDING

"Breeding" is broadly considered to include the period from nest construction and establishment to the fledging of juveniles. The notable breeding activities identified in the survey area (One Tree Point to Darch Point and thence to Home Point) were as follows:

- juvenile NZ dotterel (at risk species) rearing and variable oystercatcher (at risk species) rearing: Marsden Point to Refinery Jetty.
- variable oystercatcher nesting along the northern shoreline – Reotahi Bay, McKenzie Bay East, Urquharts Bay South, Motukaroro and Calliope Islands
- significant shag (little and pied shag – the latter an at risk species) colonies at Motukaroro Island and Home Point.
- inferred nesting by reef heron (threatened species) – Motukaroro Island.

In addition there is a very high probability of the survey areas being used for nesting by little penguin (at risk species) based on the literature review completed by Bioresearches in 2015 and the November –December 2016 surveys. Potential breeding habitat for little penguin is not shown on Figure 11 but would potentially involve all areas of shoreline.

On the basis of known and probable nesting and juvenile rearing in the survey area of one threatened and four at risk species, together with reported additional breeding

from Home Point to Bream Head, the area as a whole is considered to contain significant breeding habitats in a national context i.e. relative to the NZCPS. [(Policy 11(a) (i) and Policy 11 (b) (ii)]. That value differs from the general value of the areas as coastal bird habitat because it refers to the duration of the breeding season for each species only, but could not be necessarily applied to the habitat outside the breeding season. As a result of recorded breeding by species that are “at risk” or “threatened” on a national basis in the 2016 surveys, the following areas are of national importance, at least in part, during the breeding season of the species concerned – Marsden Point to Refinery Jetty, Reotahi Bay, Motukaroro Island, McKenzie Bay East, Calliope Island, Urquharts Bay South and Home Point.

Tree nesting pied shags (Motukaroro Island; Home Point) can lay clutches all through the year. New Zealand dotterel (Marsden Point to Refinery Jetty) that is “ground-nesting” has a breeding season extending from about August to December. The similarly ground-nesting variable oystercatcher (Reotahi Bay, Motukaroro Island, McKenzie Bay East, Calliope Island, Urquharts Bay South and Marsden Point to Refinery Jetty) has an approximate September to March inclusive breeding season.

Little penguin can be present at nesting burrows in all months except April and May.

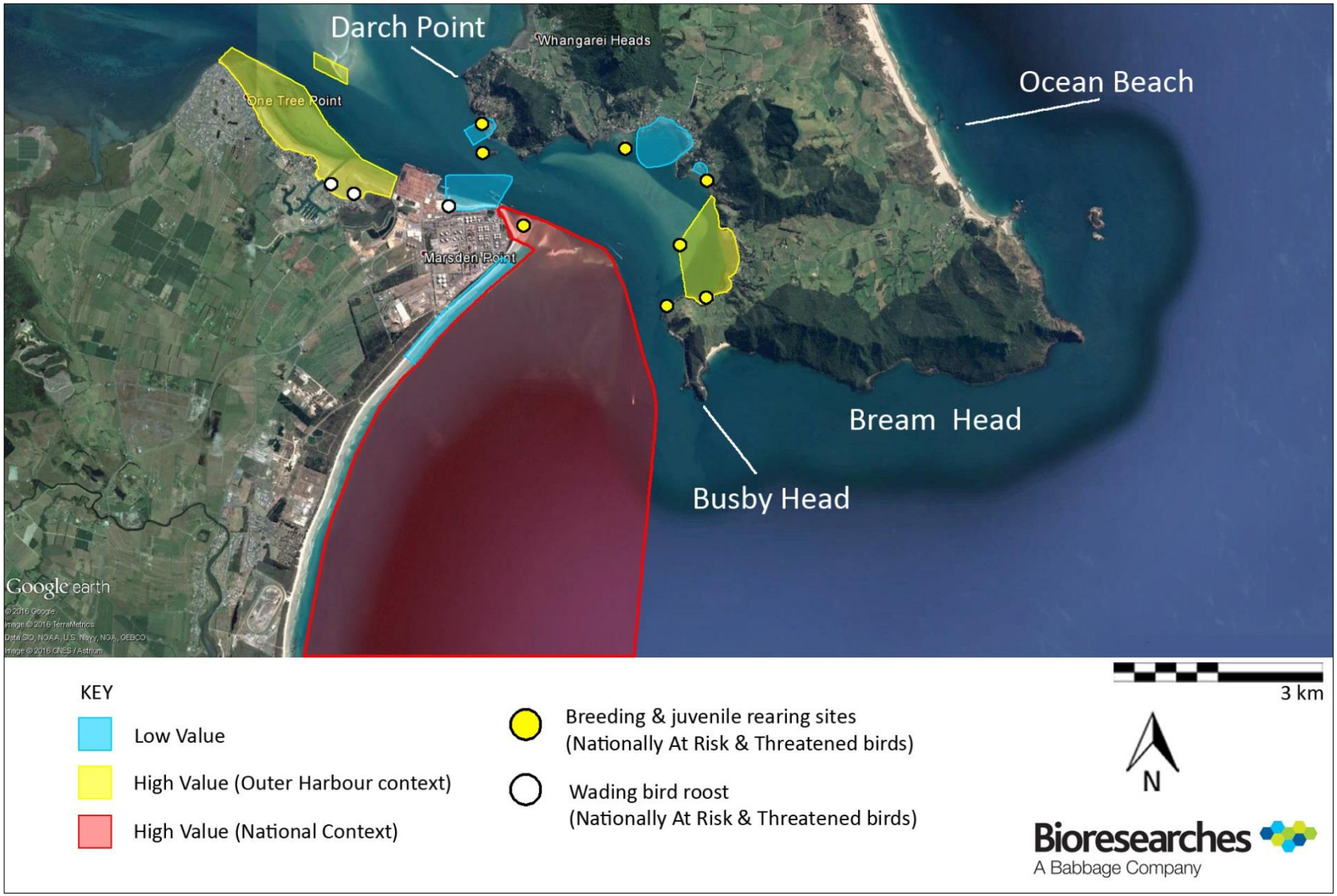

Figure 11. Overview of coastal bird values.

5. AVIFAUNAL EFFECTS

There may be effects during the consent period (limited to a maximum of 35 years by section 123 RMA) as a result of climate change. For shorebirds that could include direct effects (changes to rainfall, temperature, wind conditions, solar radiation) and indirect effects – habitat changes eg loss of intertidal flats, saltmarsh and rocky shorelines; alteration to invertebrate prey distribution and abundance; changes to predator populations; changes to both South Island breeding and feeding areas and North Island feeding areas (eg South Island pied oystercatcher). For eastern bar-tailed godwit that breeds in Western Alaska, climate change is likely to affect birds at all stages of their annual cycle ie in New Zealand, along the East Asian-Australasian Flyway and in Alaska – tundra vegetation encroachment on nesting habitat, asynchronous food production at breeding sites, loss of intertidal foraging areas and changes to synoptic weather patterns adversely affecting migratory flights.

Pelagic species will also be subject to changing climatic conditions, air temperature, sea temperature and freshwater inputs for example, all of which could affect marine productivity and food availability. Overall, the aspects listed as (i) to (iii) inclusive below could be affected by climatic change (East Asian-Australasian Flyway Partnership e-Newsletter, No.42, May 2017, Barbraud et al, 2012; Mustin et al 2007; Piersma & Lindstrom, 2004; Rehfisch & Crick, 2003; www.nzbirdsonline.org.nz).

Although effects as a result of climate change are probable, those effects are unlikely to be exacerbated by this Project.

5.1 DISCOUNTED EFFECTS

The Project will not result in the following issues that are relevant to coastal and pelagic birds

(i) there will be no permanent loss of feeding habitat

(ii) no intertidal roosting site for shorebirds will be removed or adversely affected to the degree that it is no longer used.

(iii) no nesting habitat will be adversely affected

(iv) there is no concern regarding sediment contamination or any contaminant release that could affect marine habitats and organisms relied on for food. This

includes the potential for avifauna to be impacted by bioaccumulation of contaminants.

(v) there is no concern regarding the avifaunal effects of intermittent maintenance dredging

(vi) there will be no adverse effect as a result of the erection and maintenance of navigational aids.

5.2 POTENTIAL ISSUES

The potential issues regarding the avifauna arising from the Project are as follows:

(i) turbidity increases in the dredging and disposal areas

(ii) deposition of resuspended sediment on soft substrate and hard substrate intertidal habitats

(iii) increase in vessel movements

(iv) vessel lighting

(v) underwater noise

(vi) cumulative effects

These potential issues are discussed below.

5.2.1 Turbidity Increase

5.2.1.1 Capital dredging

The dredging area totals 1.95 km2 of seabed that will be excavated on a continuous (24 hours, 7 days per week) basis for about six months. The uncontaminated sediments contain less than 6% silt (Coffey 2016). Modelling has indicated that the Trailing Suction Hopper Dredger (TSHD) sediment plumes will not disperse to adjacent beaches, sand banks or marine management areas (MetOcean, 2016).

The risk of intertidal deposition of sediment will increase in the smaller berth pocket area that would be excavated with backhoe and barge equipment (BHD). That risk may result in the operation being restricted to slack water or ebb tide periods (Tonkin and Taylor, 2016).

It is clear, however, that there will be a continual increase in the turbidity in the immediate vicinity of the dredger for the duration of the dredging which is unavoidable, in contrast to the short term, temporary increase in turbidity at the disposal sites during each spoil release.

The 2000 – 2010 average range of turbidity from One Tree Point, Marsden Point, Mair Bank and Snake Bank is 0.5 to 7.5 NTU with a grand median for those sites of 1.3 NTU (Coffey, 2016; Table 2).

The comparable secchi disk values are 1.5 to 7.5m with a grand median of 3.9m i.e. water clarify is generally excellent in these areas.

In contrast, turbidity may decrease significantly in inner Bream Bay following heavy rainfall where a level of 23.7 NTU has been recorded (Coffey 2016).

For this Project the trigger level threshold for the turbidity entering the Marine 1 Management Areas is 15-20 NTU and 15-20 g/m^3 suspended solids [i.e. Motukaroro Island, Mair Bank, Calliope Bank (northern bays) and the Home Point to Busby Head coastline].

At the Port of Melbourne a similar water quality threshold was set for a channel dredging project at 25 g/m^3 suspended solids and 17 NTU. Those thresholds were aimed at protection of feeding areas of crested tern (*Sterna cristata*) and australasian gannet (*Morus serrator*) (Sagar, 2011).

The birds that will be affected by an increase in turbidity are visual fish feeders (eg little penguin, australasian gannet, white-fronted tern, caspian tern, red-billed gull and the shag species).

Firstly an increase in turbidity may impair their ability to see and capture fish and fish may avoid areas of higher turbidity reducing the available area of feeding habitat. In general the effects of increased turbidity and suspended solids on foraging seabirds are not well known (Michel et al 2013).

The use of vision by birds to locate food aggregations and capture prey is well known however (eg Wells et al, 2016; Thiebault et al, 2014; Stempniewicz et al, 2013) and the occurrence of a continual plume of elevated turbidity is considered to present a

potential adverse effect, but only to a limited number of species and only while the dredge is operating.

A vulnerability assessment was undertaken by Cook & Burton, 2010 in the context of marine aggregate extraction. Some of the affected species are analogous with birds that occur in the Project's dredging area. The conclusions were as follows:

Northern gannet (*Morus bassanus*; compared with australasian gannet *Morus serrator*) were considered relatively insensitive to the dredging operation and associated shipping. "Their wide foraging means that despite being moderately sensitive to increased sedimentation and impacts to the benthos or associated fish communities, the vulnerability of Gannets to these issues has been assessed as being very low. Despite using vision whilst foraging their vulnerability to increased turbidity has also been assessed as being low." This conclusion is considered to have a high level of application to australasian gannet.

Similarly the effects on overseas shag species have application to shags in the Project area. European or common shag [(*Phalacrocorax aristotelis*) cf pied shag and little shag in particular; *Phalacrocorax varius* and *Phalacrocorax melanoleucos* – nesting colonies present] "Despite being highly sensitive to some aspects of marine aggregate dredging, notably disturbance and the issues related to shipping, the exposure of the European Shag to dredging operations is low. Consequently European shags have been assessed as being of low vulnerability to all of the issues associated with marine aggregate extraction."

This conclusion is considered to have a low to moderate level of application because of the recorded degree of use of the Darch Point to Busby Head area by shags and the presence of nesting colonies of pied and little shag at Motukaroro Island and Home Point. There is the potential for an adverse effect on an at risk species (pied shag) through a decreased level of feeding efficiency. The reduced efficiency to capture prey (small fish) could result from a combination of impaired underwater vision and avoidance of feeding areas close to the nesting sites by small fish. Those factors in isolation or combination would lead to a decrease in feeding efficiency and therefore the ability to sustain juvenile shags.

The potential effect would apply to the nesting periods that can be variable and extended but generally peak in the spring-summer. "Some little shags begin nesting in July or August, while others join the colony later and breeding can extend to April or May. Peak activity occurs in October-December." Regarding pied shag – "Clutches are laid in all months, with peaks during February-April and August-October" (nzbirdsonline.org.nz).

In general, gulls are likely to be of low sensitivity to the effects of dredging activities as they have a broad diet and are able to use a wide variety of habitats (Cook & Burton 2010). Although this conclusion has a high level of application to red-billed gull, an effect is most likely during the breeding period ("They have an extremely long egg-laying period that can extend from mid-September to January" – nzbirdsonline.org.nz). A nationally significant nesting colony is present within the RNZ grounds.

There are two species of terns that are common in the dredging area, white-fronted and caspian, both of which dive for small fish. Cook and Burton 2010 comment on terns as follows "As they are constrained by a short foraging range, they are highly vulnerable to reduced food availability". "Thus any changes in food availability at a local level could have a dramatic impact on populations. As they require clear water for foraging (Essink, 1999) terns may thus be particularly sensitive to the turbidity caused by dredging operations and the re-suspension of sediment." An increase in turbidity has been suggested as resulting in the reduced breeding success of sandwich tern (*Sterna sandvicensis*) in the Dutch Wadden sea as a result of adults having to fly a greater distance from the breeding colony to obtain food for their young (Essink, 1999).

In the case of the dredging area effects of this Project, the level of application is considered relatively low because both white-fronted and caspian terns will range both up the Harbour and out into Bream Bay to feed. Both species use the intertidal area, especially Refinery Jetty to Northport, for resting, while white-fronted tern commonly uses the Refinery Jetty for roosting.

In general, however, terns can be considered as being moderately to highly vulnerable to the effects of impacts on the benthos and associated fish communities, and highly vulnerable to increases in turbidity (Cook and Burton, 2010).

The species and groups of birds discussed above are all able to fly and therefore move rapidly away from visually unsuitable feeding conditions. There will be sufficient areas of habitat containing typically high clarity water close to the dredging area to prevent a significant adverse effect in general, however, a caveat applies to nesting shags, gulls and terns during the main breeding period when feeding efficiency and energy conservation obtaining food can be critical to breeding success and juvenile survival.

Specific instances may arise where greater effort may be required to secure food (eg longer feeding flights; additional feeding time in Bream Bay and beyond). These instances, if any, cannot be defined precisely but are unlikely to be any greater than the effects caused by natural, seasonal prey variation or poor weather conditions and are unlikely to reduce either breeding success or juvenile survival during the six month period of dredging.

The flightless species using the dredging area footprint is little penguin that hunts prey visually in daylight (squid, small fish) and is likely to nest around the coastline of the islands and northern shoreline. Their behaviour that informs consideration of potential effects in the dredging area is as follows from nzbirdsonline.org.nz.

Eggs are laid from July to mid-November, with additional clutches beginning as late as December. Incubation takes up to 36 days. Chicks are brooded for 18 – 38 days, and fledge after 7-8 weeks.

Little penguins are nocturnal on land. They return to nesting areas at dusk, congregating in small groups, or “rafts” offshore. Rafts usually come ashore together and are comprised of the same individuals each night. They feed at sea as solidary individuals or small groups, rarely more than 6 individuals. They must stay ashore continuously for about 2 weeks during the annual moult (mainly between January and March), when all feathers are replaced simultaneously.

During the breeding season little penguins forage within 20 km of the colony, pursuit diving for prey generally in waters less than 50m deep. Their diet is composed of varying proportions of small shoaling fish, squid and crustacean species. Important prey items include arrow squid (*Nototodarus sloanii*), slender sprat (*Sprattus antipodum*), Graham's gudgeon (*Grahamichthys radiata*), red cod (*Pseudophycis bachus*), ahuru (*Auchenoceros punctatus*) and stomatopod larvae. (nzbirdsonline.org.nz).

The concern with the dredging footprint is primarily the disruption to breeding penguins commuting between inner Harbour nesting habitats and feeding areas (i.e. probably, Bream Bay).

Although little penguins are typically seen on the water surface, the deepest dive recorded in New Zealand waters is 35m with an average dive of 5.2 – 6.4m (Doc 2015). The deepest dive recorded was at Phillip Island, Australia at 66.7m (Ropert-Coudert et al 2006), however most dives did not exceed 50m. NZ little penguins spend about 60% of their time below 1m depth while at sea.

There are two main phases of little penguin breeding of concern and during those phases behaviour can be quite different. The two phases are egg incubation and the chick-guard stage both of which are shared. In the incubation phase the foraging trips away from the nest averaged 8 days, however, the majority are about 2 – 3 days (Cannell, 2016). During the guard phase the penguins foraged closer to the nesting location and that is driven by the need for penguins to return each evening to feed their chicks (Cannell, 2016). In the guard phase satellite tracking has shown that most penguins undertake one day trips up to 22km from the colony but of a mean maximum distance of 14.2km (Preston, 2007).

The overarching behaviour that could be affected is mid-water to demersal foraging for food (Preston 2007, Preston et al 2007) – they require light penetration through the total water column to forage efficiently since they hunt by sight. Therefore areas affected by a turbidity plume could be rendered unsuitable for foraging by little penguin resulting in temporary displacement from that feeding area and a lower foraging efficiency. That would have potentially adverse effects at a local population

level but not at a national level where the national population is estimated at 50,000 – 100,000 with a world breeding population of c.350,000 – 600,000 individuals (www.penguins.cl/little-penguins.htm). In context any area of disruption is almost certainly likely to be minor relative to the wide feeding area available in Bream Bay out to the Hen and Chickens Islands.

In summary the main concern regarding little penguin is disruption of their passage between shoreline nesting areas and the nearby open water and specifically between the inner Harbour and its entrance.

The recent information on little penguin use of the Harbour is sparse. Pierce 2005 refers to past breeding (i.e. pre 1985) on Calliope Island, High Island, some northern headlands and One Tree Point and notes observations of little penguin at potential nesting areas including Little Munro Bay and McGregors Bay. Pierce, 2005 concludes that the current relative scarcity of little penguin in Whangarei Harbour probably reflects their vulnerability to predators over a long period. No little penguins were observed either singly or rafting in groups during any of the 2015 – 2016 coastal bird surveys. In addition the modification and renovation of residential dwellings on the northern shoreline may have reduced the availability of suitable nesting sites under houses.

However targeted surveys in November-December 2016 at dusk identified a population that could represent at least twelve pairs using the Harbour habitat for nesting and chick rearing. That is a notable result in the context of the Harbour but numbers recorded suggest a relatively low breeding density.

Therefore although a continual but confined plume has the potential to disrupt foraging trips during the breeding season, the risk on a population level is considered low-moderate inside Busby Head on the basis of current information and relative to the adverse effects of storm events as evidenced by beach wreck data.

Recent advice on nesting little penguin beyond the Harbour has been provided by the Ranger, Bream Head Conservation Trust (Riaan Elliot pers comm; email of 3.10.16). Little penguin is known to be currently using the shoreline from Busby Head to Bream Head and around to Ocean Beach (Bream Islands) for breeding although there are no

data on the numbers. The probability of an adverse effect in this area on a local population basis is also considered low because much of the nesting habitat is remote from the works area, it is an open water situation with high dilution and dispersion rates and the probability of a "turbidity barrier" to foraging trips being created is remote; the effects on little penguin nesting beyond the Harbour (ie along the Bream Head coastline) would be less than minor.

Nevertheless there remains a possibility of a short term change to the local little penguin population with respect to effects both inside and outside Busby Head in combination, especially the former.

The characteristics of the sediment plumes associated with the dredging would be as follows (Metocean Solutions 2016): the plumes associated with the drag head are "constrained within the lower water column, with negligible expression in the mid-water and surface levels. In contrast the sediment plumes associated with the overflow phase are spread across the entire water column". Of note was that the maximum excursion of any plume did not exceed 1200m and was constrained to the channel.

There would be a discrete inner Harbour dredging area to the southeast of Motukaroro Island and more minor works towards Home Point, with the major dredging area being predominantly outside Busby Head.

Therefore the main area of dredging disturbance, albeit temporary, will be beyond the Heads and would not affect the passage of little penguin to and from the Harbour. The turbidity effect of dredging within the Harbour will be temporary and confined to the existing channel i.e. a turbidity "barrier" across the channel at right angles would not be created allowing little penguin to traverse the channel's edges, especially along the northern side where nesting habitat is more likely. That would avoid a disruptive barrier being created between inner Harbour nesting habitats and open water (Bream Bay) feeding areas. In addition, as noted above, there will be Project-specific turbidity threshold levels that are similar to those aimed at protecting the foraging of terns and gannets at the Port of Melbourne. Finally, although the specific turbidity levels are not known, little penguins have adapted to intermittent, temporary turbidity increases

that would be accommodated during storm events, rainfall events and river discharges.

On balance the Project would be consistent with NZCPS Policy 11 (a) (i) and Policy 11 (b) (ii) and Objective 3.4 and Policy 4.4.1 of the partially Operative Northland Regional Policy Statement ('NRPS') as applied to little penguin and, indeed, to the other bird species that nest within or frequent the outer Harbour and Bream Bay.

It is acknowledged, however, that the behaviour of birds is difficult to predict and it is equally difficult to discount all effects. For that reason, recommendations are presented below for predator control and the installation of little penguin nesting boxes inside the Harbour to mitigate any short term changes that might adversely affect the local breeding population. In the longer term the maintenance of nesting boxes, especially in a predator – controlled area, would be a positive benefit to the Harbour's population, and also to any nesting variable oystercatcher, reef heron and shags.

In summary, without any mitigation the effects on the local little penguin population are concluded to be less than minor; with the initiatives outlined in Section 7.1 the nett result is viewed as ecological enhancement.

5.2.1.2 Disposal Areas

Disposal area 3.2 is 5.75 km2 and 45m deep and would be the repository for most of the dredged material. Area 1.2 is 2.5 km2 and 7-15m deep.

At Area 3.2 the average mound height would be a maximum of c.4m whereas that at Area 1.2 would average 0.6m and no shoreward migration of sediment that could adversely affect the intertidal habitat would occur.

There is no concern regarding potential contaminant release at the disposal sites and the proportion of silt is low.

The main disposal area is utilised as part of the wider Bream Bay by a relatively high diversity of pelagic birds at times as identified and described in the Bioresearches literature review (2015) and Section 3.4 of this report.

The dredge vessel's slow passage into the release site will disperse any surface resting birds as would the passage of tankers, freighters and other vessels at present. The released sediment will rapidly fall to the seafloor at 45m depth and, because of the low silt content, any adverse effect on water quality is likely to be very localised. At least in daylight there would be nothing to attract birds to the vessel in contrast, for example, with a fishing vessel and the behaviour and presence of birds can be highly variable.

Species such as grey-faced petrel are nocturnally active at breeding sites (April/May and August) but rapidly fly out to the continental shelf to feed. Birds have been recorded flying to the east coast of Australia while their partner is sitting on an egg (nzbirdsonline.org.nz). In contrast, fluttering shearwaters can form large feeding flocks in inshore and harbour waters during the summer (Gaskin & Rayner, 2013) and are typically present off Bream Bay Beach (Sime Road to Mair Road) in April (M. Hicks pers comm).

Similarly large numbers of gannets can be present from Ruakaka Estuary mouth north from September onwards and would extend into Area 1.2.

Therefore while there would be disruption to any feeding pelagic birds by the dredge vessel's passage, the effect would be less than minor on a population level. Similarly the probability of pelagic birds being attracted to the stationary vessel and diving to depths with localised elevated turbidity resulting in an adverse effect, is remote, and any effect would be very low and would not trigger NZCPS Policy 11 (a) (i) or 11 (b) (ii) and cut across Objective 3.4 and Policy 4.4.1 of the NRPS.

5.2.2 Resuspended Sediment Deposition

Based on the modelling results for the dredging area and the disposal areas there is no concern regarding an adverse ecological effect of sediment deposition on adjacent intertidal and subtidal areas that could impact on the feeding areas of coastal birds. There would be no adverse effect.

5.2.3 Vessel Movements

The vessels involved with the Project will not be very different from the range using inner Bream Bay and the Home Point to Busby Point area at present in terms of sizes

and speeds. Large ships utilise the Busby Head to Northport area on a regular basis at present. Similarly, freighters and cement carriers pass through the area en route to the Port of Whangarei and Portland, together with numerous smaller commercial and private vessels. On balance the risk of additional vessel movements resulting in an adverse effect on the avifauna is very low.

Arguably the species most at risk is little penguin but injuries and mortality from fast moving craft are more likely than from the vessels used for this Project. (Canwell 2016). Little penguins can reach speeds of up to 6 kph (3.2 knots) underwater (www.doc.govt.nz/native - animals/birds/birds-a-z/penguins/little-penguin-korora/) and have the ability to deep dive.

On balance any effect would be less than minor, and would, therefore, be in accordance with the direction set by the NZCPS and the NRPS.

5.2.4 Vessel Lighting

Light is well known to attract a variety of marine birds (Montevecchi, 2016). The adverse attraction to vessel lights by seabirds is considered to be more likely in Bream Bay beyond Busby Head. That is because the degree of ambient night lighting within Busby Head is relatively high and contributed by the Refinery, Northport, Marsden Cove, berthed vessels, residential areas and navigational aids.

Beyond Busby Head, however, the potential attraction of seabirds to a vessel dredging, in transit to and from disposal area 3.2 in particular, and stationary over that area, is considered high. Considering the operation is continuous, the potential for an adverse effect is also considered moderate-high but tempered by the fact that large vessels are moored in Bream Bay on a continual basis, 12 months a year in all weather conditions. It is not known whether these vessels are impacted by seabirds however it would be surprising if that were not the case. Nevertheless the dredger will be a large, “resident” vessel and a constant light source. Fishing vessels can also be an attractant to seabirds that impact with their decks at night. The most sensitive seabirds to light attractions are gadfly petrels (*Pterodroma genus*), storm petrels, diving petrels, prions and some smaller shearwater species (Taylor, 2014).

Petrels and shearwaters in particular are described as being very sensitive to artificial light (Le Corre et al, 2002) especially fledglings on their first flight to sea. It is thought that occurs because these species feed on bioluminescent squid and mistake the lights for potential prey. (Le Corre et al 2002). One of the species known to exhibit this behaviour is grey-faced petrel (*Pterodroma macroptera gouldi*) that nests within the adjacent Bream Head Scenic Reserve (Montevecchi, 2006).

The susceptibility of light-attracted seabirds to collision and injury or death is higher on moonless nights or during the hours of darkness when the moon is below the horizon. A critical period is a week either side of the new moon each month, whereas clear starlit nights are less risky because the birds are able to navigate and orientate normally. Similarly heavy fog and rain at night can increase the collision risk (Black, 2005; Thompson, 2013; Taylor, 2014).

Therefore it is concluded that collisions between seabirds and the dredging vessel especially in the areas between Busby Head and disposal Area 3.2 are likely.

From the advice of Taylor 2014 above the more susceptible seabirds are the gadfly petrels, grey-faced petrel (*Pterodroma macroptera gouldi*) that nests within Bream Scenic Reserve, and Pycrofts petrel (*Pterodroma pycrofti*) that nests on the Hen and Chicken Islands.

Shearwaters and diving petrels nesting on the Hens and Chickens Islands and therefore susceptible to collision are as follows -

- flesh-footed shearwater (*Puffinus carneipes*)
- sooty shearwater (*Puffinus griseus*)
- fluttering shearwater (*Puffinus gavia*)
- little shearwater (*Puffinus assimilis haurakiensis*)
- northern diving petrel (*Pelecanoides urinatrix urinatrix*)

Additional susceptible species that nest on the Poor Knights Islands are –

- fairy prion (*Pachyptila turtur*)

- Buller's shearwater **(***Puffinus bulleri*)

- white-faced storm petrel (*Pelagodroma marina maoriana*

The literature review undertaken by Bioresearches (2015) identified one nationally threatened pelagic species (flesh-footed shearwater) and twelve nationally at risk species that are potentially susceptible.

Clearly, but with the caveats on the existing use of the area by large vessels, the risk of an effect on species that are considered nationally threatened or at risk is notable and heightened by the proximity of breeding colonies at Bream Bay Scenic Reserve, the Hen and Chickens Islands and the Poor Knights Islands, and the use of Bream Bay by young, inexperienced birds.

It is understood that there has been no breeding activity by grey-faced petrel on Matakohe-Limestone Island in the inner Harbour in 2016 so that potential risk would not appear to be an issue. Any birds utilising the Island would anyway have acclimated to the ambient light levels of the Harbour environment.

On balance the general risk of light attraction and collision would be similar to that of any other large vessel and would not be significant on a population level but would increase during the post-fledging period. While NZCPS Policy 11 (a) (i) would not be triggered, some management may be appropriate, particularly to achieve the direction set in Objective 3.4 and Policy 4.4.1 of the NRPS.

There are management measures to reduce the attraction of seabirds to a vessel as summarised by Taylor, 2014 in the case of mining on the Chatham Rise and quoted in full. Such measures should be considered as part of a lighting audit (refer section 7.2 below) to address concerns, including for locally breeding grey-faced petrel in the Bream Head Reserve.

"(a) reduce all unnecessary deck and cabin lighting, cover accommodation windows at night with blinds and curtains;

(b) where possible, orientate all deck lights so they shine only downwards and shield them to prevent upwards or horizontal light projection.

(c) use light dimmers and timers to minimise lighting in areas where people are not constantly active;

(d) trial different light colour options such as green coloured lights in operational areas to reduce overall light intensity levels on the vessel;

(e) investigate the use of LED floodlights with computer controlled light levels, colours and timers;"

5.2.5 Noise

The noise generation of potential concern would be underwater noise. This is of relevance mainly to species that hunt prey underwater for longer periods than the short dives of birds such as white-fronted tern and australasian gannet. In the project area that will apply to shags and little penguin.

Roger HaskoningDHV advise that the noise generated by a TSHD will be similar to that of a large vessel. Clearly large vessels are common in the Project area at present, the difference being that the noise will be continuous rather than intermittent.

Woehler, 2002 investigated the literature during a study on the underwater hearing abilities of six species of penguin in Antarctica. Only one study was located; Cooper 1982 found that underwater acoustics (killer whale vocalisations or electronic noise) had no effect on cape cormorants (*Phalacrocorax capensis*) or jackass penguins (*Spheniscus demersus*), and concluded that underwater acoustics does not seem to be an efficient scaring technique.

However the present positon appears to be that there are no published studies on the effects of underwater noise on birds (McCauley & Kent, 2008) that provide an assurance; however Bream Bay and the Harbour support a diverse and abundant avifauna despite the passage of large ships and numerous smaller vessels. The probability of a noise-induced adverse effect on swimming and diving birds is considered negligible. Noise effects would not cut across the requirements set by either NZCPS Policy or by the NRPS.

5.2.6 Cumulative Effects

On balance it is concluded that the cumulative effects (ie general combined overall disruption) on coastal and pelagic birds and their habitats will be less than minor, especially in the context of existing conditions and activities, and the proposed mitigation.

None of the effects arising from dredging and disposal is particularly novel; large vessels traverse the Whangarei Heads and Harbour area at present on a 24 hour basis and in a wide range of sea states, weather conditions, tidal stages and turbidity levels. There is some information that little penguin nationally is subject to external pressures, including development in the coastal strip. This is evidenced by its 'at-risk' ranking. However, there is no information that the current proposal will have effects – including cumulative effects - on little penguin beyond intermittent, temporary turbidity increases confined to the existing channel. When considered together with the provision of nesting boxes and predator eradication and control proposed by way of environmental enhancement, the effect on little penguin is considered negligible.

6. CONSULTATION AND REVIEW

This assessment has benefitted from discussion (and subsequent provision of information) with Margaret Hicks at an Open Day at NZ Refining on 9 March 2015, and a review by Dr David Thompson, NIWA on behalf of Northland Regional Council.

Comment was also received from tangata whenua regarding coastal birds. While views expressed by tangata whenua regarding the nature and scale of potential effects on birds, and in particular variable oystercatcher, have been carefully considered, they are not consistent with the findings of this assessment. As described above, and following careful assessment and field investigations, the effects on birds is overall held to be less than minor, especially in the context of existing conditions and activities, and the proposed mitigation (refer Section 5.2.6).

With respect to variable oystercatcher, feeding on Mair Bank only occurs when the Bank is exposed. While there may be additional noise from the dredger, acclimation will be rapid and feeding will not be disrupted. The current environment includes movements of ships and other vessels, and a variety of noises. The key variable oystercatcher roost is within 50-100m of the Northport facility (refer Figure 3) and is subject to regular industrial noise, discharges and movement of vehicles, cranes and heavy industry. Indeed there are some variable oystercatcher nests within the RNZ property, which is a heavy industrial site. On balance the likely effects of the Crude Shipping Project on variable oystercatcher will be no more than minor and do not warrant further mitigation.

7. RECOMMENDATIONS AND MITIGATION

7.1 LITTLE PENGUIN

There is sufficient information to indicate that little penguin would be susceptible to a sustained increase in turbidity. The effect is a potential decrease in the foraging efficiency of the penguins which in turn has the potential to impact on juvenile survival and the viability of the local population. Secondly there is a concern, but only at a precautionary level, over the effect of continuous underwater noise during the breeding season. Countering that, the available information indicates that the key breeding area is possibly the shoreline from Busby Head to Ocean Beach rather than inside the Harbour and that on balance, the effect at a population level would be low. However there is clearly a local nesting population within the Harbour and beyond Busby Head, and there remains a possibility that an adverse effect on the breeding success of those populations could occur.

It is further recommended that in consultation with the Department of Conservation the breeding opportunity and potential success of little penguin should be enhanced via predator control and the provision of nesting boxes on Motukaroro Island

Focus should be on Motukaroro Island because it is in a Marine Reserve and is habitat that is readily pest controlled. Motukaroro Island is part of the DoC estate and is not currently pest controlled. Pest eradication is recommended on the Island and along its facing mainland foreshore to minimise pest incursions, commencing 6 months prior to the start of any capital dredging. That should provide a sufficient period in which to eradicate pests and assemble and deploy nesting boxes. The eradication should be paralleled by the establishment of tracking tunnels on the Island to monitor pest presence. The most efficient means for both eradication and subsequent control, especially on the Island, would be via self-setting traps for stoats/rats and possums, with about 5 stations on the Island and 10 on the mainland edge.

Pest eradication should ideally be completed prior to June when little penguins start to utilise their burrows (April – May is the only period when little penguins are unlikely to be present on land.) The pest control should be continued for a minimum of 5 years

to accommodate acclimation to the boxes and allow a positive impact on the local population in pest controlled conditions.

The Island has a total area of about 11321m^2 (ie 1.13ha). From the literature accessed, a typical maximum density of a mixture of natural burrows and nest boxes is about 0.5 per 100m^2 or 1.0 per 200 m^2 (eg Braidwood et al 2011). On that basis there is potential area available on the Island for c.57 nests/breeding pairs. On the assumptions that (a) the twelve pairs observed in the November-December 2016 surveys are typical and (b) for management purposes, all pairs nest on Motukaroro Island, then a theoretical surplus of nesting area for a further 45 pairs would be available.

Motukaroro Island is likely to consist of a relatively rough, rocky surface and the aim of 45 nest boxes may not be practicable. It is recommended that the target is 24 boxes based on an assumed current nesting population of 12 pairs that were observed during the surveys. An increase of 24 pairs would be a significant conservation gain and, in combination with pest eradication and control, would ensure any adverse effect on the local population was negligible.

7.2 VESSEL LIGHTING

In recognition of the high diversity of pelagic species, a relatively high proportion of which have national conservation ratings, the nearby presence of significant seabird breeding colonies and the reported aggregations of pelagic species, a lighting audit of the Project's vessels should be undertaken relative to the potential measures in mitigation listed in Section 5.2.4 above. Where there are deficiencies, those should be rectified where practicable in consultation with the vessel operators.

7.3 GREY-FACED PETREL

The concern with grey-faced petrel is mortality of fledged young as a result of attraction to lights and subsequent collision with the dredger in particular, especially when it is operating beyond Busby Heads at night.

As with little penguin, any potential adverse effect could be offset by the provision of nesting boxes. It is understood that the Bream Head Conservation Trust already operates a comprehensive predator control program at present and that Refining NZ is a supporter of the Trust. The grey-faced petrel nest box initiative would be specific

and targeted, with the nest boxes enhancing existing earth burrows. In consultation with the Trust and Department of Conservation, the final details could be outlined in a specific management plan or agreement. It is understood, however, that there are at least ten active burrows. It is recommended, as with little penguin, that the aim should be a significant increase of available nest sites and therefore 20 boxes should be provided contingent upon confirmation from the Trust.

8. MONITORING

The recommendations below assume that the Recommendations and Mitigation outlined in Section 7 above can be achieved.

There is no regular monitoring recommended for coastal birds because the major elements of the Project are essentially fixed and there are unlikely to be any opportunities to modify those elements in the event of an adverse effect being recorded, which based on the modelling results and analysis, is considered to be in the low risk category.

It would be more effective to focus on potential offset measures and monitoring following completion of the Project.

8.1 MONITORING

The proposal is to document the state of the coastal bird populations in specific areas following the completion of the Project so that both before and after data were on the record.

The following exercises are proposed, with the coastal bird surveys being repeats of the November 2015 – March 2016 surveys in terms of methodology and timing.

8.1.1 Coastal Birds

The following once-off state-of-environment surveys are proposed.

(a) Marsden Point to Northport breeding season (November) habitat use.

(b) Darch Point to Home Point breeding season (November) habitat use.

(c) Mair Bank coastal bird surveys (2) in the February – March period.

(d) Refinery Jetty to Northport coastal bird survey (1) in the February – March period.

(e) Urquharts Bay coastal bird survey (1) in the February - March period.

(a) and (b) would document the degree of post-dredging nesting activity by coastal birds as previously, especially variable oystercatcher, reef heron, pied shag and little shag.

Mair Bank is considered to be of national importance, is immediately adjacent to the TSHD and berth pocket dredging and is the key feeding habitat for variable oystercatcher in the outer Harbour.

The Refinery Jetty to Northport habitat is also adjacent to the TSHD and berth pocket dredging and is a key high tide wading bird roost and general resting area.

Urquharts Bay is a locally significant habitat for coastal birds, is the most notable habitat on the northern shoreline and the data would reflect the general state of the northern shoreline.

Overall, the above surveys would substantiate the state-of-environment and baseline condition of the avifauna post-dredging that is likely to be of interest to stakeholders and provide useful assurance for Refining NZ.

8.1.2 Little Penguin

Daylight counts and dusk arrival counts should be completed in the November to January period as a once-off exercise when both parents are likely to be feeding at sea and therefore more visible. In the chick-guard period (about September to October) only one adult would be feeding at sea and encounters would be lower. The survey area should cover the northern bays area from Reotahi Bay to Urquharts Bay inclusive.

In addition a regular, ongoing monitoring program to record nesting box success will be developed in consultation with the Department of Conservation. To parallel the pest control that should continue for a minimum of 5 years.

9. CONCLUSION

Overall the impact of the Project including cumulative effects on coastal and pelagic birds is considered to be low especially at a national population level; the NZCPS Policy 11 (a) (i), regarding adverse effects on threatened or at risk taxa, and Policy 11 (b) (ii), regarding adverse effects on vulnerable life stages would not be triggered at a population or regional level and, if triggered at a local level, can be mitigated. Furthermore, the other applicable (avifauna) policy from the NRPS will also be achieved if the Proposal is advanced in the manner that we have recommended.

The key initiative recommended is the provision of little penguin nesting boxes within the Harbour to offset any local effect on breeding success as a result of dredging and a turbidity increase.

In addition the provision of nest boxes for grey-faced petrel in Bream Head Scenic Reserve is recommended to offset any local effect of the dredger's lighting on fledged juveniles.

Post-capital dredging monitoring is recommended to provide before and after state-of-the-environment information on coastal birds and little penguin.

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Annexure Two: Technical Reports

k) **Assessment of Marine Ecological Effects excluding Seabirds and Marine Mammals. Brian T Coffey and Associates. Brian Coffey. Dated 10 August 2017**

Brian T. Coffey and Associates Limited
Environmental Consultants

Crude Shipping Project

Proposal to Deepen and Partially Realign the Approaches to Marsden Point

Assessment of Marine Ecological Effects Excluding Seabirds and Marine Mammals



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Table of Contents page

Preamble 3
1.0 Executive Summary 6
2.0 General Introduction to Existing Environment and Values within the Study Area 11
2.1 Climate and Exposure, 12
2.2 Bathymetry, Water Currents and Seabed / Shoreline Types 12
2.3 Soft Sediment Quality and Sediment Transport 13
2.4 Occurrence and Quality of Reef Structures and Hard Shorelines 13
2.5 Water Quality 14
2.5.1 Introduction and Background 14
2.5.1a Harbour Sites 16
2.5.1b Bream Bay Sites 17
2.5.2 Suspended Solids, Turbidity and Light Penetration 17
2.5.3 Water Quality at Marsden Point and Mair Bank 19
2.5.4 Water Quality within Bream Bay 20
2.6 Marine Community Structure 20
2.6.1 Plankton 20
2.6.2 Benthos 21
2.6.2a Open Sandy Beaches in Bream Bay 26
2.6.2b Subtidal Sand Flats in Bream Bay 26
2.6.2c Disposal Area 1.2 26
2.6.2d Disposal Area 3.2 27
2.6.2e The Dredging Footprint 27
2.6.2f Soft-bottom communities in the lower Whangarei Harbour 27
2.6.2g Hard shore habitat and submerged reefs within the study area 28
2.6.3 Fish 29
2.6.4 Marine Birds 30
2.6.5 Marine Mammals 30
2.6.6 Noise 30
2.7 Recreational and Commercial Harvesting of Marine Resources 30
2.8 Other Uses, Discharges and Disturbance Activities 30
2.8.1 Northport Limited 31
2.8.2 Ruakaka Wastewater Treatment Plant Ocean Outfall 32
2.8.3 NIWA Aquaculture Facility 33
2.9 Marine Sites of Special Scientific or Conservation Value 33
3.0 Description of Proposed Disturbance Activities 35
3.1 Introduction and Background 35
3.2 Dredge Type and Management 36
4.0 Assessment of Environmental Effects of Proposed Disturbance Activities 38
4.1 Area affected by Capital Dredging and Disposal 38
4.1.1 Prediction of Seabed Effects 38
4.1.1a Bathymetry and Topography 38
4.1.1b Sediment texture and Contaminants 38
4.1.1c Sediment Transport 40
4.1.2 Prediction of Water Column Effects 41
4.1.2a Sediment Plumes 41
4.1.2b Suspended solids, Turbidity and Light Penetration 42
4.1.2c Return of decant water to sensitive environments 42
4.1.2d Analysis against Regional Coastal Plan Performance Standards 43
4.1.2e Summary and Recommendations 44
4.1.3 Prediction of Effects on Marine Community Structure 45
4.1.3a Plankton 45
4.1.3b Benthos 46
4.1.3c Fish 47
4.2 Maintenance Dredging and Disposal of Maintenance Dredging's 48
4.3 Ecological hazard of potential Hydrocarbon Spillages 48
4.4 Relocation of Navigational Aids adjacent to the realigned channel 49
4.5 Summary of Environmental Effects of Proposed Disturbance Activities 50
5.0 Avoidance, Remediation or Compensation Measures for Disturbance Activities 51
5.1 Short term loss of soft-bottom benthic productivity in the northern sector of Bream Bay 51
5.2 Avoiding adverse sedimentation effects within sensitive hard bottom communities adjacent to the dredging footprint 51
5.3 Summary 52
6.0 Planning Matters (Resource Management Act, 1991) 53
6.1 Section 6(c) 53

6.2 Section 7 53
6.3 Section 8 54
6.4 Section 15B 54
6.5 Section 105 55
6.6 Section 107 55
7.0 Recommended Monitoring 56
7.1 Immediately Prior to Dredging and Disposal 56
7.2 During Dredging and Disposal 58
7.3 Post Dredging and Disposal 59
8.0 Overall Conclusions 60
Acknowledgements 61
9.0 Bibliography 62
Appendices 76

Preamble

The New Zealand Refining Company Limited (trading as 'Refining NZ' or 'RNZ') operates a crude oil refinery at Marsden Point on the southern side of the Whangarei Harbour mouth (see Figure 1). Deep water access to Marsden Point from Bream Bay is via a natural tidal inlet that varies in depth from 15 to 32 metres (see LINZ, 2010, LINZ, 2004 and Figure 2).

Figure 1: Locality Diagram for Marsden Point Oil Refinery.



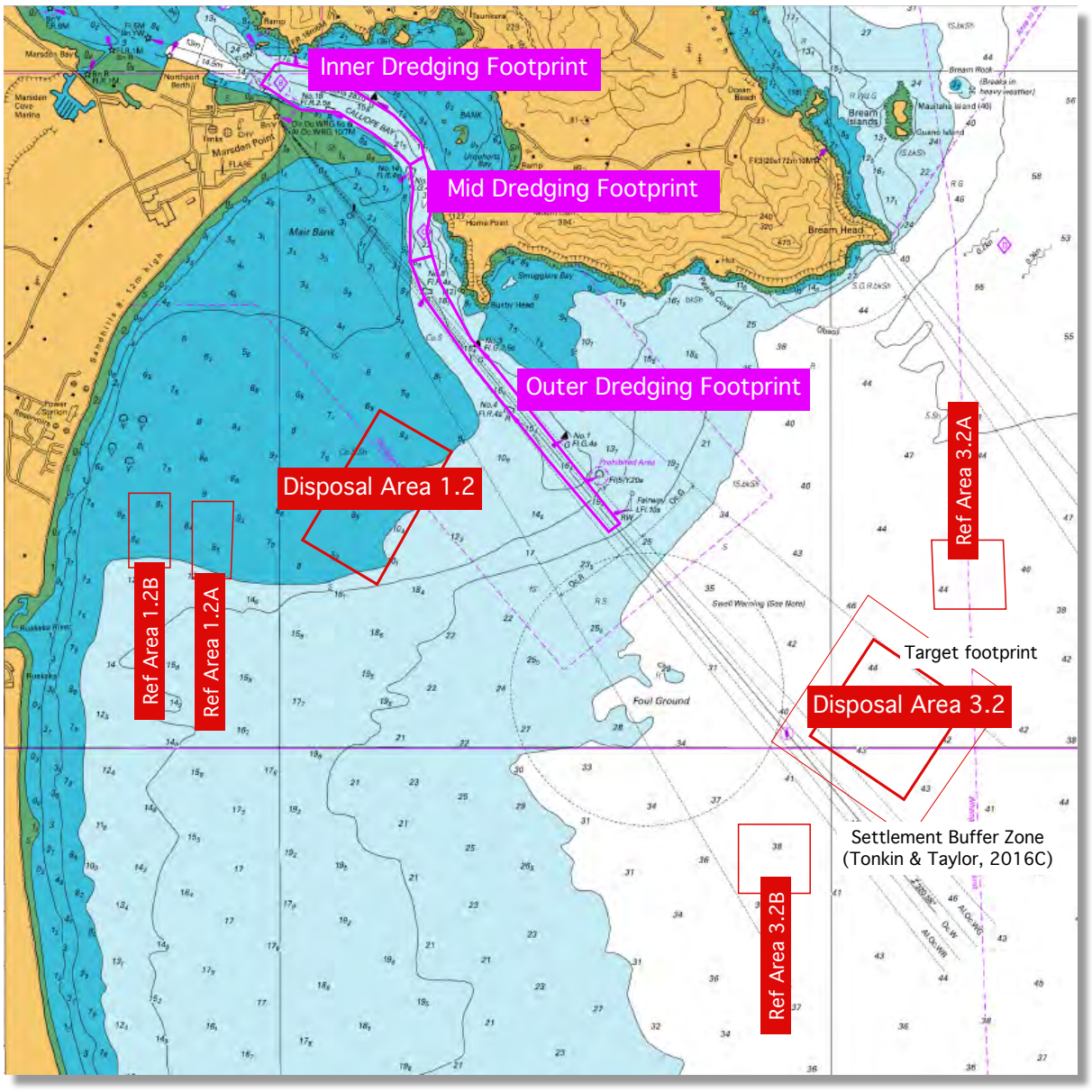
Crude oil supply to the refinery is currently delivered by smaller fully-loaded "Aframax" ships and larger partially-loaded "Suezmax" ships. "Suezmax" ships can only be partially loaded due to existing port draft requirements.

There would be financial and efficiency returns for RNZ if fully-loaded "Suezmax" ships could access the Marsden Point berthing terminal from Bream Bay (Tonkin & Taylor, 201A).

To this end, RNZ is applying for resource consents required:

- to partially realign the access channel to provide safe navigational access for fully-loaded "Suezmax" ships,
- to remove / replace / relocate / add to navigational aids along the new channel alignment (see Figure 3 and Royal HaskoningDHV, 2016C),
- for targeted capital and maintenance dredging to achieve and maintain a minimum depth to support 16.6m ship draught in the access channel, and
- to dispose of dredged materials.

Figure 2: Study Area Showing Footprints for Proposed Dredging and Disposal of Dredged Material (Chart courtesy of LINZ, 2010).



With reference to Figure 2, a range of access channel alignments have been evaluated[1] but only the preferred access footprint (Option 4.2) is considered and described in this Assessment of Ecological Effects (see Figures 3 and 4).

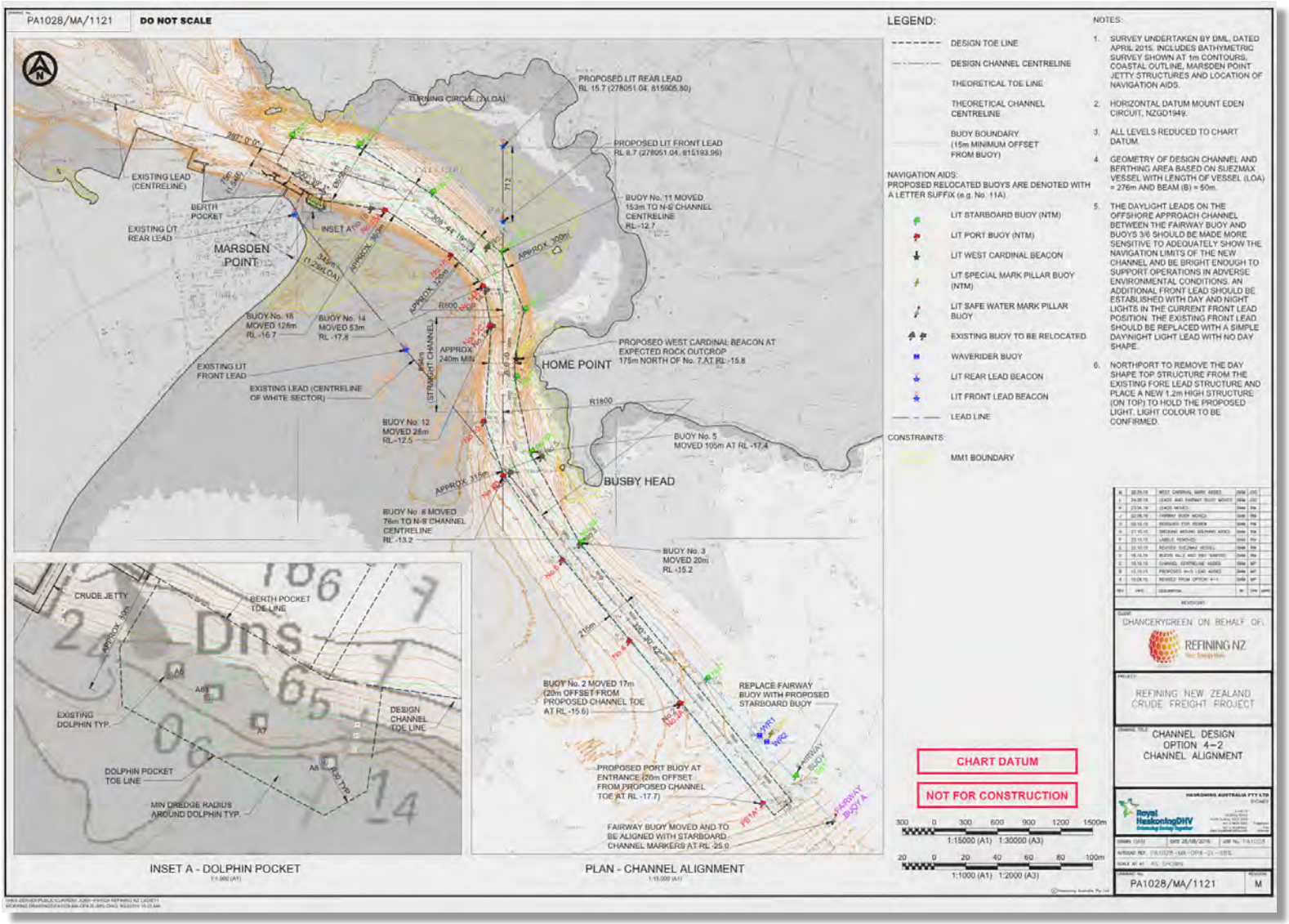
Similarly, a range of preferred options for offshore disposal sites have been evaluated[2] but only the preferred options (Areas 1.2 and 3.2) are considered and described in this Assessment of Ecological Effects (AEE).

These choices were the subject of a mid-point multi-criteria alternatives assessment by Tonkin & Taylor (2017C)

[1] MetOcean Solutions (2016B), Royal HaskoningDHV (2016A), Tonkin & Taylor (2017A).

[2] MetOcean Solutions (2016B), Tonkin & Taylor (2017A), West and Don (2016B), Kerr and Grace (2016E).

Figure 3: Proposed changes to Navigational Aids for Channel Alignment Option 4.2.



1.0 Executive Summary

The ecological context for these resource consent applications is that both the proposed dredging footprint and the footprint of proposed disposal areas 1.2 and 3.2 (see Figure 2) are occupied by soft-bottom benthic communities that colonise seabed materials (silts, sands, shell and gravel) that are actively sorted / moved by tidal and wave-induced disturbance effects.

Benthic communities within these soft-bottom areas of seabed are typical of the coastal environment off the north-east coast of the North Island and are included within the Marine 2 (Conservation) Management Area as recognised and defined in the Regional Coastal Plan for Northland (Northland Regional Council, 2004). They are generally dominated by sand dollars, starfish, polychaete worms, hermit crabs, flatfish, shellfish and crabs.

Proposed dredging activities would physically remove existing benthic communities from a substantial proportion of the footprint shown in Figure 2 and the placement of dredged material within Disposal Areas 1.2 and 3.2 (see Figure 2) would bury and effectively eliminate existing benthic communities within part or all of these areas.

This would result in a short-term displacement (c. 6 to 24 months – Coffey, 2017A) of benthic communities (that include shellfish resources and fish food reserves) within disturbed areas until they are expected to be recolonised by a similar assemblage of taxa that occur at a similar depth on the surrounding soft-bottom seabed.

Invasive taxa (marine pests) are also potential re-colonisers of the vacant niche that would be created by proposed disturbance activities, but are considered to be a low risk as they have not proved problematic at other comparable dredging programmes at the Ports of Auckland, Tauranga or Otago.

Benthic communities such as kelp beds and sponge gardens that occur on hard-bottom areas of Northland's Coastal Marine Area (rock and stable boulders) are of high ecological value[3] and whilst they would not be directly affected by proposed disturbance activities, submerged reefs and rocky shorelines adjacent to disturbance activities are potentially vulnerable to sediment plumes and sedimentation effects that can be associated with dredging activities and the disposal of dredged material within the Coastal Marine Area.

In this regard, there are two soft-bottom Marine 1 Management Areas (Mair Bank and Calliope Bank) and two hard-bottom Marine 1 Management Areas (Motukaroro Island Whangarei Marine Reserve and Home Point) immediately adjacent to the proposed dredging footprint (see Figure 4) where existing values are to be protected.

These management areas are from Map A3 of the Northland Regional Coastal Plan (Northland Regional Council, 2004) and it is important that their conservation values are protected from potentially adverse turbidity, sedimentation and potential fuel spill effects, for example, that can be associated with dredging activities and the disposal of dredged material.

Three Mile reef is a fishing area west of Disposal Area 3.1 (see foul ground in Figure 2 and Greenaway, 2015). Whilst not afforded any particular recognition in the Operative Regional Coastal Plan, it is recognised that Three Mile reef has local recreational and ecological value within the study area.

Table 1 provides a summary of the actual and potential ecological effects of the proposed dredging programme, the associated avoidance, remediation and compensation measures, and the magnitude of the effects post the application of the avoidance, remediation and compensation measures.

[3] e.g. Golder (2010), Hay and Grant (2004), Kamo High School (2002), Kerr and Moretti (2012), Kerr and Grace (2006A), Kerr and Grace (2006B), Morrison (2003) and Morrison (2005).

Figure 4: Marine 1 (Protection) Management Areas adjacent to the proposed dredging footprint in the approaches to Marsden Point.

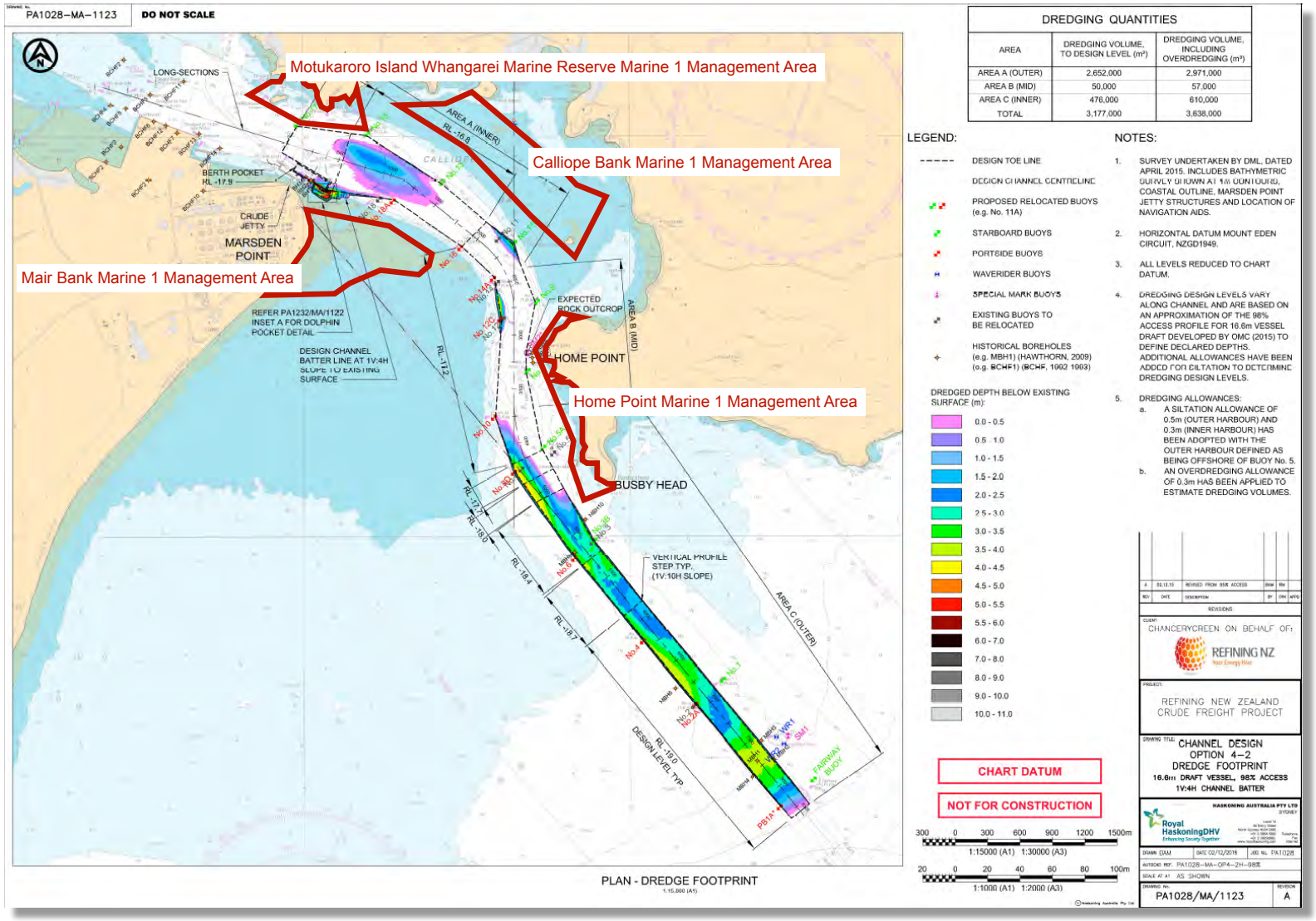


Table 1: Summary of Ecological Effects of Proposed Dredging Activities (excluding Marine Birds and Marine Mammals)).

	Actual Effects	Potential Effects	Avoidance Factors	Remediation / Compensation	Final Significance
Dredging Activities (see Figure 2)					
Disturbance and removal of bed material					
Seabed Effects					
Bathymetry	Increased water depth	Changed currents / sediment transport / wave climate	Not required (MetOcean Solutions, 2016B)	Not required (MetOcean Solutions, 2016B)	Less than minor (MetOcea Solutions, 2016B)
Exposure of new surficial sediments	Removal of benthic communities and some biological armouring	Change sediment type / texture / transport	Not required as vibrocores show similar sediment will be exposed	Contribution to enhancement of local harbour water quality / seagrass habitat for example	Minor to moderate, localise short term loss of benthos within dredging footprint
Water Column Effects					
Sediment Plumes	Increased sedimentation and turbidity within dredging footprint	Dissolved Oxygen sags / toxicity / sedimentation issues outside of dredge footprint	Dredged material is not contaminated and has a low silt content	Manage turbidity thresholds at boundary of adjacent habitats	Avoid effects on adjacent reef habitats, avoid / mitiga effects on others
Suspended Solids	Increased concentration within dredging footprint	Increased concentration outside dredging footprint	Monitor and respond to turbidity limits in adjacent communities	Not applicable for adjacent reef habitats.	Avoid effects on adjacent reef communities, avoid / mitigate for effects on othe
Turbidity	Increased value within dredging footprint	Increased value outside dredging footprint	Monitor and respond to turbidity limits in adjacent communities	Not applicable for adjacent reef habitats.	Avoid effects on adjacent reef communities, avoid / mitigate for effects on othe
Light penetration	Decreased value within dredging footprint (but no attached macrophytes present)	Decreased value outside dredging footprint	Managed via response to turbidity limits in adjacent habitats	Not applicable for adjacent reef habitats.	Avoid effects on adjacent reef communities, less tha minor effects on others.
Effects on Communities					
Plankton	Less than minor due to high replenishment rates	Less than minor due to high replenishment rates	Not required	Not required	Less than minor
Benthos	Removal & death of resident benthos from dredging footprint	Adventive pests may colonise vacant niche	Not applicable	Contribution to local enhancement of harbour water quality / seagrass habitat for example	Minor to moderate, localise short term loss of benthos within dredging footprint
Fish and Wildlife	Minor, localised, disturbance and avoidance during dredging activities	Minor, localised, and short-term reduction in available food supplies	Not applicable	Not required	Less than minor outside c dredging footprint

Table 1 continued.

	Actual Effects	Potential Effects	Avoidance Factors	Remediation / Compensation	Final Significance
Dredge in transit between dredging / disposal sites					
Water Column Effects	None if zero discharge from dredge	None if zero discharge from dredge	Not applicable	Not Applicable	none
Effects on Communities	None if zero discharge from dredge	None if zero discharge from dredge	Not applicable	Not Applicable	none

Table 1 continued.

	Actual Effects	Potential Effects	Avoidance Factors	Remediation / Compensation	Final Significance
Disposal Sites for Dredged Material (see Figure 2)					
Disturbance and Deposition of bed material					
Water Column Effects					
Sediment Plumes	Increased sedimentation increased turbidity within disposal footprint	Dissolved Oxygen sags / toxicity / sedimentation issues outside of disposal area	Not required. Material not contaminated and with low silt content.	Not required if placement confined to disposal area	Less than minor outside d disposal footprint
Suspended Solids	Increased concentration within disposal footprint	Increased concentration outside disposal footprint	Monitor and respond to turbidity limits in adjacent habitats	Not required if placement confined to disposal area	Less than minor outside d disposal footprint
Turbidity	Increased value within disposal footprint	Increased value outside dredging footprint	Monitor and respond to turbidity limits in adjacent habitats	Not required if placement confined to disposal area	Less than minor outside d disposal footprint
Light penetration	Decreased value within disposal areas (but attached macrophytes not present)	Reduced value outside disposal footprint	Managed via response to turbidity levels in adjacent habitats	Not required due to lack of attached macrophytes within disposal areas	Less than minor outside d disposal footprint
Effects on Communities					
Plankton	Less than minor due to high replenishment rates	Less than minor due to high replenishment rates	Not required	Not required	Less than minor
Benthos	Burial & death within disposal footprint	adventive pests may colonise vacant niche	Not applicable	Contribution to local enhancement of harbour water quality / seagrass habitat for example	Minor to moderate, localise short term loss of benthos within disposal areas
Fish and Wildlife	Minor, localised, disturbance and avoidance during disposal activities	Minor, localised, and short-term reduction in available food supplies	Not applicable	Not required	Less than minor outside d disposal footprint

Table 1 continued.

	Actual Effects	Potential Effects	Avoidance Factors	Remediation / Compensation	Final Significance
Changes to Navigation Aids (see Figure 3)					
Water Column Effects	Less than minor because of limited footprint	Less than minor because of limited footprint	Not applicable	Adoption of Best Industry Practices	Less than minor
Effects on Communities	Less than minor because of limited footprint	Less than minor because of limited footprint	Not applicable	Adoption of Best Industry Practices	Less than minor

Table 1 considers the:

- disturbance and removal of bed material from the proposed dredging footprint,
- transport of seabed material between the dredging and disposal areas,
- disposal of dredged material at offshore disposal sites, and
- effects of changes to navigation aids for Alignment Option 4.2.

It is considered that bathymetric changes at dredging and disposal sites will have less than minor effects on current wave climate and water currents (Tonkin & Taylor, 2017B; MetOcean Solutions, 2016B).

Survey and analytical results presented in this AEE provide reassurance that the concentration of metals and potentially toxic organic materials associated with seabed materials that are to be relocated from the access channel to the two nominated disposal sites are not likely to be associated with toxicity issues (Maritime Safety Authority of New Zealand, 1999).

Similarly, a low proportion of silt and organic matter in seabed materials that will be dredged and disposed of is expected to avoid water quality issues in plumes (such as excessive turbidity and dissolved oxygen sags) beyond a reasonable mixing zone down-current of disturbance activities.

Stewart (2017) established a 1:1 correlation between the concentration of suspended solids ($g.m^{-3}$) and turbidity (Nephelometric Turbidity Units [NTU]) when these particular seabed sediments are temporarily suspended in the water column. This permits real time monitoring of potential sedimentation effects (suspended solids concentrations) during proposed disturbance activities using field turbidity meters.

Provided there is no discharge from the Trailing Suction Hopper Dredger when it is in transit between dredging and disposal sites, no ecological effects are expected to be associated with the transport of material between dredging and disposal areas.

Due to the limited footprint and construction methodology involved, the ecological effects of modifying navigation aids for Alignment Option 4.2 are expected to be less than minor.

Therefore, provided adverse sedimentation effects can be confined to the nominated footprint of both dredging and disposal footprints,

- water column effects,
- effects on plankton, fish and wildlife, and
- effects on adjacent coastal habitats (particularly the more sensitive rocky intertidal areas, submerged reefs and ecologically significant banks),

are expected to be localised and minor or less than minor.

Potential sedimentation effects down-current of dredge activities are to be managed by responding to real time turbidity recorders on the boundaries of adjacent habitats.

Provisional turbidity limits / thresholds have been derived / are being developed that require the following responses in terms of concurrent operational controls on dredging / dredged spoil disposal activities.

- Level 1: the reason for elevated suspended solids concentrations down-current of the operational dredge need to be investigated,
- Level 2: operational changes are required by the dredge to reduce down-current suspended solids concentrations, and
- Level 3: suspended solids concentrations down-current of the operational dredge result in dredge activities being stopped.

Best management practices are also proposed to avoid, to the greatest extent practicable, the potential for issues such as hydrocarbon spillages within, and adjacent to disturbed areas. Navigational and environmental risk have been separately assessed (Bilderbeck and Oldham, 2016: Oldham and Bilderbeck, 2017) and it has been concluded there would be benefits of improved navigational safety resulting from the RNZ dredging proposal.

The capital dredging programme would result in the short term (6 to 24 months) displacement / reduction of benthic productivity within a 4.37 km^2 (437 ha) area of seabed (see Figure 2 and Coffey, 2017A). While these soft-bottomed areas include indigenous taxa, they are not of national or regional significance and no benthic taxa within these predominantly sandy sites are considered to be endangered or at risk.

Nevertheless, due to the local and short-term effect of proposed dredging activities on benthic productivity, some form of compensation is considered to be appropriate. Compensation in the form of a contribution to the enhancement of the overall health of the Whangarei seagrass communities within and adjacent to the study area is recommended for consideration (Coffey and Stewart, 2017).

A monitoring programme is recommended to describe the effects of the dredging programme separately from other temporal ecological changes that are occurring within the study area.

The baseline description of pre-impact community structure by Bioresearches, Kerr and Associates and the Cawthron Institute (within and adjacent to areas that would be disturbed by the proposed dredging programme) is considered to be robust in terms of providing a comparison with post impact surveys of the same areas. However, a benchmark description of seagrass and shellfish communities (that are in a current state of flux) requires to be undertaken immediately prior to capital dredging activities.

2.0 General Introduction to the Existing Environment and Existing Values within the Study Area (see Figure 2)

The character of an area of marine coastline is largely determined by latitude and the water currents that flood it.

Notwithstanding direct developers such as marine gastrods and lecithotrophic larvae (e.g. some fish and some benthic invertebrates such as tunicates) most benthic invertebrates have a planktotrophic larval development where larvae join the plankton and are dispersed by water currents. If adequate quality habitat is available downstream of where planktotrophic marine organisms spawn and form offspring, sessile organisms will settle out of the plankton to colonise benthic habitats and pelagic / demersal taxa will form part of the downstream water column community.

Along the north-east coast of New Zealand (from North Cape down to East Cape), the most influential current is the East Auckland Current that introduces a tropical / subtropical element into the marine flora and fauna from the Kermadec and Three Kings Islands.

Commercial fisheries such as crayfish, paua, cockles, pipi, scallops, fin fish and edible seaweeds rely on recruitment from resident populations upstream of a particular locality. This explains much of the resilience of marine communities to overfishing and disturbance events in that once such disturbance factors cease, there is the potential for recruitment via planktonic larvae to recolonise previously compromised habitats.

In contrast to waters south of the subtropical convergence, the East Auckland Current is warmer, more transparent and more saline than subantarctic waters and supports kelp forests to a depth of 30 m on rocky reefs along the eastern coast of Northland.

The setting of the East Auckland Current during summer is associated with a world renowned big game fishery off the Northland coast down to White Island in the Bay of Plenty. The most prized catches include billfish such as marlin.

The East Auckland Current occasionally delivers a range of novel taxa such as sun fish, sea turtles, sea snakes, manta and devil-spined rays to Northland's east coast (Morrison, 2005).

The most informative articles describing the extraordinary marine biodiversity that occurs on the open coast and offshore islands of Northland are arguably that of Morrison (2005) and Andrew and Francis (2003).

2.1 Climate and Exposure

Northland, with its low elevation and close proximity to the sea is characterised by a mild, humid, and rather windy climate. Summers are warm and tend to be humid, while winters are mild, with many parts of the region having only a few light frosts each year. Rainfall is typically plentiful, all-year round, with sporadic very heavy falls. However dry spells do occur, especially during summer and autumn.

Most parts of Northland receive about 2000 hours of sunshine per year. It can be very windy in exposed areas and occasionally Northland experiences gales, sometimes in association with the passage of depressions of tropical origin (Chappell, 2013).

In enclosed waters, such as Whangarei, Kaipara, and Hokianga Harbours, wind generated waves are unlikely to exceed two metres. This is because winds required to generate such waves would need to be either a steady 70 $km.hr^{-1}$ or more (a very rare event in Northland), or would require a longer fetch than the enclosed harbours provide (Chappell, 2013).

On the east coast of Northland, swells from an easterly or north-easterly direction tend to predominate. These can originate from tropical cyclones well to the north of New Zealand or from anticyclones far to the east. Of all swells observed on the eastern coast the frequency of those less than one metre is about 40 percent, while for those greater than two metres is eight percent (Gorman et al., 2003).

Whilst Bream Head and the Hen and Chicken Islands offer some protection to Bream Bay in terms of the wave climate (see Figure 1), the entrance to Whangarei Harbour can be very exposed in occasional south-easterly storms.

In Bream Bay, seawater temperatures vary from 24-25°C in summer and 13-14.5°C in winter (Golder (2010).

2.2 Bathymetry, Water Currents and Seabed / Shoreline Types

Whangarei Harbour is a drowned river valley system that covers some 10,000 ha and includes 5,400 ha of intertidal flats, 1,400 ha of mangroves and 200 ha of saltmarsh (Morrison 2003).

The harbour is connected to Bream Bay via a 2.4 km wide inlet between Marsden Point and Home Point. The main channel extends inland some 24 km in a north-westerly direction and then divides into two arms, the Hātea River in the north and the Mangapai River in the south.

The harbour drains a catchment of 29,507 ha that has been heavily modified, with a large amount of native vegetation cleared for urban use in the north-west and agricultural land use in the east and south.

Water currents within Bream Bay and at the mouth of the harbour have been measured and modelled by MetOcean Solutions (2016B). Relatively low wind speeds, low to moderate wave heights and moderate tidal currents are associated with the confines of the entrance channel. Calm conditions (winds less than 2 $m.s^{-1}$) occur more than 90% of the time and moderate to low wave climate (sea and swell wave heights less than 1 m) occur for more than 90% of the time at the entrance to the channel. Within the mid and inner parts of the channel, wave heights are less than 0.6 m 99% of the time. Peak tidal velocities reach 2.0 to 2.5 knots over the length of the channel (MetOcean Solutions, 2016B).

Bream Bay and Whangarei Harbour tides have a period of 12 hours and 25 minutes, and a mean tidal range of 1.36 m for neap tides to 2.25 m for spring tides (LINZ, 2004, 2010).

Bream Bay is a sand-dominated environment, forming a key part of offshore sand resources present on this coastline that extend southward to Pakiri Beach. Soft shorelines also dominate the southern (right bank shores of the lower harbour and entrance channel (see Figure 4). Calliope and Mair Banks fringe the deep sandy-shell channel in the lower harbour.

The 18 km stretch of coastline along Bream Bay from Marsden Point to the Waipu River Mouth (see Figure 1) is largely comprised of clean exposed beach with up to 5 m high fore dunes accreting and eroding in response to storm events. Bream Bay has a wide (80 m) mid to low tide platform seaward of a relatively narrow (9 m) mid to high tide rise to an upper beach platform at the seaward base of the fore dune (Coffey, 2004).

However, the northern shoreline of Bream Bay (Busby Point to Bream Head) is a predominantly rocky headland that bottoms out onto sand in approximately 10 m water depth, with small sandy beaches in the western sector of the northern shoreline and in Smugglers Bay.

Similarly, the downstream section of Whangarei Harbour and northern (left bank) shoreline of the entrance includes hard shore communities between Busby Head and Home Point, at High and Motukararoro Islands, and on headlands between Darch Point and Home Point.

Moreover, there is an area of foul ground shown on Marine Chart NZ 5219 (Approaches to Marsden Point, LINZ, 2010) inshore of Disposal Area 3.2 (see Figure 2) that is known locally as three-mile reef.

Kerr and Grace (2016D) have logged reference photoquadrats for this area that show it includes a rocky–boulder lined seabed that supports a low-profile reef community that is partially / intermittently covered by sand and shell movement along the seabed.

2.3 Soft Seabed Sediment Quality and Sediment Transport

Basement rock for Whangarei Harbour and catchment area consists of greywacke from the Waipapa Group, which is overlain by sedimentary rocks, andesitic volcanic facies and quaternary sand and mud deposits (Northland Harbour Board 1989). The landform behind Bream Bay is dominated by Quaternary dune sands (Edbrooke and Brook, 2009).

The sand in Bream Bay consists of feldspar (65-70%), quartz (25%), rock fragments (1 -4%), heavy minerals (1-4%), shell (1-2%), and a variable amount of organic material (Christie & Barker 2007) and is generally low in organic carbon (Golder, 2010).

West and Don (2016B) and Tonkin & Taylor (2017B) have described the chemical characteristics and particle size composition of soft seabed sediments within the proposed dredging footprint which were relatively “clean” predominantly medium and fine sands with low silt contents (less than 6%).

Kerr and Grace (2016C) have described soft sediment quality within Disposal Area 1.2. Kerr and Grace (2016B) and the Cawthron Institute (Appendix B) have described soft sediment quality within Disposal Area 3.2.

Black (1983) reported sediment transport occurs in a northerly direction in Bream Bay towards Mair Bank then out of Whangarei Harbour via the main channel.

2.4 Occurrence and Quality of Reef Structures and Hard Shorelines

Within the study area, reef structures and hard shorelines occur along the northern shoreline of Bream Bay (Busby Point to Bream Head). In the downstream section of Whangarei Harbour, hard shore communities also occur between Busby Head and Home Point, at High and

Motukararoro Islands (including the marine reserve), and on headlands between Darch Point and Home Point.

Kerr and Associates (2016A) have described reef structures and hard shoreline communities adjacent to the dredging footprint in the downstream section of Whangarei Harbour.

The high quality of these habitats has been confirmed by Golder (2010), Hay and Grant (2004), Kamo High School (2002), Kerr and Moretti (2012), Kerr and Grace (2006A), Kerr and Grace (2006B), Morrison (2003) and Morrison (2005).

2.5 Water Quality

2.5.1 Introduction and Background

Water quality in Bream Bay and in the Lower Whangarei Harbour (see Figure 5) is generally good, as a result of regular tidal flushing with ocean water (Andries, C., 2010; Beca Planning, 2002; Cornelisen, et. al., 2011; Golder, 2010; Griffiths, R., 2013; MWH, 2009; Northland Regional Council, 2004; Northland Regional Council and Whangarei District Council, 2012; Northland Regional Council, 2012) and supports high habitat quality in the four Marine 1 Management Areas shown in Figure 4.

Figure 5: Water Quality Sampling Sites Monitored by Northland Regional Council (2011).



Tweddle et. al. (2011) have summarised 10 years of monitoring data for 16 sites in Whangarei Harbour (see Figure 5) and MWH (2009) have reported on baseline water quality monitoring sites in the lower Whangarei Harbour and in Bream Bay between 2008 and 2009 (Figure 6).

The MWH (2009) water quality data were sourced from field sampling that was undertaken by Northland Regional Council staff for Whangarei District Council at nine sites in Bream Bay, Whangarei Harbour entrance and Ruakaka River over the period June 2008 to May 2009. Surface water samples were collected on seven occasions, including ebb and flood tides, and dry and wet weather.

Figure 6: Water Quality Sites Monitored by MWH (2009).



Northland's Regional Coastal Plan (Northland Regional Council, 2004) has adopted water quality standards for coastal waters (see Table 2). These standards specify acceptable changes to ambient water quality as a result of a discharge for example and in the lower Whangarei Harbour, a general quality standard CA applies.

In the case of Bream Bay which is a Marine 2 (Conservation) Management Area, general performance standards as listed in section 31.4.13 of the Regional Coastal Plan apply (Northland Regional Council, 2004).

Section 31.4.13 of the Regional Coastal Plan states that discharges to water shall, after reasonable mixing, comply with the relevant receiving water quality standards and shall not contain any contaminants which could cause:

(i) the production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.

(ii) any conspicuous change in the colour or visual clarity of the receiving waters.

(iii) any emission of objectionable odour.

(iv) accumulation of debris on the foreshore or seabed underlying or adjacent to the discharge point.

(v) any significant adverse effects on aquatic life or public health.

The requirements of section 31.4.13(c) of the Regional Coastal Plan closely reflect section 107(1) of the RMA and Policy 4.4.1 of the Northland Regional Policy Statement (Northland Regional Council, 2016B).

Neither the Regional Coastal Plan nor the RMA define an appropriate mixing zone. Instead, this is to be determined having regard to the attributes of a particular location (for instance, currents, tides, bathymetry, and roughness coefficient of the seabed).

Table 2: Coastal water quality standards (Northland Regional Council, 2004).

	Standards for Coastal Waters
Standard	General Quality Standard CA (for lower Whangarei Harbour)
Purpose	Provides for virtually all uses and protection of marine ecosystems
Natural temperature	Not changed by more than 3°C
Natural pH	Not changed by more than 0.2 units
Concentration of dissolved oxygen	Not reduced below 80% saturation
Natural visual clarity	Not reduced more than 20%
Natural hue	Not changed more than 10 Maunsell units
Natural euphotic depth	Water deeper than $0.5.z_{eu}$ not changed more than 10% Water shallower than $0.5.z_{eu}$ maximum reduction in light at sediment bed not more than 20%
Oil/grease film, scum, foam, odour	No conspicuous oil or grease film, scums or foams, floatable or suspended materials, or emissions of objectionable odour
Toxic Metals	
Total Arsenic	50 mg/m^3
Total Cadmium	2 mg/m^3
Total Chromium	50 mg/m^3
Total Copper	5 mg/m^3
Total Lead	5 mg/m^3
Total Zinc	50 mg/m^3
Faecal Coliforms	Based on not fewer than 10 samples for any 30-day period median < 14/100 ml 90%ile < 43/100 ml
Nutrients (Default standards in the absence of specific site investigations)	DRP 1-10 mg/m^3 NO3-N 10-60 mg/m^3 NH4-N <5 mg/m^3
Other toxicants and parameters	As per Table 2.1 of ANZECC Water Quality Guidelines 1992

Here, a reasonable mixing zone within Bream Bay is considered to be in the order of 300m (20 x average water depth), however in proximity to some hard-shore communities (e.g. Home Point) only 100m is available for a mixing zone (Tonkin & Taylor, 2016C).

The same performance standards as Section 31.4.13 of the Regional Coastal Plan for Marine 2 (Conservation) Management Areas, apply to Section 31.7.12 for Marine 5 (Port Facilities) Management Areas in which dredging activities will occur in the lower Harbour.

In terms of the Section 31.4.13(v) of the Regional Coastal Plan and Chapter 19 of the Regional Coastal Plan (Northland Regional Council, 2004), humans are not expected to come into contact with sediment plumes that might be generated by proposed disturbance activities and survey and analytical results presented in this AEE, provide reassurance that seabed materials that are to be relocated from the access channel to the two nominated disposal sites are not contaminated with toxic metals or potentially toxic organic materials (Maritime Safety Authority of New Zealand, 1999).

2.5.1a Harbour Sites

Tweddle et. al. (2011) reported that sites within Whangarei Harbour with the best water quality ("judged according to Coastal Water Quality Standards, Table 2) are located close to the harbour entrance and sites with the worst water quality are located in the Hātea River and the Mangapai River.

Sites near the entrance of the harbour are more heavily influenced by coastal water, while sites in the Hātea and Mangapai Rivers, are more influenced by freshwater input from rivers and streams. By ranking sites based on results from seven parameters, the site with the best water quality was located at Marsden Point and the site with the worst water quality was located in the Waiharohia Canal.

Of the parameters where default trigger values have been developed by ANZECC, the median value was within the recommended guideline for turbidity, dissolved oxygen (%) and enterococci at all sites.

Four sites had a median value that fell outside of the guideline value for faecal coliforms; all 16 sites had a median value outside of the guideline value for dissolved reactive phosphorus; 10 sites had a median that fell outside of the guideline value for total phosphorus; 13 sites had a median value that fell outside of the guideline value for nitrate-nitrite nitrogen; and nine sites had a median value that fell outside of the guideline value for ammonium.

Water temperatures were lower in Blacksmith Creek than One Tree Point, Snake Bank, Marsden Point or Mair Bank. Dissolved Oxygen concentrations were highest and the enterococci numbers were lowest in the harbour entrance.

Nutrients were present at the lowest concentrations at the Harbour entrance but some such as Dissolved Reactive Phosphorus exceeded Table 2 guideline values at all harbour sites.

2.5.1b Bream Bay Sites

MWH (2009) found nutrient levels are higher in winter and become depleted over summer. The principal cause of nutrient depletion is uptake by microalgae (phytoplankton and microphytobenthos), which reach their highest concentration in late winter and spring. Three sources of nutrient replenishment are identified, these being recycling from the seafloor, inputs from deep oceanic upwelling and inputs from terrestrial sources following freshes or floods in the Ruakaka River and other watercourses.

The results of this monitoring programme confirm that the Ruakaka River has a significant influence on the water quality of a large portion of Bream Bay at times of fresh or flood. Other watercourses discharging to upper Whangarei Harbour and Bream Bay will also contribute to changes in Bream Bay water quality in wet conditions.

2.5.2 Suspended Solids, Turbidity and Light Penetration

Water quality data that are of particular interest to this assessment are those relating to water clarity and suspended solids, as these can be potentially affected by dredging activities and the disposal of dredged materials. However, in some instances nutrient release from sedimentary pore waters related to the disturbance of benthic sediments may also be of concern during dredging activities.

Table 3 summarises the turbidity data generated by Tweddle et. al. (2011) for the Whangarei Harbour monitoring sites shown in Figure 5.

Harbour sites (from Tweddle et. al., 2011) that were of particular interest to this study were Marsden Point and Mair Bank which are in the Lower Harbour (see Figure 5).

The ANZECC (2000) default trigger values for turbidity in estuarine and marine environments are 0.5-10 NTU (note this is for south eastern Australia as there are no trigger values established for NZ). None of the sites had median values for turbidity that exceeded 10 NTU (see Table 2). The highest median values for turbidity (lowest water clarity) were found at sites close to freshwater inputs in the Mangapai River and the Hātea River.

Sites with the lowest median turbidity (highest water clarity) were located near the harbour entrance at One Tree Point, Blacksmith's Creek, Marsden Point and Mair Bank, where freshwater inflows are likely to have less influence on water quality. However, it is of interest that turbidity at Snake Bank ranged from 1.0 to 15.3 NTU.

Both turbidity and Secchi depth visibility are measures of water clarity. Table 4 summarises Secchi depth visibility at a number of Whangarei Harbour sites (Tweddle et. al. (2011).

Table 3: Turbidity (NTU) at 16 sites in Whāngārei Harbour, 2000-2010.

Site Name	No. of Samples	Range (NTU)	Median (NTU)	% of samples within guideline value (<10 NTU)
One Tree Point	25	0.5 – 5.7	1.0	100
Blacksmith's Creek	18	1.0 – 3.4	1.0	100
Marsden Point	38	0.4 – 6.6	1.0	100
Mair Bank	39	0.2 – 2.4	1.0	100
Snake Bank	18	1.0 – 15.3	2.1	94
Tamaterau	39	1.0 – 37.0	2.9	92
Town Basin	25	3.4 – 63.0	5.0	92
Onerahi	18	2.5 – 12.4	5.1	89
Lower Port Road	18	3.6 – 11.9	5.4	89
Kaiwaka Point	22	3.4 – 11.7	5.4	91
Kissing Point	50	2.8 – 92.0	5.4	94
Riverside Drive	18	3.4 – 11.1	5.7	94
Waiharohia Canal	18	3.4 – 13.2	6.6	83
Portland	18	4.0 – 18.1	7.4	78
Limeburners Creek	25	4.1 – 67.0	7.9	88
Mangapai	18	4.6 – 15.2	9.3	67

There are currently no ANZECC default trigger values for Secchi depth. A similar spatial trend to turbidity was observed, with the lowest median Secchi depths (lowest water clarity) found in the Hātea River and Mangapai River, and the highest median Secchi depths (highest water clarity) found near the harbour entrance.

Table 4: Secchi depth visibility in Whāngārei Harbour, 2000-2010.

Site Name	No. of Samples	Range (m)	Median (m)	% of samples within guideline value
Marsden Point	37	0.9 – 9.0	4.5	N/A
Blacksmith's Creek	15	1.6 – 6.0	4.0	N/A
Mair Bank	34	1.8 – 7.5	3.85	N/A
One Tree Point	24	2.0 – 6.3	3.8	N/A
Snake Bank	14	1.3 – 7.0	3.65	N/A
Tamaterau	33	0.3 – 4.7	2.4	N/A
Onerahi	17	0.9 – 2.2	1.5	N/A
Kaiwaka Point	18	0.47 – 1.8	1.4	N/A
Lower Port Road	17	0.8 – 1.7	1.3	N/A
Portland	17	0.6 – 2.1	1.3	N/A
Town Basin	18	0.5 – 1.9	1.23	N/A
Kissing Point	47	0.15 – 2.1	1.2	N/A
Waiharohia Canal	17	0.7 – 2.0	1.1	N/A
Riverside Drive	17	0.7 – 1.8	1.0	N/A
Limeburners Creek	21	0.3 – 2.2	1.0	N/A
Mangapai	17	0.2 – 1.5	0.9	N/A

Median Secchi disc values of 3.65 to 4.5 m for One Tree Point, Snake Bank, Blacksmith Creek, Marsden Point and Mair Bank represent good water clarity (>2.0 metres).

Water clarity can be reduced by the growth of phytoplankton and human activities that increase levels of suspended solids entering the coastal environment. High levels of material in the water column can restrict light transmission which affects the amount of photosynthesis (primary production) of aquatic plants and consequently other species that are dependent on them such as fish, zooplankton and shellfish.

Seaweeds and seagrass typically require more light for photosynthesis than phytoplankton and are particularly susceptible to reduced light levels resulting from suspended sediments by nature of being attached to the seabed (Thrush *et al.*, 2004). High concentrations of

suspended sediments can also clog fish gills and reduce the ability of fish to see prey and detect predators (ANZECC, 2000).

MWH (2009) reported turbidity and suspended solids data for the lower Whangarei Harbour and Bream Bay between June 2008 and May 2009. Suspended solids and turbidity levels were elevated in the Ruakaka River (Site 9) but generally low at the harbour entrance and in offshore sites, although some variability was evident at most locations. During the heavy rainfall event of 16 June 2009, high suspended solids concentrations were recorded in the Ruakaka River and in the Bay, offshore and south of the river mouth. On that occasion, on the ebb tide, a clearly visible coloured and turbid plume extended from the river mouth out into the Bay and to the south. That plume would be expected to migrate to the north on the flood tide (MWH, 2009).

There was a poor correlation between turbidity and suspended solids concentrations for this data base (MWH, 2009). However, on the basis of turbidity reaching 23.7 NTU at Site 3 in December 2008, it appears that background levels of turbidity may occasionally exceed the ANZECC guideline of 10 NTU.

Stewart (2017) has analysed back up vibrocore samples from the dredging foortprint (see Section 4.1.1b) and has established there is a 1:1 relationship for Total Suspended Solids ($g.m^{-3}$) and Turbidity (NTU) when these bed materials are suspended in the water column.

This relationship is important for relating plume modelling data (based on suspended solids data) to the ANZECC (2000) default trigger values for turbidity in estuarine and marine environments.

2.5.3 Water Quality at Marsden Point and Mair Bank

Water quality at Marsden Point and Mair Bank between 2000 and 2010 in relation to Northland Coastal Water Quality Standards is summarised in Table 5 (Tweddle et. al., 2011).

Table 5: Water quality at Marsden Point and Mair Bank (Tweddle et. al. (2011) in relation to coastal water quality standards CA (Northland Regional Council, 2004).

Parameter and standard	Marsden Point: Median (range)	Mair Bank: Median (range)
Turbidity <10 NTU	1.0 (0.4 – 6.6)	1.0 (0.2 – 2.45)
Dissolved oxygen >80% saturation	96.8 (80.9 – 137.2)	98.1 (81.2 – 135.5)
Enterococci <140/100mL	5 (1 – 31)	5 (1 – 42)
Faecal Coliforms <14/100ml	1 (1 – 20)	1 (1 – 68)
Total Phosphorus <0.03 mg/L	0.015 (0.005 – 0.03)	0.014 (0.005 – 0.032)
Dissolved Reactive P 0.01 mg/L	0.008 (0.005 – 0.015)	0.007 (0.005 – 0.028)
Nitrate nitrogen <0.015 mg/L	0.015 (0.001 – 0.057)	0.017 (0.001 – 0.050)
Ammonium (<0.015 mg/l)	0.005 (0.005 – 0.36)	0.005 (0.005 – 0.37)

Turbidity records at both Marsden Point and Mair Bank were fully compliant with < 10 Nephelometric Turbidity Units during this sampling period.

Dissolved oxygen saturation was also fully compliant with CA water quality standard of > 80% saturation.

Enterococci counts were all <140 cfu per 100ml, with 98% and 97% compliance with the Faecal Coliform standard of <14 cfu per 100ml for CA water quality.

Marsden Point samples were 100% compliant with the Total Phosphorus threshold of 0.03 milligrams per litre. Mair Bank samples were 87% compliant with the Total Phosphorus threshold of 0.03 milligrams per litre. Dissolved Reactive Phosphorus concentrations at Marsden Point were 65% compliant with a CA water quality standard of 0.01 mg/l compared to 73% of samples at Mair Bank.

Compliance with a CA water quality standard of 0.015 mg/l for Nitrate Nitrogen was 50% for Marsden Point samples and 46% for Mair Bank samples.

Compliance with a CA water quality standard of 0.015 mg/l for Ammonium Nitrogen was 89% for Marsden Point samples and 87% for Mair Bank samples.

2.5.4 Water Quality within Bream Bay

Specific water quality data for Bream Bay was provided by MWH (2009) to support the resource consent application by Whangarei District Council to discharge wastewater from the Ruakaka wastewater treatment plant via an offshore diffuser in Bream Bay. That data showed that freshwater inputs from the Ruakaka River can adversely impact water quality in Bream Bay during wet weather events, but generally the Bay is flushed with highly transparent oceanic water that may during winter and spring, support phytoplankton blooms.

2.6 Marine Community Structure

Golder (2010), Hay and Grant (2004), Kamo High School (2002), Kerr (2016A and 2016B), Kerr and Moretti (2012), Kerr and Grace (2006A, 2006B, 2016C, 2016D and 2016E), Morrison (2003) and West and Don (2015, 2016A and 2016B) have all described the high biodiversity of marine communities in Bream Bay and the Lower Whangarei Harbour.

2.6.1 Plankton

Plankton is a combination of phytoplankton, zooplankton, bacteria and dispersing larvae. Marine phytoplankton around the New Zealand shoreline includes some 620 species of diatom and 230 marine species dinoflagellates.

Phytoplankton provide nearly half of the earth's atmospheric oxygen, they regulate carbon dioxide levels in the water and atmosphere and they are the founding organisms of aquatic food webs.

The distribution and quantity of phytoplankton depends on light penetration, the stability of water layers and the availability of nutrients. Around New Zealand there is usually a spring-time bloom of phytoplankton algae in surface waters. At this time, surface temperatures rise, sunlight hour's increase and nutrients become abundant following winter cooling and the stirring action of storms. Phytoplankton grow and reproduce rapidly, doubling their population each day and sometimes reaching nuisance proportions. Increased growth may raise toxicity levels and deplete the water of oxygen. However, phytoplankton usually exhaust their nutrient supply before this happens. Phytoplankton numbers are generally kept in check by grazing zooplankton.

Zooplankton around the New Zealand shoreline include about 1,000 species of foraminifera and 150 species of radiolarian, but it is the copepods that form the most important link from phytoplankton to other animals in the food chain. Bacteria digest copepod faeces, and by doing so, release nutrients back into the water that help sustain the phytoplankton.

Within Bream Bay coastal waters nutrient levels are higher in winter and become depleted over summer. The principal cause of nutrient depletion is uptake by phytoplankton, which reach their highest concentration in late winter and spring. Three sources of nutrient replenishment are recycling from the seafloor, inputs from deep oceanic upwelling and inputs from terrestrial sources following freshes or floods in the Ruakaka River and other watercourses (MWH, 2009).

There is also ample evidence that extensive algae blooms within the study area might be directly related to oceanic upwelling driven by north-westerly wind stress MWH (2009).

A few phytoplankton species produce powerful toxins. In suitable conditions, they can grow and reproduce in great abundance, creating what is called a toxic bloom. They produce poisons that accumulate in the bodies of filter-feeding shellfish such as oysters, mussels, pipi and cockles. Usually the shellfish remain unaffected, but the fish, shore birds and marine mammals which eat them can be poisoned and die. In humans, they can cause paralysis, respiratory difficulty, memory loss or diarrhoea.

New Zealand has recorded four types of toxin, with at least 34 different species responsible. An extensive toxic algal bloom affected the north-east coast of the North Island during the summer of 1992-1993 and caused food poisoning to a large number of people (>100) who ate shellfish contaminated with the toxins (MacKenzie et al. 1995). The effects of the bloom extended from the Firth of Thames/Coromandel area to at least as far north as Bream Bay and Whangarei Harbour. Following this outbreak, shellfish toxins have been regularly monitored. It is becoming increasingly common for areas of the North Island coast and the Marlborough Sounds to close shellfish gathering during spring and summer.

Whangarei Harbour has a history of such issues which resulted in the Northland Regional Council imposing restrictions on dredging in Whangarei Harbour outside of winter months. The rationale for imposing dredging restriction in the harbour was that dredging during the summer “high risk period”, might lead to the generation of new blooms by re-suspending the resting cysts of the micro-algae that caused the problem in the water column.

Mackenzie (2009) undertook a risk evaluation of dredging and the potential for harmful algal bloom initiation in Whangarei Harbour, and recommended the seasonal restriction on dredging in Whangarei Harbour could be relaxed. The species that caused the 1992 – 1993 event has no known benthic resting cyst in its life cycle and there is nothing to suggest that toxic shellfish blooms will reoccur in the harbour as a result of earlier incidents.

In terms of monitoring marine plankton around the New Zealand coast, the traditional approach of using plankton nets or settling plankton from water samples for counting under an inverted microscope has now largely been replaced by Ocean colour data from the NASA Seaviewing Wide Field-of-view Sensor (SeaWiFS) being used to estimate chlorophyll a concentrations in sea water.

New Zealand northern subtropical and Tasman Sea waters have a classical cycle of spring and autumn chlorophyll blooms consistent with production being co-limited by nitrate and light. Subantarctic waters have a low-magnitude annual cycle of chlorophyll abundance that peaks in early autumn, consistent with production being predominantly limited by a combination of iron and light (Murphy et. al., 2001).

2.6.2 Benthos

These are the bottom-dwelling communities that will be adversely impacted by the dredging, disposal and navigation aid modification / construction activities described in Section 3. Fish, marine mammals and marine birds have the ability to avoid disturbance areas.

In addition to literature surveys (West and Don, 2015A; Coffey 2016B), the source of the novel benthic database generated on behalf of RNZ for this AEE is summarised in Table 6.

West and Don (2016A) described benthos, sediment particle size and sediment chemistry in three candidate disposal areas that have not progressed to the identification of the preferred disposal sites. That information is still useful in terms of describing adjacent soft bottom sites.

West and Don (2016B) have provided a detailed description of the existing marine ecology in the dredging footprint (benthos, sediment particle size and chemistry for surficial sediments). The sampling footprint used by West and Don (2016B) extended beyond the final Option 4.2 dredging footprint, particularly in the outer channel (see Figure 7).

Table 6: Source of ecological data (excluding marine mammals and birds) generated on behalf of RNZ that has been used for this Assessment of Environmental Effects.

		Work Undertaken / reported by:			
		Field Sampling	Benthic ID and Counts	Contaminant Testing	Particle Size Analysis
Dredging Footprint					
	Photoquadrats	West & Don 2016B			
	Grab & Dredge Samples	West & Don 2016B*	West & Don 2016B*	Hill Labs*	WU*
	Vibrocore Samples	Tonkin & Taylor 2016C		Hill Labs (App C)	WU (App C)
Disposal Area 1.2					
	Photoquadrats	Kerr & Grace 2016E			
	Diver Core Samples	Kerr & Grace 2016E**	Cawthron (App A1)	Hill Labs **	WU **
Reference Areas 1.2A and 1.2B					
	Photoquadrats	Kerr & Grace 201CE			
	Diver Core Samples	Kerr & Grace 2016C**	Cawthron (App A1)	Hill Labs**	WU **
Disposal Area 3.2					
	Photoquadrats	Kerr and Grace 2016D			
	Grab Samples	Cawthron	Cawthron (App A2)	Hill Labs (App B)	WU (App B)
Reference Areas 3.2A and 3.2B					
	Photoquadrats	Kerr and Grace 2016C			
	Grab Samples	Cawthron	Cawthron (App A2)	Hill Labs (App B)	WU (App B)
Adjacent Habitats: Soft Bottomed					
	Photoquadrats	Kerr & Ass. 2016A			
		Kerr & Ass. 2016B			
	Photoquadrats	West & Don 2016A			
	Grab & Dredge Samples	Kerr & Ass. 2016A***	Kerr & Ass. 2016A***		WU ***
		Kerr & Ass. 2016B^	Kerr & Ass. 2016B		WU ^
	Grab & Dredge Samples	West & Don 2016A^^	West & Don 2016A	Hill Labs^^	WU ^^
Adjacent Habitats: Hard-Bottomed					
	Photoquadrats	Kerr & Ass. 2016B	Kerr & Ass. 2016B		
		Kerr and Grace 2016D			
	Photoquadrats & Video	West & Don 2016B			

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The habitats adjacent to the dredging footprint were described in two phases. The first phase involved a preliminary qualitative description of 18 transects as shown in Figure 8 (Kerr and Grace 2016A). On the basis of that survey and a consideration of the sensitivity of adjacent habits to potential turbidity / sedimentation effects that could arise from proposed dredging activities, the specific sites shown in Figure 9 were quantitatively surveyed by Kerr and Associates (2016A).

The baseline description of hard bottom sampling sites was done by Kerr and Associates; sediment particle size was carried out by Waikato University and benthos in soft bottom core samples were identified and counted by the Cawthron Institute.

Figure 7: Overlay of Figures 2.2 and 2.3 of West and Don 2016B in relation to the final Dredging Footprint Option 4.2.

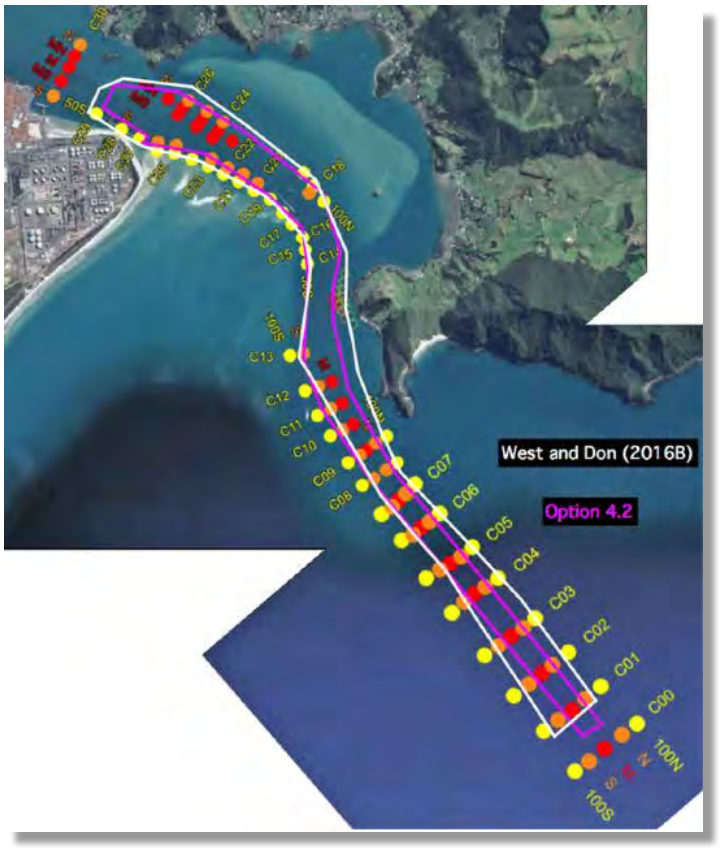


Figure 8: Locality of the 18 transects qualitatively described by Kerr and Grace (2016A) to select specific sampling sites for a baseline description of communities potentially affected by proposed dredging activities.

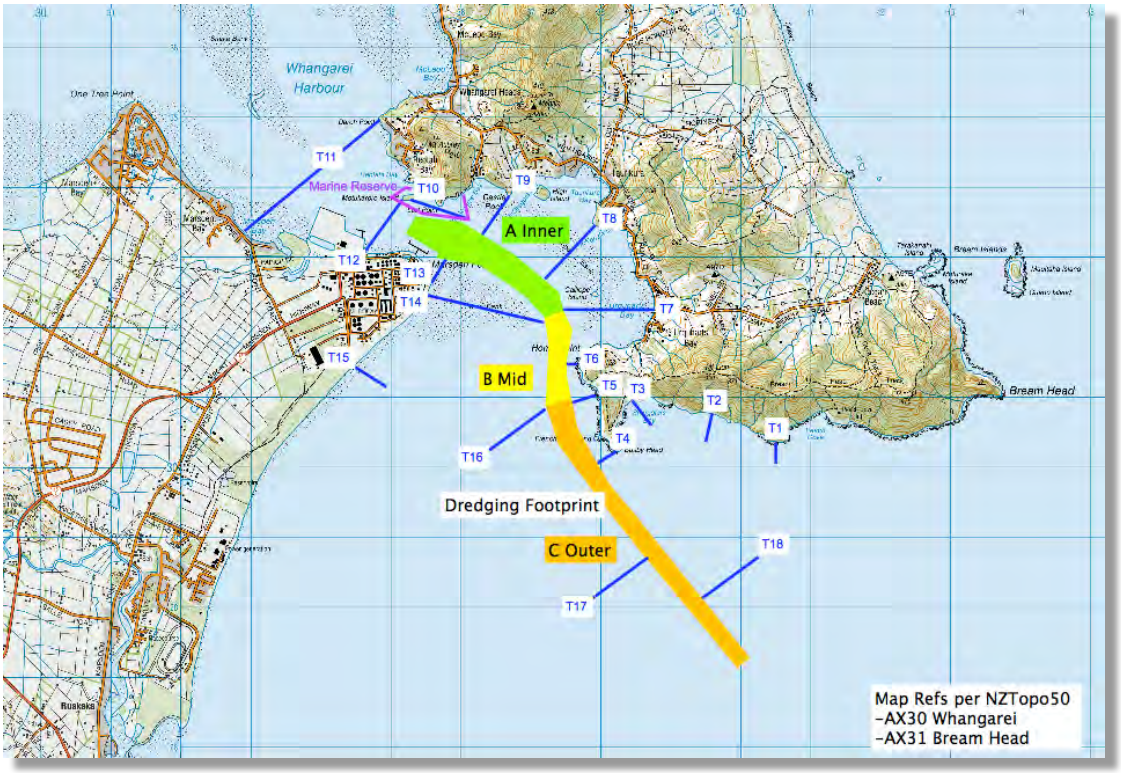
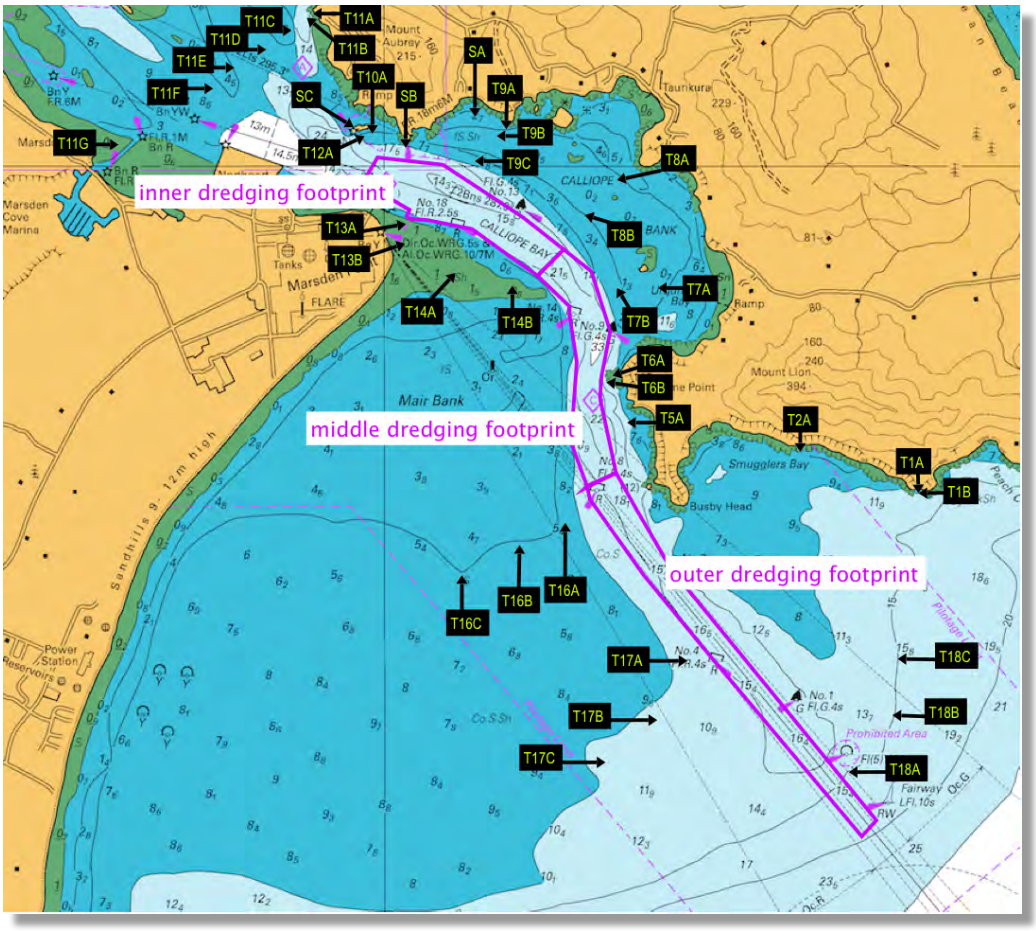


Figure 9: Sampling Localities for a Baseline Description of Habitats Adjacent to the Dredging Footprint that was undertaken by Kerr and Associates 2016A).



West and Don (2016B) also described 15 sites close to Home Point that are outside the dredging footprint.

The description of these foul ground sites now provides a baseline description of hard-bottom sites adjacent to the dredging footprint to complement those hard-bottom sites described by Kerr and Associates (2016A).

Kerr and Associates (2016D) have also provided reference photographs from the foul ground at 3-mile reef as shown in Figure 2.

Hard-bottom sites were non-destructively described with fixed photoquadrats.

Soft bottom communities have been described by a combination of photoquadrats within a particular sampling site (that have recorded surficial sediment texture and epibenthos) and five random sediment samples from which infauna has been sieved, identified and counted.

Where appropriate, additional soft bottom samples have been collected and analysed for sediment particle size and contamination status (see Table 6).

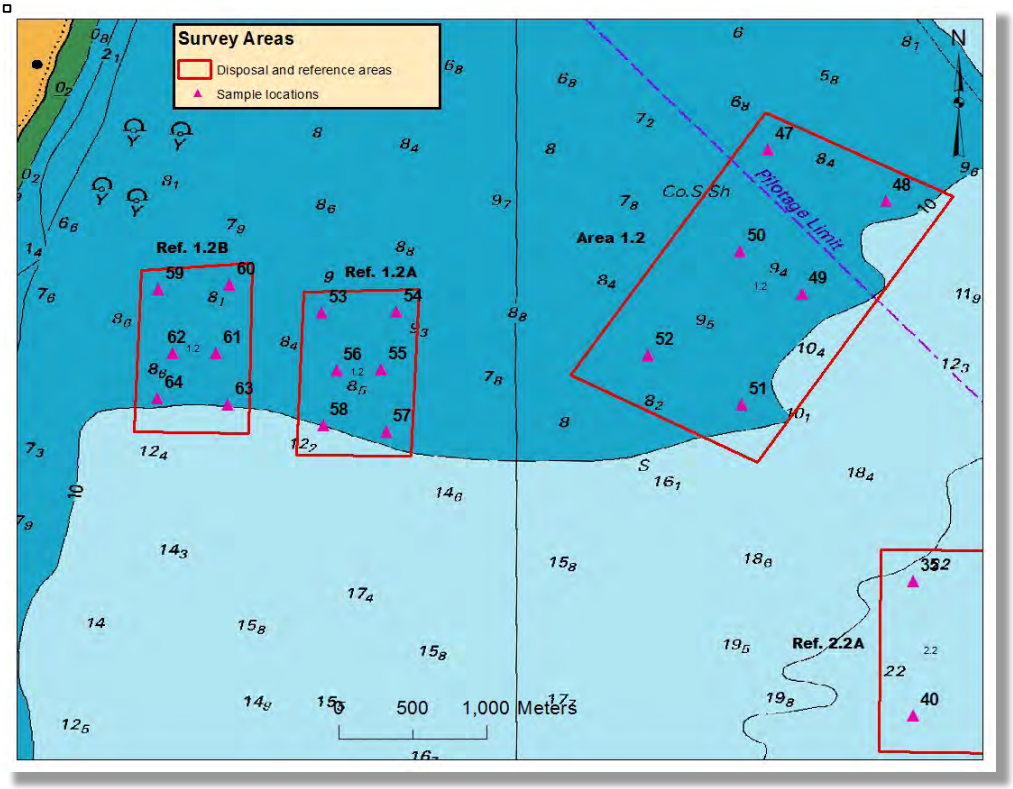
There is a great deal of supporting information, particularly photoquadrat and video records that has been obtained to benchmark baseline community structure and habitat types within the study area. This information is available to interested parties on request from Refining New Zealand.

A soft copy of the videos and photographs will be provided to the Northland Regional Council once the resource consent application for the project is lodged.

The underwater photography that had been produced by Bioresearches and Kerr and Associates is of a very high standard and will be used to monitor the effects of the dredging operation and the disposal of dredged material on hard shorelines where the same specific quadrats can be relocated and re-photographed in a time sequence.

In terms of offshore Disposal Area 1.2 for dredged material, Kerr and Grace (2016E) undertook the sampling for a baseline ecological survey and have reported on sediment particle size analysis and the contamination status of samples submitted to the Cawthron Institute for analysis (see Figure 10).

Figure 10: Sampling Sites 47 to 64 used by Kerr and Grace (2016C) to describe disposal site 1.2 and reference sites 1.2A and 1.2B within Bream Bay (see Figure 2). From Figure 2 of Kerr and Associates (2016C).



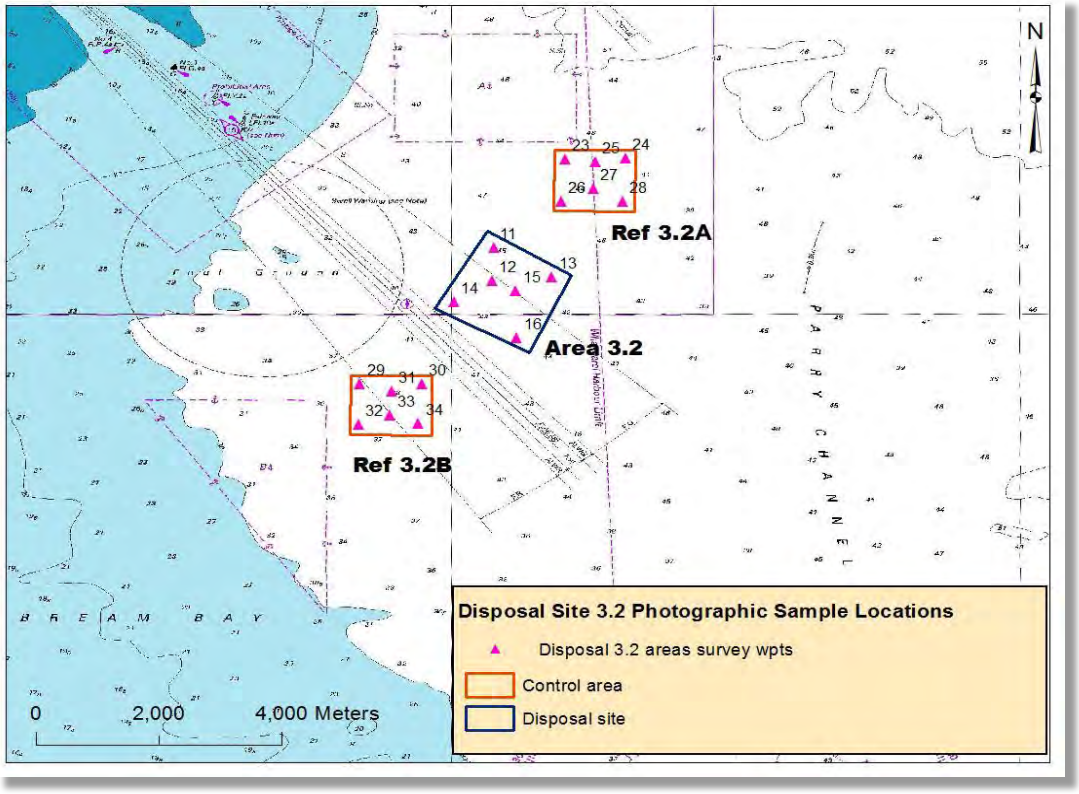
These results of benthic sample analyses (five replicates for each of samples 47 to 64) are attached as Appendix A1.

In terms of Disposal Area 3.2, Kerr and Grace (2016A) undertook a preliminary ecological assessment (sediment particle size and soft-bottom benthos) of the site in January 2016.

The Cawthron Institute then undertook a quantitative survey of Disposal Area 3.2 and Reference Sites 3.2A and 3.2B in early May 2016 (see Figure 11). Data they have provided on sediment particle size and the contamination status of sediments are summarised in Appendix B. Identification and counts of soft bottom benthos at the 18 sites shown in Figure 11 (five replicates per site) are summarised in Appendix A2. A comparison of the two disposal sites and reference sites is provided by Kerr and Associates (2016C).

Both the proposed dredging footprint and the footprint of Disposal Areas 2.1 and 3.2 are soft bottom areas of seabed that support a benthic community that is considered typical of the coastal environment off the north-east coast of the North Island.

Figure 11: Sites 11 to 16 (Area 3.2), 23 to 28 (Ref Area 3.2A) and 29 to 34 (Ref Area 3.2B) sampled by the Cawthron Institute within Bream Bay (see Figure 2). From Figure 2 of Kerr and Associates (2016D).



2.6.2a Open Sandy Beaches in Bream Bay

Crustacea of the open sandy beaches in Bream Bay include the sea-slater (*Scyphax ornatus*), common sandhopper (*Talorchestia quoyana*), isopods of the families Sphaeromidae and Eurydicidae, paddle crab (*Ovalipes catharus*), ghost shrimp (*Callianiassa filholi*) and mantis shrimp (*Squilla sp*.). The tuatua (*Paphies subtriangulata*) is the most common bivalve on this and other east coast beaches. (Kerr 2005).

2.6.2b Sub-Tidal Sand Flats in Bream Bay

Benthic communities through the subtidal sand flats in Bream Bay are generally dominated by sand dollars *(Fellaster zelandica),* the starfish *(Patiriella regularis)*, polychaete worms, hermit crabs *(Pagurus sp.)* flatfish, the morning star shell *(Tawera spissa),* the gastropod *Amalda depressa* and crabs *(Ovalipes catharus and Petrolisthes sp.),* together with *Circomphalus yatei, Dossinia subrosea, Pahies australis, Ostea sp., Sigapatella sp., Austrominius sp. and mysids* (Golder, 2010).

2.6.2c Disposal Area 1.2

Benthos within the shallower Disposal Area 1.2 (see Appendix A1) was dominated by nematodes, urchins (echiniodea), polychaetes (members of the Paraonidae, Syllidae), amphipods (including members of the Haustoridae and Phoxocephalidae), the isopod *Exosphaeroma sp*. and cumacea.

2.6.2d Disposal Area 3.2

Benthos within deeper Disposal Area 3.2 and its reference sites was dominated by nematodes, oligochaetes, polychaetes (the spionid *Spiophanes modestus*, the nereid *Nereididae sp. A*, the onuphid *Onuphis aucklandensis* and members of the Maldanidae, Paraonidae, Syllidae [including *Sphaerosyllis sp*.), amphipods (particularly members of the Phoxocephalidae), bryozoans and ostracods (see Appendix A2).

2.6.2e The Dredging Footprint

The fine sand habitat that was most common within the dredging footprint supported the most diverse benthos that was dominated by smaller biota such as polychaete worms and amphipods (West and Don, 2016B).

A coarse sand habitat that was present both seawards and inshore of Busby Head differed slightly in composition inshore compared to seawards. Seawards of Busby Head the biota was dominated by the bivalve *Tawera spissa* and the primitive chordate, *Epigonichthys hectori*. Inside the harbour mouth the coarse sand habitat was dominated by the community defining bivalve *Venerupis largillierti* and juvenile gastropods (West and Don, 2016B).

The shell gravel habitat had a higher proportion of larger species than the sandy habitats. The species composition was different from the sandy habitats with 36 taxa only found in the shell gravel habitat. The community defining bivalve *Tucetona laticostata* and the primitive chordate, *Epigonichthys hectori* were abundant in the shell gravel seaward of Home Point, but almost absent inside the harbour mouth. Inside the harbour mouth the shell gravel had greater numbers of the bivalves *Corbula zelandica* and *Venerupis largillierti* and juvenile gastropods. (West and Don, 2016A).

West and Don (2016A) concluded that no species of marine invertebrates or marine fish reported as present in the dredge area are listed as “Threatened” or “At Risk” and that the habitats within the proposed dredge area were not considered to be of national significance.

2.6.2f Soft-bottom communities in the lower Whangarei Harbour

Beds of pipi (*Paphies australis*), and cockle (*Austrovenus stutchburyi*) are present on intertidal and adjacent subtidal sandy substrates within the lower harbour and scallops (*Pecten novezealandiae*) are locally common in subtidal channels and in Bream Bay.

However, it is of some concern that benthic communities on Mair Bank have undergone significant recent changes, without a satisfactory explanation of cause and effect (Williams and Hume 2014).

The most recent study commissioned by RNZ is by Pawley (2016) who reported that:

- the bathymetry of Mair Bank appears to have changed since the 2010 and 2014 surveys. Mair Bank is no longer separated from neighbouring Marsden Bank by a channel, and the northern edge now extends further (compared to 2014). This view is supported by Williams and Hume (2014),
- both the total abundance and biomass of pipis have reduced significantly since his 2010 survey. The total population has declined from around 460 million (2010) to around 4.95 million individuals, and the 2016 estimate of absolute biomass, 44.7 t, is around only 1% of the 2010 estimate (4,450 t) and less than 1% of the 2005 estimate (10,542 t).

Between 1986 and 2010, the average commercial landings of pipi from Whangarei Harbour was 176.6 tonnes per annum (Report from the Fisheries Assessment Plenary, May 2014). It is now non-existent (Pawley, 2016). This report did not consider cockle populations.

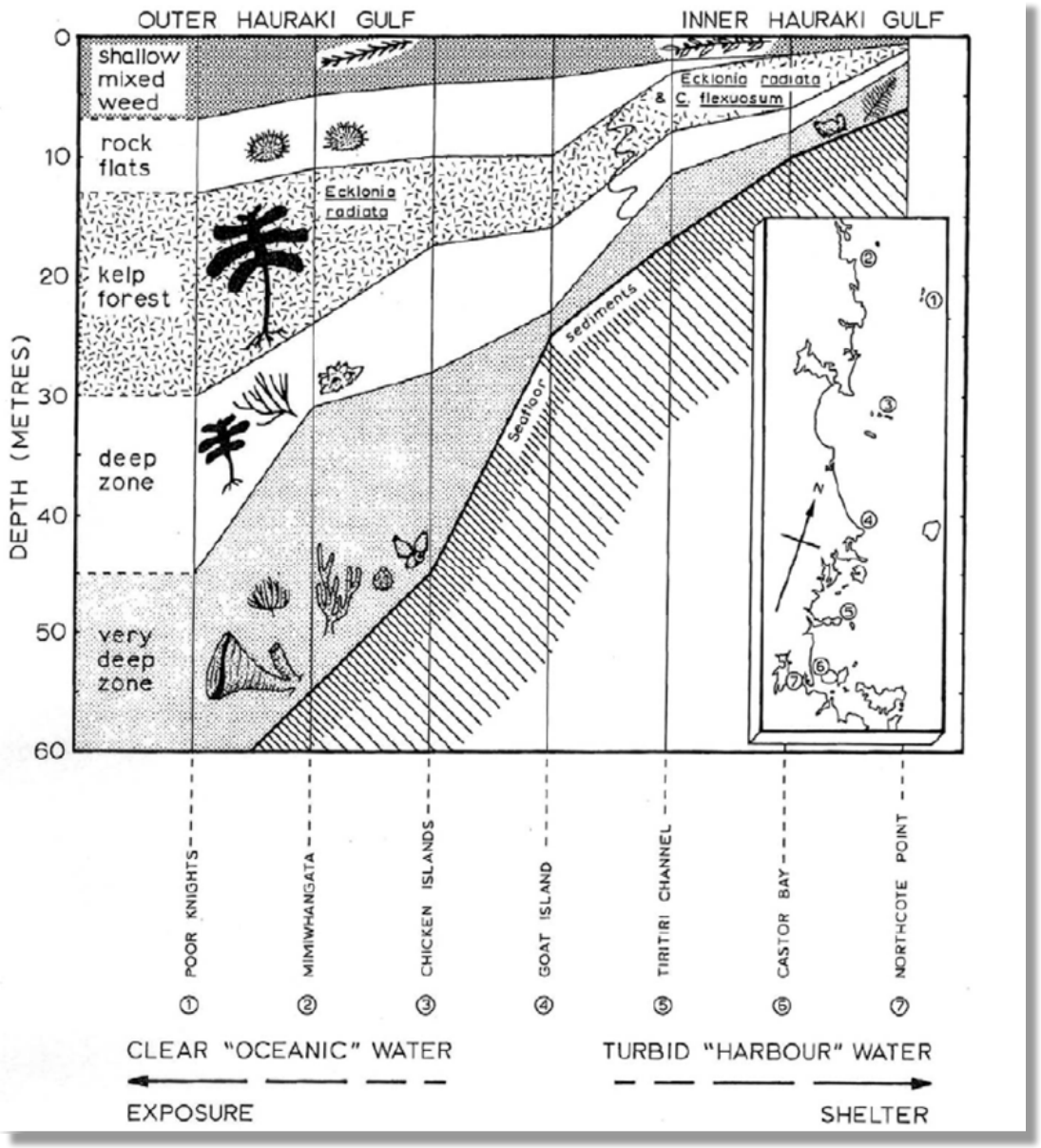
In recent years, an expanding bed of green-lipped mussels (*Perna canaliculus*) has established on Mair Bank (Pawley, 2016 and pers. comm. Riaan Elliot, Refining NZ).

Moreover, seagrass beds at One Tree Point are currently recovering from a former dieback event (NIWA, 2004, 2005), so it is important to benchmark these changes that are not associated with the proposed dredging programme.

2.6.2g Hard-shore habitat and submerged reefs within the study area

The zonation of hard shore communities between Darch Point and Bream Head (see Figure 8) have been characterised by Kerr (2005) and are consistent with generalised zonation of hard shores in the Hauraki Gulf (see Figure 12).

Figure 12: Generalised zonation on hard shores in the Hauraki Gulf (Kerr, 2005).



The sheltered rocky intertidal shore is characterised by zones of barnacles (*Chamaesipho columna*), rock oysters, *Pomatoceros* tubeworms, red algae (*Corallina* sp.) and brown algae Neptune's necklace (*Hormosira banksii*).

A range of mobile and attached invertebrates with adaptations to avoid desiccation (e.g. chitons, crabs and shellfish), remain in the intertidal zone as it is dewatered between high tides, whilst other mobile animals such as fish return to the intertidal zone on a rising tide.

The sublittoral fringe (at and immediately below low tide) consists of large brown algae (notably species of *Carpophyllum* and *Cystophora*) that are typically separated from submerged forests of tall-growing kelp by rock or kina flats.

The kelp forests are dominated by the attached brown alga *Ecklonia radiata*, whose canopy provides shelter for a wide range of fish and mobile / attached invertebrates.

Rock overhangs and caves are common throughout the rocky shore profile and the taxa that colonise these shaded habitats add to the diversity of the zones depicted in Figure 4.

Below the *Ecklonia* forest there are deep and very deep zones dominated by sponge gardens. Throughout the rocky profile a diverse range of fish and mobile and attached invertebrates can be found on and under the cover of seaweeds and within the deep sponge gardens.

Within more turbid harbour waters, kelp forests may only penetrate to a depth of 10 m, whereas on clearer, open coast, they can extend to a depth of 30 metres (see Figure 12).

MacDiarmid et. al., (2013) have nominated sensitive marine benthic habitats in New Zealand that include the kelp beds and sponge gardens featuring in Figure 12.

2.6.3 Fish

(Kerr and Moretti, 2012) report that the six most common fish in the Motukaroro Island, Whangarei Marine Reserve are goatfish (*Upeneichthys lineatus*), jack mackerel (*Trachurus novaezelandiae*), parore (*Girella tricuspidata*), spotty (*Notolabrus celidotus*), sweep (*Scorpis lineolatus*) and snapper (*Pagrus auratus*). This is also likely to be the case for other reefs within the study area.

Others include (Kerr and Moretti, 2012) banded wrasse (*Notolabrus fucicola*), blue maomao (*Scorpis violaceus*), butterfish (*Odax pullus)*, butterfly perch (*Caesioperca lepidoptera*), conger eel (*Conger wilsoni*), demoiselle (*Chromis dispilus*), eagle ray (*Myliobatis tenuicaudatus*), John dory (*Zeus faber*), kahawai (*Arripis trutta*), kelpfish (*Chironemus marmoratus*), kingfish *(Seriola grandis)*, koheru (*Decapterus koheru*), leatherjacket (*Parika scaber*), black pipefish (*Stigmatopora nigra)*, parore (*Girella tricuspidata*), piper (*Hyporhamphus ihi*), red moki (*Cheilodactylus spectabilis*), scarlet wrasse (*Pseudolabrus miles*), short-tail stingray (*Dasyatis brevicaudata*) and silver drummer (*Kyphosus sydneyanus*).

Blue mackerel *(Scomber australasicus)*, yellow-eyed mullet *(Aldrichetta forstefl),* grey mullet *(Mugil cephalus), (Pseudocaranx dentex)*, butterfly perch (*Caesioperca lepidoptera*) and marblefish (*Aplodactylus arctidens*) are also caught along the coast and within the Whangarei Harbour (Fisher & Bradford 1998, Mason & Ritchie 1979).

A number of subtropical species present at the Hen and Chickens Islands also occur around Bream Head (the nearest mainland point), such as half-banded perch (*Hypoplectodes* sp.), single-spot demoiselle (*Chromis hypsilepis*), red pigfish (*Bodianus unimaculatus*) and *Coris sandageri*, the Sandager's wrasse (per. obs).

Flounder are known to be in Whangarei Harbour (pers. obs.) and eels and whitebait migrate through the harbour to freshwater streams.

Northland Regional Council has recently sponsored a "fish ladder"' in a culvert under Whangarei's Western Hills bypass to enable native fish access to the Kirikiri Stream from Whangarei Harbour for example (Scoop Regional Independent News, 25 August, 2015).

It is expected that pelagic fish in general (but not shellfish) have the ability to avoid potential disturbance activities that are described in Section 3. However, epibenthic taxa such as flounder and goatfish maybe more likely to be smothered by dredged material being placed at the nominated disposal sites.

2.6.4 Marine Birds

Marine Birds have been described by Don (2015 and 2016) and a separate avifauna report is to accompany the resource consent application that is lodged by Refining NZ. As a consequence, marine birds are not addressed further in this report.

2.6.5 Marine Mammals

The impacts of marine dredging activities on marine mammals have recently been reviewed by Todd et. al. (2014) and are the subject of a stand-alone report by Clement and Elvines (2016).

Therefore, marine mammals will not be considered further in this report.

2.6.6 Noise

Pine and Styles (2015) and Styles (2017) have provided a separate airborne and underwater acoustic assessment for the Whangarei Harbour Entrance and Marsden Point.

Therefore, noise and the effects of noise on wildlife will not be considered in this report.

2.7 Recreational and Commercial Harvesting of Marine Resources

The Bream Bay coastline (Northland Regional Council, 2004) is an important commercial and recreational fishing / diving area, with the main target species including kahawai (*Arripis trutta*), kingfish (*Seriola grandis*), snapper (*Pagrus auratus),* lobsters (*Jasus edwardsii* and *J. verreauxi*) and scallops (*Pecten novaezelandiae*).

Other shellfish are also harvested along the Bream Bay coastline (MWH, 2009), in estuaries and within Whangarei Harbour. These populations include cockles, pipis, tuatua, paua and various oyster species. However, as noted in in Section 2.6.2.f, in terms of commercial shellfish harvesting, the pipi resource at Mair bank has been depleted in recent years and was effectively non-existent as of 2016 (Pawley, 2016).

Reference to Greenaway (2015 – Section 4.2) shows the access channel and the major disposal area for dredged spoil are within an area of high recreational boat usage area in Bream Bay and Whangarei Harbour.

Recreational matters are being addressed by Rob Greenaway and will not be considered further in this report.

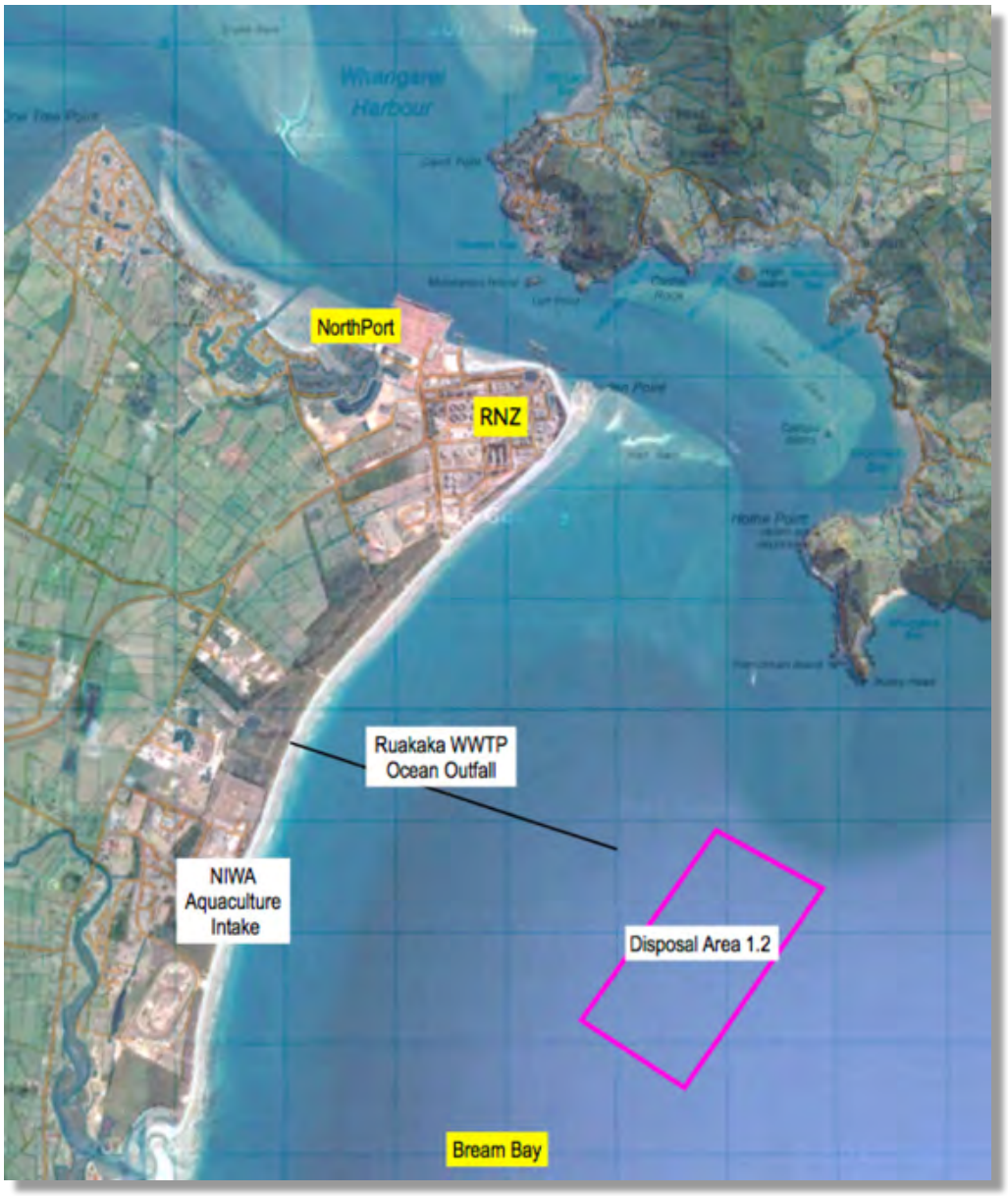
Commercial fishing is to be addressed by Rick Boyd and will also not be considered further in this report.

2.8 Other Uses, Discharges and Disturbance Activities

There are a number of other uses, discharges and disturbance activities within the Study Area that are not associated with the proposed RNZ dredging activities.

It is important that the effects of the RNZ dredging programme are described separately from the effects of the following existing and / or proposed uses of the area (see Figure 13).

Figure 13: Locality Diagram for other uses, discharges/disturbance activities in the Study Area.



In addition, the potential for cumulative effects to arise as a result of activities by any of these third parties occurring in conjunction with the proposed RNZ dredging have been considered.

2.8.1: Northport Limited

The adjacent deep-water cargo port facility at Northport (see Figure 13) is also associated with large vessel movements, stormwater discharges and consent provisions for maintenance dredging activities.

The principal cargos that are handled at Northport are *Pinus radiata* logs, wood chips, phosphate rock, cement clinker and packaged cargos.

Sweeny (2015) reported that, with the exception of two out of seven occasions during 2014 and 2015 when total suspended solids exceeded 50 $g.m^{-3}$, and an unexpected spike in aluminium concentrations in the stormwater discharge from Northport to the lower Whangarei Harbour, all conditions of consent were currently being met. This was supported by a

Stormwater Discharge Review for Northport Ltd by Poynter and Kane (2015) that was attached as Appendix V to the Northport stormwater monitoring report for 2014 / 2015.

There are also maintenance dredging provisions for the Northport deep water cargo port to maintain a working depth of 14.5 m for the facility (Coastal Permit No. 2).

During pre-lodgement consultation undertaken by RNZ, concerns were raised regarding potential tannin and resin acid discharges to the harbour from the Northport Stormwater treatment system (sourced from open storage areas for logs and wood chips). It was suggested that if these materials had accumulated in the seabed that would be disturbed by the proposed RNZ dredging programme, there was the potential for them to be remobilised in the water column as a result of dredging activities.

Resin acids and tannins are compounds which occur naturally in wood. These materials, on release to aquatic environments, have been reported to cause toxicity in some biota. Most toxicity has been reported in relation to freshwater fish and resin acids, and is best documented for salmonid species (e.g. *Salmo gairdneri* and *Oncorhynchus mykiss*) in lakes and rivers.

Poynter and Kane (2015) have provided a review on this matter for the 2014 / 2015 stormwater monitoring report for Northport Limited (Sweeny, 2015). Poynter and Kane (2015) report resin acids have not been measured in the port stormwater discharge. However, pond influent total resin acids have been measured and concentrations are low. For example, 0.19 $g.m^{-3}$ Total Resin Acids were present in a pond influent sample collected on 15/12/2014.

There is no ANZECC 2000 threshold for resin acids and no "*Action Value*" for total resin acids, therefore the pond influent sampling was undertaken only for trend analysis purposes.

Poynter and Kane (2015) considered concentrations of resin acids would be reduced to trace levels very quickly in close proximity to the Northport stormwater discharge and that resin acid toxicity is not considered to pose environmental concern for the Northport stormwater discharge. Poynter and Kane (2015) included a summary of a literature review they had undertaken on resin acid toxicity as Appendix E to their report to support their views.

Given these findings, resin acids and tannins were not analysed for in sediments to be disturbed by the proposed dredging programme and are not discussed further within this report.

Northport hold resource consents enabling the future extension of their facilities to include a new Berth 4 [NRC, 2004]. Whilst there is no indication as to when these extant consents may be implemented, the potential cumulative effects of further wharf extensions in conjunction with the Refining NZ dredging programme have been considered. From an ecological perspective, the key effect would be turbidity and sedimentation, particularly with regard to those more sensitive receiving environments, being the rocky reef habitats. Discharge limits conditions placed on the Northport resource consents, together with the proposed real-time monitoring, and response mechanisms, applying to the Refining NZ dredging proposal, are considered to be adequate to avoid, remedy or mitigate potentially adverse cumulative effects that could occur.

2.8.2: The Ruakaka Wastewater Treatment Plant (WWTP) Ocean Outfall.

An ocean outfall has been consented for the Ruakaka WWTP but it has yet to be constructed / commissioned (see Figure 13, and MWH, 2009). It was prudent therefore, to locate Disposal Area 1.2 at a non-interactive (0.5 km) distance from the planned diffuser for this outfall. This was done during revised phases of the project (Tonkin & Taylor, 2016B).

Accordingly, due to this separation distance, cumulative effects are unlikely to occur. Further, the Ruakaka WWTP is expected to result in different contaminants to the Refining NZ disposal operations, the latter expected to have only short-term effect on sedimentation.

2.8.3: NIWA Aquaculture Facility

A seawater supply and discharge is required at the NIWA Aquaculture Centre at the former Marsden B Power Station Site.

This facility is located to the south west of the Ruakaka WWTP and so is considered to be at a non-interactive distance (c. 3 km) from the proposed RNZ dredging and disposal site 1.2 for dredged material and is not considered further in this report.

2.9 Marine Sites of Special Scientific or Conservation Value

The Northland Regional Coastal Plan recognises four marine sites of special scientific or conservation value within and / adjacent to the Study Area (see Figure 3).

The first is the Motukaroro Island Whangarei Marine Reserve (established under the Marine Reserves Act 1971). This area is also zoned as the Reotahi[4] Marine 1 Management Area in the Regional Coastal Plan. The area was established as the Whangarei Marine Reserve for the purpose of preserving it in its natural state as the habitat of marine life for scientific study. The Reotahi Marine 1 Management Area zoning recognises the following values: protected areas, birds, ecosystems, habitat values. Marine reserve habitat features include high species diversity including subtropical species.

Two other areas (Calliope and Mair Bank Marine 1 Management Areas) are zoned in the Regional Coastal Plan on the basis of the following values: protected areas, ecosystems, birds, habitats, coastal landforms. The Plan records that inter-tidal areas provide internationally significant habitat for international migratory and NZ endemic wading and wetland birds, including threatened species.

The fourth area, (Busby Head) Marine 1 Management Area is zoned under the Regional Coastal Plan on the basis of the following values: protected areas, ecosystems, habitats. The Plan specifically records that rocky shore internationally significant habitat for NZ endemic wading and coastal birds, including threatened species.

The Marine 1 (Protection) Management Area is applied to those areas within Northland's coastal marine area identified as being Areas of Important Conservation Value. The priority in these areas is the protection of those significant described values specifically identified as occurring within each particular area**.**

The Calliope Bank, Mair Bank and Busby Head Marine 1 Management Areas are considered to be of regional significance. The Motukaroro Island Whangarei Marine Reserve is considered to be of national significance because it forms part of a national network of marine protected areas that have been created for scientific study.

Northland Regional Council has recently released its draft Northland Regional Plan (Northland Regional Council, 2016A). While the rules in the draft plan do not currently have legal effect, the three Marine 1 Management Areas of the northern side of the access channel would no longer be separate but would be part of a continuous “Significant Ecological Area” on the northern side of the harbour entrance and the Mair Bank Marine 1 Management Area on the south side of the heads would be enlarged (see Figure 14).

It is agreed that Castle Rock, High Island and other rocky points between Reotahi Bay and Busby Point should appropriately be included as significant ecological areas and that the northern shoreline of Bream Bay from Busby Point to Bream Head would quality for a similar status.

[4] Boundaries coincide with the Motukaroro Island Marine Reserve, as indicated in the Regional Coastal Plan Maps, map sheets A3, B25, C13.

Figure 14. Significant Ecological Area overlay proposed in the draft Northland Regional Plan at the entrance to Whangarei Harbour (compare and contrast with Figure 4).



"Significant Bird Areas" are part of a more extensive overlay area than Significant Marine Ecological Areas and include the sandy shoreline of Bream Bay (see Don, undated).

However, given the current ecological condition of Mair Bank where there has been a significant, recent population decrease for pipi and a recent proliferation of green-lipped mussels (Pawley, 2014; Pawley, 2016) without a satisfactory explanation of why such changes are occurring (Williams and Hume 2014), it is more difficult to justify an expansion of the Mair Bank site in terms of current ecological values.

These areas of elevated ecological significance can be grouped into two headings for the purposes of the NZ Coastal Policy Statement (Department of Conservation, 2010) ('NZCPS').

- First, are those areas falling within Policy 11(a) of the NZCPS, being: the marine reserve, kelp beds, and sponge gardens associated with the rocky reef habitats extending roughly from Motukaroro Island to Busby Point. These areas contain nationally significant examples of indigenous community types.
- Second are the remaining coastal areas which fall within Policy 11(b) of the NZCPS, including the channel, disposal areas, Calliope and Mair Banks, and Three Mile Reef.

In accordance with the NZCPS, within the areas covered by Policy 11(a) it is necessary to avoid all adverse effects of activities.

Within the areas covered by Policy 11(b) of the NZCPS, the requirement is to avoid significant effects, and to avoid, remedy or mitigate other effects of activities.

3.0 Description of Proposed Disturbance Activities

3.1 Introduction and Background

The Marsden Point Oil Refinery is located at Marsden Point and is the only oil refinery in New Zealand, making the refinery one of New Zealand's nationally strategic infrastructural assets. The oil refinery's location was chosen due to the deep water at Marsden Point, low risk of earthquakes, flat topography of the site and close proximity to large residential populations in the North Island (MWH, 2009).

Construction started in 1962, and the refinery was opened in 1964. An expansion between 1979 and 1981 included the installation of a hydrocracker and a 170-km long pipeline to Wiri in South Auckland. In 2005, the refinery undertook another expansion to allow for the de-sulphurising of diesel and removing of benzene from petrol to occur on site.

Another expansion of the refinery in 2009 increased the refinery's capacity by 15%, which equates to approximately 135,000 barrels per day or some 80% of all fuel products in New Zealand (MWH, 2009). A \$365 $x10^6$ CCR project to produce petrol at the plant has also been completed recently (McNeill, 2016).

Current deep-water access to Marsden Point from Bream Bay is via a natural tidal inlet that varies in depth from 15 to 32 metres (see Figure 2). This is adequate for vessels visiting the Northport log berth that requires 14.5 m clearance, and for smaller "Aframax" vessels visiting the refinery, but not for fully loaded "Suezmax" oil tankers that require a 16.6 m clearance.

Therefore, crude oil supply to the refinery is currently delivered by smaller fully-loaded "Aframax" ships and larger partially-loaded "Suezmax" ships.

Royal HaskoningDHV (2016C) and Tonkin & Taylor (2017A) have evaluated alternatives to dredging (primarily ship-to-ship transfer, and a single buoy mooring system), and a range of access channel alignments but only the preferred access footprint (Option 4.2) is considered and described in this report. The preferred dredging footprint (Option 4.2) avoids rock / boulder outcrops on the western side of Home Point that were evaluated by West and Don (2016A), so dredging activities would be restricted to soft-bottom communities that have been described by West and Don (2016A). Similarly, a range of disposal location options have been considered and evaluated (MetOcean Solutions, 2016B; Tonkin & Taylor, 2017A; West and Don, 2016B and Kerr and Grace, 2016E). Following refinement through the process of scoping the proposal, only the preferred options (Disposal Areas 1.2 and 3.2) are considered and described in this report (see Figure 2).

The anticipated capital dredge volume is a total of 3,638,000 m^3 (Royal HaskoningDHV, 2016C). This can be broken down into 610,000 m^3 (from the inner channel alignment), 57,000 m^3 (from the mid channel alignment) and 2,971,000 m^3 (from the outer channel alignment). The area or footprint of direct disturbance within the entrance channel (see Figures 2 and 4) involves a total area of 1.62 square kilometres. Up to 97.5% of capital dredgings would be disposed of in disposal area 3.2 (see Figure 2 and Tonkin % Taylor 2017A).

The average annual rate of sedimentation in the dredged footprint is assessed to be between 56,000 to 122,000 m^3 per annum (i.e. up to 4% of the capital dredge volume) with the main areas of focus expected to be the berth pocket and the outer section (Tonkin & Taylor, 2017A). Maintenance dredging may need to occur every 2 to 5 years in the berth pocket area and in targeted areas of the inner and mid channel to maintain navigable draft around the jetty dolphins. Assuming uniform distribution of sedimentation within the outer section, the 0.5 m sedimentation allowance could be reached within 5 to 20 years requiring a maintenance dredging campaign in this area (Tonkin & Taylor, 2017A).

Maintenance dredgings may be disposed of on land or in either of disposal areas 1.2 and / or 3.2 (Tonkin & Taylor 2017B). Tonkin and Taylor (2017A) consider the capital dredging programme is likely to last up to six months with maintenance dredging involving smaller vessels and a shorter time frame.

3.2 Dredge Type and Management

The dredge methodology is described in detail in the reports prepared by Tonkin & Taylor (2017C) and Royal HaskoningDHV (2016B) as part of this application. A brief summary is provided here.

Dredgers are generally hydraulic or mechanical. A hydraulic dredger delivers dredged material to the discharge site or to temporary storage (e.g. a hopper) in the form of a slurry (e.g. Trailing Suction Hopper Dredgers [TSHD] and Cutter Suction Dredgers [CSD]).

Trailing suction hopper dredgers are self-propelled ships with hoppers (dredged material storage internal to the hull). They have articulated dredging pipes, or "drag-arms", that extend to the sea bottom. They dredge at low speeds while underway. The drag-head can be either passive or active. No additional power is applied to a passive head and material to be excavated is scoured by hydraulic flow induced by the suction at the drag-head. An active drag-head uses power to drive cutting teeth or high-pressure water jets to excavate the material and to aid in forming a solid/water slurry.

Cutter Suction Dredgers are stationary hydraulic dredgers that use centrifugal pumps to produce the flow required to mobilise and transport dredged material.

A mechanical dredger collects dredged material in a bucket or grab and then places it directly into the discharge site or into a temporary storage device for transport to a discharge site. Alternatively, the temporary storage device can remain on site and the dredged material is re-handled (e.g. pumped through a pipeline or transported away using a truck or a barge). An example of a mechanical dredger is a Backhoe Dredger (BHD).

A Backhoe Dredger is generally an excavator mounted on a dredging pontoon and is suitable for dredging soils made of an unconsolidated, heterogeneous mixture of clay, sand, pebbles, cobble and boulders. They can also handle fragmented or soft rock. To ensure stability and counter the large digging forces of the BHD, the pontoon is anchored and its position maintained by spud poles.

A dredging operation involves four phases: excavation, lifting, transportation and placement.

- Excavation is the physical removal of sediment from the seabed and can be done using hydraulic forces and/or mechanical forces.
- Lifting is the vertical transport of the dredged material from the seabed to the water surface and can be achieved using hydraulic or mechanical means.
- Transportation is the process of transferring the dredged material from the excavation site to the placement site.
- Placement of the dredged material at a designated site involves disposal of dredged material at an underwater or onshore location.

There are also a range of ancillary vessels that are required to support a dredging operation. These include:

- survey vessels to complete hydrographic survey of the dredged areas. These are typically small craft (around 9 to 11 m in length) and will be present within the vicinity of the project area (channel and disposal areas) for the project duration,
- a crew boat for the transfer of project staff between the dredger and shore. This typically is a small launch 8 to 15 m in length averaging 4 trips per day, and
- a tug for towing the bottom dump barge to the disposal location that could make two trips per day.

All support vessels will generally sail within the shipping channel, but due to the shallower draft of these vessels they can go outside the channel if shipping traffic is present.

Royal HaskoningDHV (2016B) conclude preferred dredging methodology is to use a TSHD for mid and outer dredging footprint and a BHD for the berth pocket (inner dredging footprint).

With regard to the capital dredging programme, Tonkin and Taylor (2017A) advise as follows:

- The TSHD dredging operation would be up to 24 hours per day, seven days per week whereas the BHD dredging operation within the berthing area would only occur during daylight hours, seven days per week, subject to any noise restrictions.
- The majority of capital dredging (up to 97.5%) could be placed within Disposal Area 3-2. The area of placement is 2.5 km^2 with a maximum area of 5.75 km^2 defining the outer boundary of where placed sediment may settle. This area is situated around 45 m below Chart Datum to the south east of the channel. Disposal Area 3.2 has been sized to enable all capital and maintenance dredging to be placed within the area for the maximum duration of the consent period allowed (35 years). The average height of the placement mound after the capital dredging campaign would be 1.5 m with a maximum height of less than 2.5 m. The average height after 35 years assuming the majority of maintenance dredging is placed in this area would be less than 4 metres.
- Some sediment (2.5 to 5%) will be placed in the nearshore Area 1-2, a 2.5 km^2 area of seabed situated on the southern end of the ebb tidal delta in water depth of between 7 and 15 m Chart Datum. Disposal Area 1.2 is designed to enable placed sediment to be slowly transported landward during higher energy wave events to maintain sediment volumes on the ebb delta. It is also sufficiently large to enable different locations to be targeted for the placement of maintenance dredging. If the dredged sediment is placed uniformly in this area the average depth would be around 0.06 m. However, it is more likely that there would be a smaller area targeted within this larger area during each campaign, with average placement depths of around 0.6 m (i.e. covering an area of around or 10% of the total placement area).
- Both marine disposal areas comprise sand of a similar composition to the channel area to be dredged.
- Land based locations may also be used to dispose of some of the capital dredging although this will only be undertaken where there is a demand by others, and they have the necessary environmental authorisations (including resource consents) in place to enable the use. Given that any land-based options will be authorised via other processes, they are not considered further in this report.
- When the TSHD reaches the marine disposal area it reduces speed and manoeuvres itself via GPS to the allocated area where the load can be discharged. When the vessel is at the correct location the dredge-master opens the bottom doors and the sediment drops out of the hopper.
- The BHD is likely to be required for dredging around the berthing area and is not expected to be used for the main dredging activity. The dredged material would either be placed in a barge for marine disposal or transported for land based disposal.

4.0 Assessment of Environmental Effects of Proposed Disturbance Activities

4.1 Area affected by capital dredging and disposal

The capital dredging programme proposed would displace benthos from 1.62 km^2 of seabed within the entrance channel and the disposal of dredged spoil would bury benthos in 2.5 km^2 of Disposal Area 3.2. (Tonkin & Taylor, 2017A). In terms of disposal area 1.2, only 10% of the area (0.25 km^2) is expected to be used for capital dredging, hence benthos will be displaced from a total area of 4.37 km^2 of seabed as a result of the capital dredging programme.

4.1.1 Prediction of Seabed Effects

4.1.1a Bathymetry and Topography

Tonkin and Taylor (2017A) illustrate the change in bathymetry for the dredging footprint as a result of capital dredging in their Figure 2-1 (Channel design depths for Option 4-2, 98% access channel - Source: RHDHV, 2016B).

Tonkin and Taylor (2016D) expect the peak depth within Disposal Area 3.2 to reduce by up to 4 m (10% of existing) as a result of the disposal of dredged material at that site. On average, the expected mound height (and therefore depth reduction) in Area 3.2 would be 1.5 metres.

MetOcean Solutions (2016B) expect a less than minor difference in tides, currents or wave heights as a result of this change and in the medium to long term the mound will be expected to reduce (depending on the volume and frequency at which additional maintenance dredgings are added to the site).

The specific detail of the size and shape of mounds of dredged material is currently intended to be left to detailed design and tendering. In any event, post placement effects of the sorting of dredged materials placed within Disposal Areas 1.2 and 3.2 (due to water currents generated by wind and wave action) are not expected to interfere with the rate or succession of benthic taxa that recolonise these disturbed areas.

As a consequence, the changes to the bathymetry and topography are not expected to cause any adverse effects on the marine ecology adjacent to the disturbed areas.

4.1.1b Sediment Texture and Contaminants

Surficial sediment texture and heavy metal content were sampled and described in all three proposed disturbance areas and four reference sites (West and Don, 2016B; Appendix B, Kerr and Grace 2016B, Kerr and Grace, 2016C – see Figure 2).

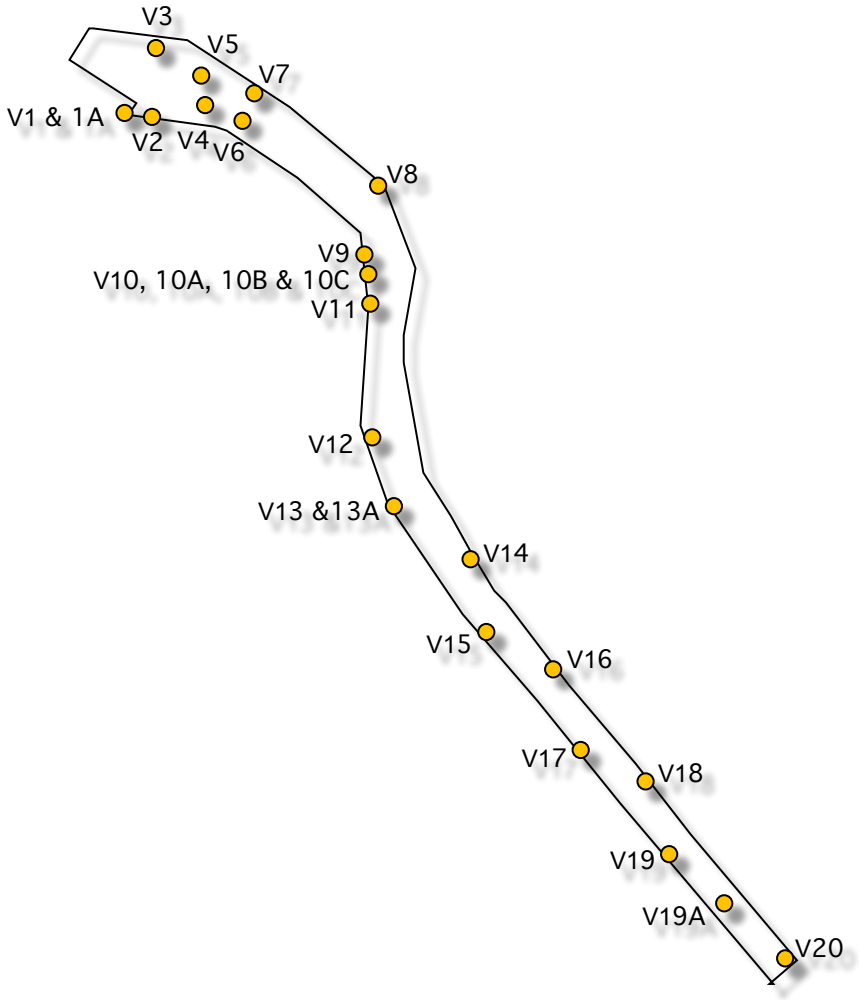
West and Don, 2016B also analysed surficial sediment samples from the dredging footprint for a comprehensive suite of organic materials (antifouling cobiocides, haloethers in SVOC, nitrogen containing compounds in SVOC, organochlorine pesticides in SVOC, other compounds in SVOC, other halogenated compounds in SVOC, phenols in SVOC, plasticisers in SVOC, polycyclic aromatic hydrocarbons in SVOC and total hydrocarbons).

Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel and Zinc were used as proxys or “indicators” for potential contamination of soft-bottom seabed sediments that would be disturbed by the disposal of dredged materials at disposal sites 1.2 and 3.2.

In a separate sampling exercise, Tonkin and Taylor (2017A) collected and analysed 26 depth-integrated vibrocores from the dredging footprint to describe sediment texture and contamination status through the profile of materials that would be dredged (see Figure 15).

Tonkin and Taylor (2017A) have considered sediment particle size distribution at the three disturbance areas and concluded “*Both marine disposal areas comprise sand sediments of a similar composition to the area to be dredged*” and hence the traditional objective of placing “like on like” would be achieved with the proposed dredging and relocation of dredged material.

Figure 15: Location of Vibrocore samples in relation to Dredging Footprint Option 4.2 (see Figure 3).



West and Don (2016B) concluded "*sediment chemistry and particle size were assessed at all sites to ascertain the risk associated with the disturbance of this material during dredging. The chemistry results were compared against the ANZECC interim sediment quality guidelines (where available). None of the surface sediment samples exceeded the ANZECC ISQG Low values with the exception of Fluoranthene, Phenanthrene and Pyrene at site C26S. This minor exceedance at one site suggests that no adverse effects are expected to occur from the redistribution of sediments during dredging or from the disposal of the dredge spoil at a nearby marine disposal site*".

Sampling site C26S is immediately south of the Option 4.2 dredging footprint (see Figure 7) but it is reasonable to assume that whilst Fluoranthene, Phenanthrene and Pyrene may be present in the inner basin sediments, they are not considered to be present at ecologically significant concentrations.

No potentially contaminated sediment was sampled within the surficial footprints of Disposal Areas 1.2, 1.2A or 1.2B (Kerr and Grace, 2016C) or within the surficial footprints of Disposal Areas 3.2, 3.2A or 3.2B (see Appendix B).

The sediment guidelines listed in Table 7 were approached for Nickel (20 v 21 mg/kg dry weight) in Vibrocore Sample V19A 0 – 0.5 m depth (see Appendix C1) and in the case of Vibrocore Sample V20 0 – 0.5 m depth (see Appendix C1) the Effects Range-Low was exceeded for Chromium (210 mg/kg dry weight) and Effects Range-High was exceeded for Nickel (123 mg/kg/dry weight).

Table 7: Thresholds of potential concern for heavy metals (ANZECC, 2000).

		Sediment Guideline Effects Range-Low	Sediment Guideline Effects Range-High
Total Recoverable Arsenic	mg/kg dry wt.	20	70
Total Recoverable Cadmium	mg/kg dry wt.	1.5	10
Total Recoverable Chromium	mg/kg dry wt.	80	370
Total Recoverable Copper	mg/kg dry wt.	65	270
Total Recoverable Lead	mg/kg dry wt.	50	220
Total Recoverable Mercury	mg/kg dry wt.	0.15	1
Total Recoverable Nickel	mg/kg dry wt.	21	52
Total Recoverable Zinc	mg/kg dry wt.	200	410

On this basis, back up samples for both V19A (0-0.5 m depth) and V20 (0-0.5 m depth) were submitted for elutriate testing (using seawater collected from Bream Bay) and a full range of organic analyses. Elutriate testing provides a better indication of what contaminants are biologically –available than standard chemical tests.

Reference to Appendix C2 (for V19A) and C3 (for V20) show all organic materials tested for were not detectable in either sample.

Chromium and Nickel were not detectable in the elutriate for Sample V19 and for Sample V20, total Chromium was < 0.0011 $g.m^{-3}$ in the elutriate sample and total Nickel was 0.014 $g.m^{-3}$ in the elutriate sample.

Given the results of the follow up elutriate testing that was conducted on samples from Vibrocore Sites V19A and V20, it was concluded that there are no issues with the potential contamination status of material to be disposed of from the proposed dredging footprint.

Overall therefore, no adverse contamination effects are anticipated, and the sediment sizes of the dredged material and that existing at the disposal sites are compatible.

As noted in Section 2.5.1, in terms of the Section 31.4.13(v) of the Regional Coastal Plan and Chapter 19 of the Regional Coastal Plan (Northland Regional Council, 2004), humans are not expected to come into contact with sediment plumes that might be generated by proposed disturbance activities and survey and analytical results presented in this AEE, provide reassurance that seabed materials that are to be relocated from the access channel to the two nominated disposal sites are not contaminated with toxic metals or potentially toxic organic materials (Maritime Safety Authority of New Zealand, 1999).

4.1.1c Sediment Transport

Black (1983) reported sediment transport occurs in a northerly direction in Bream Bay towards Mair Bank then out of Whangarei Harbour via the main channel.

Tonkin & Taylor (2017B) have recognised the benefit of placing dredged material within Disposal Area 1.2 as sediment transport to the north would nourish sediment supply to Mair Bank that is currently undergoing morphological changes (Pawley, 2016).

There are no adverse ecological effects associated with sediment transport that occurs as a consequence of sediment being placed in Disposal Area 1.2. Such transport is a naturally occurring process that existing communities are adapted to.

4.1.2 Prediction of Water Column Effects

4.1.2a Sediment Plumes

MetOcean Solutions (2016B) have gathered data on tides, waves and currents within the study area and have modelled expected sediment plumes under a range of conditions for both the winning and disposal of dredged material.

Potential sediment plume effects within the dredging footprint between Home Point and the Motukaroro Island Whangarei Marine Reserve are of greater concern than in the outer dredging footprint and at the two disposal areas. This is because the dredging footprint is immediately adjacent to hard-bottom habitat between Home Point and the Motukaroro Island Whangarei Marine Reserve, but the outer dredging footprint is surrounded by a less sensitive (soft-bottomed) receiving environment.

MetOcean Solutions (2016B) found that currents in the dredging footprint between Home Point and the Motukaroro Island Marine Reserve, are such that plumes will largely be confined to the deepest part of the channel with limited lateral dispersion into adjacent areas.

Tonkin & Taylor (2017A) consider the presence of predominantly medium and fine sands with low silt contents (less than 6%) that are to be dredged, significantly reduces the extent of turbid plumes during dredging and placement of sediment in the disposal areas. On that basis, they predict sediment plumes and overspill from the TSHD whilst winning dredged spoil will be manageable. This opinion has been supported by plume testing conducted by Brian Stewart of Ryder Consulting Limited and video monitoring of dredging around the dolphins at the Marsden Point Wharf.

In order to understand the potential ecological effects, there is a need to focus on overspill (return of decant water from the hopper) from a Trailing Suction Hopper Dredge adjacent to Marine 1 Management Areas (see Figure 4).

A conservative standard that the turbidity of plumes that enter the Marine 1 Management Areas should not exceed a level 2 threshold of 20 $g.m^{-3}$ / NTUs (or revisions thereof), see Table 8) is proposed to safeguard their nominated values (see Section 5.2). The achievement of these guideline values should ensure that the habitats and species with the areas adjacent to the dredging do not experience adverse effects.

Given the low organic matter content of the sands to be relocated (Appendix C), no water quality issues such as dissolved oxygen sags are expected to be associated with sediment plumes that are associated with winning and disposing of dredged material.

In this regard, West and Don (2016B) commented:

> "*higher percentages of very fine sands and silts will likely result in greater plumes of sediment discoloured water at the point of dredging and at the disposal site. In addition, there would be greater spread of fine sediments which could potentially smother some habitats, resulting in loss of or changes in biota. The proportion of very fine sand and silt is generally very low in the surface sediments in the proposed dredge area. The proportion of very fine sand is highest at the furthest extent offshore of the proposed dredge area (C01) and beyond (C00). Silt was only detected in abundance at two sites; C11M, mid channel adjacent to Frenchman Island. Both samples up and downstream from this site were considerably coarser, suggesting the sample was anomalous or the result or some peculiarity in the currents in this area. Similarly, silt was detected at site HP01 in the small bay between Home Point and Busby Head. Current flow data provided by Ocean Currents Ltd. (2015) showed that a counter current (eddy) is formed in this area on both the rising and falling tides; thus the deposition of silts is natura*l".

The soft-bottom taxa within and adjacent to the Disposal Sites for dredged material are less sensitive to sedimentation effects than the hard-bottom communities surrounding the dredging

footprint (Coffey, 2016A) and the special communities such as *Sabella* fan worm monitoring site described by Kerr and Associates (2016A).

Nevertheless, it is intended to restrict sedimentation effects to the nominated footprint at each of the disposal areas.

Following the initial placement of dredged material within either of the disposal areas, there will be subsequent movement / transport of that material on the seabed, albeit on a lesser scale than during the initial placement phase (as modelled by MetOcean Solutions, 2016B). This is particularly the case at Disposal Area 1.2 where longshore drift is expected to nourish Mair Bank with a supply of sand.

Clearly, these processes are occurring at present and resident benthic communities that have been described on and in the seabed, can cope with this low-level disturbance (i.e. sediment transport in response to waves and water currents). Consequently, no further adverse ecological effects are anticipated following the initial placement of dredged material within disposal areas.

4.1.2b Suspended solids, Turbidity and Light Penetration

Table 2 lists the guidelines for coastal water within the study area and refers to changes in the euphotic depth and light reduction at the sediment bed rather than suspended solids, turbidity and light penetration that are usually easier to model (MetOcean Solutions, 2016B).

In the present instance, it is the settlement of suspended solids onto sensitive taxa and community types that is of most concern, hence the use of suspended solids rather than turbidity as a reference standard. However, it is only turbidity that can be measured in real time on site during disturbance activities and therefore a robust correlation between these two parameters is required to manage proposed works.

A 1:1 relationship has been established between turbidity and suspended solids (see Section 2.5) that will allow suspended solids concentrations that arise from disturbance activities to be managed on the basis of real time turbidity monitoring.

Existing water quality is discussed in Sections 2.5.3 and 2.5.4. As a result of the proposed Crude Shipping Project, effects on water quality are likely to be limited to a reasonable mixing zone in the water column. These actual and potential effects are detailed below.

Within the lower Whangarei Harbour, dredging activities outside of a reasonable mixing zone, are not expected to compromise current water quality limits for Class CA waters.

Disposal of dredged material within Disposal Areas 1.2 and 3.2 is expected to comply with Clauses (i) and (iii) of Section 31.4.13(c) of the Regional Coastal Plan (see Section 2.5.1).

In terms of sediment plumes compromising water clarity, clause [ii] of Section 31.4.13(c) of the Regional Coastal Plan is expected to be met beyond a reasonable mixing zone of 300 m in Bream Bay.

4.1.2c Return of decant water to sensitive environments

The use of “overflow” or the discharge of decant water from the hopper of the dredge to increase the payload of dredged material moved by the barge on each movement from the dredging site to a disposal site increases the potential for TSHDs to generate turbidity (Royal HaskoningDHV, 2016A).

On moderate to larger dredges, overflow from the hopper back to the sea is likely to be via an outlet at the bottom of the hull (the keel) where a “green valve” or equivalent could be used to reduce air bubbles within the discharge both to reduce the potential for turbidity and to

increase the speed of settlement of the plume discharged from the keel of the dredger. This would be an appropriate means to minimise the effects on sedimentation and turbidity.

Sediment plume dispersion modelling has been undertaken by MetOcean Solutions (2016B) to determine potential sedimentation impacts at the dredging site. That modelling concludes that the plumes can be largely confined to the dredged channel.

4.1.2d Analysis against Regional Coastal Plan Performance Standards

Discharges to water are required to be assessed against the General Performance Standards in the Northland Regional Coastal Plan (Northland Regional Council, 2004). Relevant standards include, for disposal of dredged material within Disposal Areas 1.2 and 3.2, those standards listed in Section 31.4.13. In relation to dredging activities, including return of decant water, the standards in both Section 31.4.13 and Section 31.7.12 apply, given the area to be dredged includes areas zoned Marine 2 (Conservation) Management Area and Marine 5 (Port Facilities) Management Area. Within Sections 31.4.13 and 31.7.12, performance standard (c) is identical, and is the only relevant general performance standard concerning discharges to water. It reads:

> *(c) Discharges to water shall, after reasonable mixing, comply with the relevant receiving water quality standards and shall not contain any contaminants which could cause:*
>
> *(i) the production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.*
>
> *(ii) any conspicuous change in the colour or visual clarity of the receiving waters.*
>
> *(iii) any emission of objectionable colour.*
>
> *(iv) accumulation of debris on the foreshore or seabed underlying or adjacent to the discharge point.*
>
> *(v) any significant adverse effects on aquatic life or public health.*

The proposed dredging and disposal activities are expected to meet these performance standards. Outside a reasonable mixing zone (300m, or 100m in proximity to sensitive hard-shore communities) it is not expected that the proposed activities will result in any of the matters listed in (c) (i)-(iii). This is reflected in the modelling undertaken (MetOcean Solutions, 2016B). Further, video footage of a smaller, distinct, dredging operation undertaken by Refining NZ in December 2016 - February 2017 to undertake urgent emergency works around its berthing ‘dolphins’ did not reveal any oil or grease films, scums or foams, and no floatable materials. Moreover, video of the plume generated by the dredge indicated the plume was not associated with a conspicuous change in the colour or visual clarity after reasonable mixing.

In terms of standard (c)(iv), which refers to an accumulation of “debris” on the foreshore or seabed, a reasonable interpretation of this standard is that it seeks to avoid any accumulation of harmful contaminants from point source discharges (for example, litter/waste products associated with a wastewater outfall). It is of course a necessary aspect of a dredging and disposal project that there will be an accumulation of dredged material on the seabed. It is acknowledged that, construed narrowly, this particular performance standard could be interpreted as including disposal of any / all dredged material - although it could be expected the terminology used would reflect this, rather than the specific use of the term “debris”. However, it is not considered to be a reasonable (nor intended) application of the standard. Accordingly, the proposed disposal activity can be considered to be compliant with the standard.

In terms of clause (v), which relates to significant adverse effects on aquatic life, it has been concluded that that adverse effects on benthos within the dredge and disposal areas should be minor to moderate, which is consistent with that performance standard (refer Section 2.5.1).

Overall, it is not expected there will be a compliance issue with any of the clauses of performance standards 31.4.13(c) or 31.7.12(c).

In terms of Regional Coastal Policy 21.4, there will be an effective net zero take of coastal water as a result of proposed dredging activities.

4.1.2e Summary and Recommendations

Given the:

(i) modelling of sediment plume dispersal,

(ii) reasonable / available mixing zone around the dredge and disposal footprints, and

(iii) real time turbidity monitoring at the boundary of sensitive rocky reef habitats,

water column effects are expected to be less than minor.

Coastal water quality standards discussed in Section 2.5.1 are expected to be met after reasonable mixing of sediment plumes generated by proposed dredging activities and the disposal of dredged material at disposal sites 1.2 and 3.2.

Derived turbidity limits / thresholds are proposed in Table 8 to manage suspended solids concentrations within adjacent sensitive communities.

These require the following responses in terms of concurrent operational controls on dredging / dredged spoil disposal activities.

- Level 1: the reason for elevated suspended solids concentrations down-current of the operational dredge need to be investigated,
- Level 2: operational changes are required by the dredge to reduce down-current suspended solids concentrations, and
- Level 3: suspended solids concentrations down-current of the operational dredge result in dredge activities being stopped.

Accordingly, it is recommended:

(1) real time turbidity recorders are installed and monitored on the boundaries of adjacent sensitive rocky reef communities during dredging activities (refer A and D in Table 8 and Section 7.2), and

(2) hand-held turbidity meter measurements are used to ensure compliance with thresholds where dredging and disposal activities are undertaken in proximity to other receiving environments (see B, C and E in Table 8 and Section 7.2).

The turbidity thresholds proposed in Table 8 (from Coffey, 2016D, Elliot 2017 and Tonkin & Taylor, 2017C) are also based on comparative studies conducted by the Ports of Tauranga and the Ports of Otago (Bryan et. al., 2014; Fenwick and Stenton-Dozey, 2015; Port of Tauranga, 2014; Warren et. al., 2015: Warren, 2016, Stewart, 2011, Stewart 2013 and 2015).

MetOcean Solutions (2017) calculated suspended sediment concentrations in the water column within disposal area 1.2 in relation to wave height using historical weather records. They found (see Table 3-4 of Tonkin & Taylor, 2017A) that average suspended solids concentrations in the water column exceeded 100 $g.m^{-3}$ for 10% of the year when wave heights exceed 1.5 m and hence it could be assumed resident benthos within that area were tolerant of at least 100 $g.m^{-3}$ of suspended solids for short periods of time.

On this basis, the Level 3 turbidity threshold of 40 proposed for Bream Bay by Coffey (2016D) has been increased from 40 to 100 for disposal area 1 because natural events involving high winds and extreme wave events, may on occasions, result in higher turbidity events than have been described in Section 2.5.2 (MetOcean Solutions 2017).

Similarly, Refining NZ (pers. comm. Riaan Elliot) have been trialling the deployment of continuous recording, data transmitting, turbidity meters on the Motukaroro Island Whangarei Marine Reserve Marine 1 Management Area boundary since May 2017 (see Section 7.2 and Figure 16) and have reported background turbidity records greater than 10 grams per cubic metre (see Table 8).

Table 8: Recommended turbidity thresholds (NTU) for the dredging programme. A and D relate to a six-hour average of one-minute interval records from fixed turbidity metres. B, C and E relate to hand-held turbidity meter readings as per Figure 17.

Location	Concern	Level 1 Threshold	Level 2 Threshold	Level 3 Threshold
A - Motukaroro Island Whangarei Marine Reserve Marine 1 Management Area	Rocky Reef Taxa	**15***	**20***	**25***
B - Calliope Bank Marine 1 Management Area	Shellfish benthic invertebrates	**15**	**20**	**35**
C - Mair Bank Marine 1 Management Area	Shellfish benthic invertebrates	**15**	**20**	**35**
D - Home Point Marine 1 Management Area	Rocky Reef Taxa	**15***	**20***	**25***
E - Bream Bay including Three Mile Reef	Shellfish benthic invertebrates	**20**	**25**	**40** (**100**** for Disposal Area 1.2

* provisionally based on RNZ data base (Elliot, 2017) for Location A between May and July, 2017.
** based on Table 3-4 of Tonkin & Taylor (2017B).

Therefore, the suspended solids standards / thresholds adopted in Table 8 can be considered to be conservative, precautionary and subject to revision on the basis of further monitoring data.

Neither the Regional Coastal Plan nor the RMA define an appropriate reasonable mixing zone. Instead, this is to be determined having regard to the attributes of a particular location (for instance, currents, tides, bathymetry, and roughness coefficient of the seabed). Here, a reasonable mixing zone within Bream Bay would be 300m, however in proximity to some hard-shore communities (e.g. Home Point) only 100m is available for a mixing zone (Tonkin & Taylor, 2016C).

4.1.3 Prediction of Effects on Marine Community Structure

4.1.3a Plankton

As described in Section 2.6.1, plankton is abundant along the north-east coast of the North Island and can on occasions bloom to nuisance proportions. The study area (including the mouth of Whangarei Harbour) is well flushed with open oceanic water with its associated plankton community.

It is considered very unlikely that the large-scale drivers for plankton productivity and potential toxicity within Bream Bay or the lower Whangarei Harbour would be affected by the dredging and disposal activities proposed.

Localised and transient effects of reduced light levels and fine particles clogging the filter feeding mechanisms of zooplankton could occur within sediment plumes generated by disturbance activities, but it is not considered that these short-term potential impacts warrant the imposition of a monitoring regime that specifically describes plankton.

Overall, any adverse effects on plankton associated with the proposed disturbance activities are predicted to be negligible, and are not expected to adversely impact on significant ecological areas.

4.1.3b Benthos

Soft-bottomed benthic communities are routinely subject to high turbidity / suspended solids concentrations during high energy wave events (MetOcean Solutions, 2017) and are considered tolerant of sediment plumes that will be generated when winning and disposing of dredged material.

However, soft-bottomed benthic communities within the area to be dredged (see Figure 4) will be removed with dredged material and very few are expected to survive excavation, transport and disposal at an alternative site.

Similarly, those benthic animals and occasional plants at disposal sites 1.2 and 3.2 on which dredged sediment is placed are expected to be buried and not survive.

The bulk of moribund benthic organisms that are buried at disposal sites would be decomposed by bacteria and fungi.

On the basis of a marine habitat map for Northland (Kerr, 2009), the conservation status of New Zealand marine invertebrates (Freeman et. al., 2013) and nominated sensitive marine benthic habitats in New Zealand (MacDiarmid et. al., 2013), it is concluded the indigenous fauna that would be removed from the dredging footprint and buried by the placement of dredged material in proposed disposal areas 1.2 and 3.2 (see Figure 2) is not of national or regional significance. No benthic taxa in these predominantly sandy sites are considered to be endangered or at risk.

However, surrounding some of these soft bottom areas (particularly those dredging locations within the Whangarei Harbour) that will be disturbed by proposed dredging activities are hard-bottom reef communities of high intrinsic, conservation and recreational value.

Capital dredging would impact on (displace) benthic communities from an area of 1.62 km^2, and disposal of that dredged material will disturb an area of 2.75 km^2 for a period of up to 12 months.

Shallow (<20m), high-energy, coastal environments tend to become recolonised more rapidly than deeper offshore environs environments following dredging activities and there are a wide range of variables that determine the rate of recolonisation (Coffey, 2017A).

However, on the basis of monitoring other dredging sites in New Zealand (Port of Auckland[5] Tauranga[6] and Otago[7]), it is expected that an ecologically constructive benthic community would have re-established within a period of 6 - 24 months (albeit of a smaller size class than perennial taxa that were displaced by the dredging event).

This is considered to be a localised, minor to moderate impact on benthic productivity (and available food for fish in the local area) and hence compensation is proposed (see Section 5 and Coffey and Stewart, 2017). There will be a progressive reduction in the level of these effects over time, and it is expected that the dredge and disposal areas will support an ecologically constructive community 6 - 24 months after proposed disturbance events (Coffey, 2017A).

It is recognised that whilst re-colonisation sequences that have occurred following dredging activities to maintain access to other NZ ports (see footnotes 5, 6 and 7) have generally

5 http://www.poal.co.nz/sustainability/environmental-management/dredging

6 http://www.environmentguide.org.nz/issues/marine/major-marine-development/im:2115/

7 www.portotago.co.nz/our-harbour/overview/

involved endemic benthic community types that were disturbed by dredging activities, adventive pests have the potential to become pests in areas that have been disturbed within dredging footprints or disposal grounds for dredged material (Inglis and Seaward, 2016; Ministry for the Environment and Statistics New Zealand, 2016).

Such adventive pests include *Arcuatula senhousia*, the Asian bag (or date) mussel, *Charybdis japonica* the Asian paddle crab, *Eudistoma elongatum* the Australian droplet tunicate, *Sabella spallanzanii* the Mediterranean fanworm, *Styela clava* the Clubbed tunicate, and *Theora lubrica* the Fragile clam.

Monitoring is required to check this does not happen.

The post-impact monitoring regime recommended in Section 7 includes drop-camera and physical sampling within the disturbed areas. In the event that adventive pests are found to have dominated the re-colonisation process within these areas, Refining NZ would notify the Ministry of Primary Industries ('MPI') and RNZ would co-operate / collaborate with any response plan MPI consider appropriate.

4.1.3c Fish

Local finfish stocks are expected to avoid planned disturbance activities and disturbed sites until their feeding grounds have recovered (Desprez, 2000; Sutton & Boyd, 2009; Slabbekoorn et al., 2010).

The proposed dredging and disposal activities are likely to result in in an initial reduction of the population of species such as snapper, kahawai and kingfish using the disturbance footprints, but a progressive recovery of these populations would be expected to be complete within the subsequent 6 to 24-month period (Coffey, 2017A).

Parties at consultation meetings conducted by RNZ have also raised the question of how the proposed dredging programme and disposal activities might impact on sharks and fish migrations to and from freshwater.

In response, Sharks are also expected to avoid areas that are subject to active disturbance due to reduced benthic production following a dredging or disposal event and are less likely to feed in disturbed areas until benthic production is re-established.

Eels have a strong sense of purpose in terms of migrating from fresh water to their breeding grounds in the tropical Pacific, and in returning home to fresh water as glass eels and elvers. Like most native fish (including whitebait) returning to fresh water from the sea, they have the ability to avoid obstacles, or to wait until conditions are suitable to continue with their migration. Consequently, the activities proposed by Refining NZ are not expected to adversely affect eels, either as individuals commencing or completing their migrations or as a population.

In terms of whitebait (primarily the young of: inanga (*Galaxias maculatus*), koaro (*G. brevipinnis*) and banded kokopu (*G. fasciatus*); inanga is by far the most commonly caught taxa. Giant kokopu (*G. argenteus*), short-jawed kokopu (*G. postvectis*) and smelt (*Retropinna retropinna*) are also occasionally present along with the young of many other fish such as eels, bullies and brown trout.

All whitebait species spend part of their life cycle in fresh water and part in the sea. Fish hatch in late autumn and are carried along rivers out to sea where they live and grow over the winter. In late winter and early spring whitebait migrate back up rivers and streams, finally settling and growing in bush covered streams and swamps. The start of the migration is thought to be influenced by river flows (i.e. shortly after floods) and phases of the moon. Mature inanga adults migrate downstream to lower river sections and estuaries to spawn in grasses covered by water during spring tides. The eggs remain in the grass until the next spring tide covers them again when the young hatch and are carried out to sea.

The effect of the proposed disturbance activities on fish feeding and fish migration is expected to be relatively minor with the most important effect being a temporary reduction in food availability for those taxa that feed on benthos in the entrance channel and disposal grounds for dredged material. In this regard, the fish species that feed in the disturbed areas are likely to avoid them in the short term, but will return as re-colonisation occurs. As such, the disturbance activities proposed are not considered likely to contravene Policy 11(b) of the Coastal Policy Statement (Department of Conservation, 2010) or provisions of the Northland Regional Policy Statement relating to Indigenous Ecosystems and Biodiversity (Northland Regional Council, 2016).

4.2 Maintenance Dredging and Disposal of Maintenance Dredgings

Maintenance Dredgings (up to 150,000 m^3 over 35 years) may be placed in any or all of disposal area 1.2, disposal area 3.2, or possibly on land (assuming any relevant consents or authorisations are separately obtained).

Disposal area 3.2 has been sized to enable all capital and maintenance dredging to be placed within the area for the duration of the maximum consent period allowed (35 years) and disposal area 1.2 is sufficiently large to enable different locations to be targeted for the placement of maintenance dredging as required to retain sand within the littoral system.

As discussed in Section 3, maintenance dredging may need to occur every 2 to 5 years in the berth pocket area and in targeted areas of the inner and mid channel to maintain navigable draft around the jetty dolphins. Assuming uniform distribution of sedimentation within the outer section, the 0.5 m sedimentation allowance could be reached within 5 to 20 years requiring a maintenance dredging campaign in this area (Tonkin & Taylor, 2016C).

All issues and comments in 4.1 above apply equally to maintenance dredging activities. The difference would be the reduced scale and the reduced duration of these effects. Tonkin and Taylor (2016C) report maintenance dredging will involve smaller vessels and a time frame of less than 6 months.

In terms of the recovery of benthos within disturbance areas, each successive disturbance event (which could occur as frequently as once every two years) will again remove the benthic community and re-colonisation will restart.

However, the difference is that if only 10% rather than 60% of a dredging / disposal footprint is involved with maintenance versus capital dredging activities for example;

- the area of reduced benthic productivity is reduced in a linear fashion, and
- the likelihood of recolonising taxa being recruited from adjacent seabed communities at a similar depth rather than from adventive organisms at adjacent wharf / berthing structures / areas is improved.

4.3 Ecological effects associated with potential Hydrocarbon Spillages

In terms of proposed capital dredging activities, the operation of dredge(s) for a six-month period within the study area would increase the risk of spills of oil and fuel and exhaust emissions (Royal HaskoningDHV (2016B).

Royal HaskoningDHV (2016B) advise that dredging operations have now improved with respect to environmental awareness and that the risk of an oil or fuel spill is unlikely with modern professional dredging operations. Furthermore, oil spill contingencies are available at RNZ (Marsden Point).

In terms of the changed pattern of oil deliveries that would occur as a result of the capital dredging programme, Bilderbeck and Oldham (2016), who assessed the risk of an oil spill as

a result of the Option 4.2 channel access improvements, concluded that the benefits of improved navigational safety and fewer tanker visits would significantly outweigh the countervailing effects of the proposed larger crude oil cargo sizes on the volume of oil released and subsequent environmental consequences in the unlikely event of a spill.

This is because tankers would clear Home Point with a greater safety margin after the channel realignment and that there would be a reduction of tanker movements to the RNZ oil terminal per annum.

4.4 Relocation of, Additions to, Navigation Aids adjacent to the Realigned Access Channel

The proposed aids to navigation (AtoN) are shown on Royal HaskoningDHV, 2016C Drawing PA1028-MA-1121 Revision M (see Figure 3).

The existing channel demarcation is provided by a safe water mark (also referred to as the fairway buoy) and eighteen (18) channel markers consisting of nine (9) starboard buoys and nine (9) port buoys.

Eight of the existing buoys will need to be relocated to accommodate the reconfigured channel alignment. These are buoys 2, 3, 5, 8, 11, 12, 14 and 18.

Two additional channel marker buoys (being one starboard buoy and one port buoy) will be installed at -17.7m depth and the existing fairway buoy will be moved to be aligned with the starboard channel markers and installed at -25.0 m depth to accommodate a lengthened entrance channel.

Other AtoN improvements proposed (Royal HaskoningDHV, 2016C) involve an improved Port Entry Light, modification of the (rear) lead light marking the offshore approach channel and installation of a set of lead lights in Taurikura Bay to assist with the night time navigation of arriving Suezmax Tankers and other vessels.

The construction of these navigational aids includes both the initial effects of installing the aid (e.g. anchors, blocks, poles or rock / boulder pins) and routine maintenance visits to service the structures (e.g. lights, marks). The expected effects associated with the removal, installation and maintenance of navigational aids will be localised and temporary.

Further, the navigation aids are expected to have positive effects in that they will reduce the likelihood of ships stranding or colliding with the shoreline, they will reduce the likelihood of accidents and potential hydrocarbon spillages. Accordingly, in my view, the ecological effects associated with the installation, modification and removal of navigational aids will be less than minor.

In addition, it is noted that approval to install, alter or remove aids to navigation aids in the Coastal Marine Area is required from the Director of Maritime New Zealand and there are industry best management practices for such activities.

Due to the rock outcrop, and therefore potential navigational hazard in the vicinity of Home Point, it is proposed that a West Cardinal Beacon or buoy be installed 175 m north of Buoy No. 7 at a relative depth of 15.8 metres. This is the only AtoN that will be constructed within habitats covered by Policy 11a of the NZCPS (Department of Conservation, 2010) and it is noted that the construction methodology for the beacon would involves a tripod base utilising two MT blocks on each leg to hold in position to avoid a requirement to fix too or drill into the reef. Alternatively, the buoy would involve three separate mooring blocks and chain. It is considered that these construction strategies and the limited footprint of reef involved would avoid adverse effects on reef habitat at that site.

4.5 Summary of Environmental Effects of Proposed Disturbance Activities

An adverse effect of the capital dredging proposal would be a localised and temporary reduced food supply for animals such as finfish and rays that feed in the entrance channel and the nominated sites that are used for the disposal of dredged material.

Seafloor sediments within the proposed dredging footprint are not contaminated and their relocation to the nominated offshore disposal areas is not expected to be associated with water column issues such as toxicity.

Given the low organic matter content of the sands to be relocated, no water quality issues such as dissolved oxygen sags are expected to be associated with sediment plumes that are associated with winning and disposing of dredged material.

The deepening of the access channel and the placement of dredged material at nominated disposal sites is expected to have a minor or less than minor effect on tides, currents, and/or wave heights within the study area (Met Ocean Solutions, 2016). No adverse marine ecology effects are expected as a result of such changes.

Existing soft-bottomed communities are adapted to naturally occurring sediment transport and there are no ecological issues associated with proposed disturbance activities at these sites. However, when these soft-bottom communities are instantaneously buried by a layer of sediment that is too deep for them to migrate up through to reach the new seabed surface, they are smothered and a conservative approach is to assume complete mortality of pre-exiting benthos. It is expected that such areas will be recolonised by like communities within a relatively short time-frame (i.e. 6 - 24 months after disposal is compete, Coffey, 2017A).

The habitat of indigenous fauna that would be disturbed by proposed dredging activities and buried by the placement of dredged material in proposed Disposal Area 1.2 and 3.2 is not of national or regional significance. No benthic taxa in these predominantly sandy sites are considered to be endangered or at risk (West and Don, 2016A).

However, surrounding some of these soft-bottom areas that will be disturbed are hard-bottom reef communities of high intrinsic, conservation and recreational value. These communities are of regional and national significance and it is proposed that potential adverse effects on these areas are to be avoided by monitoring and responding to real time telemetering of turbidity meters on the boundary between disturbance activities and these sensitive habitats (Bryan et. al., 2014).

The effect of the proposed disturbance activities on fish migration is expected to be minor with the most notable effect being a temporary proportional reduction in food availability for those taxa that feed on benthos in the entrance channel and disposal grounds for dredged material.

The proposed new alignment for the entrance channel and a reduced number of tanker visits per year will reduce the likelihood of significant oil spill from oil tankers within the study area (Bilderbeck and Oldham, 2016).

The ecological effects associated with the relocation and / or modification of existing, and / or the establishment of new navigation aids adjacent to the realigned channel entrance are expected to be less than minor.

While the winning and placement of the dredged material will result in the loss of benthic biomass at disturbed sites, the expected re-colonisation of disturbed areas should ensure that such effects are short-term, and overall, the effects are expected to be minor to moderate. There will be a progressive reduction in the level of these effects over time, and it is expected that the dredge and disposal areas will support an ecologically constructive area 6 - 24 months following disturbance.

In terms of the dredging footprint at Marsden Point, the fine sand habitat was the most common, most diverse, and dominated by smaller biota such as polychaete worms and

amphipods (see Figure 3.14 of West and Don 2016). Benthic recovery in this habitat type is expected to be relatively rapid (c. six months).

It is anticipated that the fine sand habitat will also dominate the dredging footprint following capital dredging works.

The coarse sand habitat (see Figure 3.14 of West and Don 2016) was dominated by the bivalve Tawera spissa and the primitive chordate, Epigonichthys hectori. Inside the harbour mouth the coarse sand habitat was dominated by the community defining bivalve Venerupis largillierti and juvenile gastropods. These communities would be expected to take two years to recover (in terms of longer lived bivalves) but ecologically constructive benthic communities (in terms of providing feeding grounds for fish) would be expected to recover within 12 months.

The shell gravel habitat (see Figure 3.14 of West and Don 2016) had a higher proportion of larger species than the sandy habitats. The species composition was different from the sandy habitats with 36 taxa only found in the shell gravel habitat. The community defining bivalve Tucetona laticostata and the primitive chordate, *Epigonichthys hectori* were abundant in the shell gravel seaward of Home Point, but almost absent inside the harbour mouth. Inside the harbour mouth the shell gravel had greater numbers of bivalves *Corbula zelandica* and *Venerupis largillierti* and juvenile gastropods.

Maldanid polychaetes that are indicative of stable rather than disturbed benthic communities were more common in the outer section of the proposed dredging footprint.

In terms of proposed disposal grounds for dredged material, Disposal Area 1.2 was a more disturbed site than Disposal Area 3.2 (in terms of Maldanid polychaetes and longer-lived bivalves) and recolonisation would be expected to be more rapid (c. 6 months) within Disposal Area 1.2 than within Disposal Areas 3.2 (c. 1 – 2 years). Again however, ecologically constructive benthic communities (in terms of providing feeding grounds for fish) would be expected to recover within 12 months within Disposal Area 3.2.

5.0 Avoidance, Remediation or Compensation Measures for Disturbance Activities

5.1 Short term loss of soft-bottom benthic productivity in the northern sector of Bream Bay

There will be a short-term loss of benthic productivity within the dredge and disposal areas. This area totals 4.37 km^2 or 437 hectares.

As an offset / compensation measure for this effect, it is recommended that RNZ consider supporting / collaborating with / making a financial contribution to, a Regional Council or Department of Conservation catchment management initiative that would improve the overall health of the Whangarei Harbour (Coffey and Stewart, 2017). Failing that, the recommended approach would be for RNZ to collaborate with the Regional Council, the Department of Conservation and Tangata Whenua to establish and support a Stream Care Group for Blacksmith's Creek and Estuary, or initiate / contribute to a planting programme to enhance the current recovery of seagrass beds in the downstream reaches of Whangarei Harbour.

NIWA and the Regional Council (Cummings and Hatton, 2003; Cummings, 2006; Lundquist and Broekhuizen, 2012; Reed et. al, 2004, NIWA, 2005) have already pioneered initiatives in Whangarei Harbour to understand and to re-dress the demise of pipi populations and seagrass beds in Whangarei Harbour.

5.2 Avoiding adverse sedimentation effects within sensitive hard bottom communities adjacent to the dredging footprint.

Given the regional and national significance of kelp beds and sponge gardens that are on the boundary of (but not within) the proposed dredging footprint and the Motukaroro Island marine

reserve and Home Point, then to be consistent with Policy 11(a) of the NZCPS (Department of Conservation, 2010), adverse sedimentation effects within these areas need to be avoided.

In addition, there are other specified receiving environments which also require significant adverse sedimentation effects to be avoided, and other effects to be avoided, remedied of mitigated. These include Calliope Bank, Mair Bank, and Bream Bay including Three Mile Reef.

Whilst there is less concern with potential sedimentation effects in soft-bottom communities that are on the boundary of the proposed dredging footprint (as they are less sensitive to sedimentation effects) the intention is to confine adverse ecological effects to the specific footprint of proposed disturbance activities wherever possible.

The usual approach is to establish background sedimentation rates to which surrounding communities are subject and to assume they are tolerant of these background conditions. Provided these worst-case concentrations of suspended solids are not exceeded as a result of proposed disturbance activities (and it has been established the sediment suspended by the dredging activities is not contaminated), it can be concluded the surrounding communities are not expected to be adversely affected if these thresholds are not exceeded.

Monitoring of turbidity levels at the boundary of each of the above sensitive receiving environments is proposed in Section 7 below.

Based on this monitoring, responses in terms of concurrent operational controls on dredging / dredged spoil disposal activities are summarised in Table 8 and Section 4.1.2d above and are expected to be effective in protecting adjacent community to adverse sedimentation effects arising from proposed disturbance activities.

5.3 Summary

With proposed avoidance, remediation and compensation measures in place, any adverse ecological effects within the footprints of the dredging and disposal activities are expected to be localised and short term (6 - 24 months) and further compensated for by proposed contributions to projects such as enhancing the overall health of the harbour / seagrass habitats (Coffey and Stewart, 2017).

Similarly, given the very conservative approach that is proposed in close proximity of ecologically significant areas (Motukaroro Island Whangarei Marine Reserve and kelp beds and sponge communities at Home Point), any adverse effects on the adjacent communities and environs is expected to be avoided.

In terms of Policy 11 of the New Zealand Coastal Policy Statement, the proposed activities would be conducted in accordance with the direction it sets. Adverse effects on matters listed in 11(a) will be avoided; and significant effects on matters listed in 11(b) will be avoided, and other effects avoided, remedied or mitigated.

6.0 Planning Matters (Resource Management Act 1991[8])

Some relevant matters that are set out in the Resource Management Act (1991) are now addressed.

6.1 Section 6(c)

The protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna is a matter of national importance under section 6(c) of the Resource Management Act 1991 (the Act) and are expected to be achieved if more than minor sedimentation effects can be avoided in sponge garden and kelp bed habitats adjacent to proposed disturbance activities.

The proposed monitoring regime details a threshold limit for turbidity, and establishes real time monitoring at the boundary of the sensitive Motukaroro Island Whangarei Marine Reserve and Home Point, with hand-held monitoring at the boundary of other receiving environments as set out in Table 8. That regime specifically considers the potential effect on significant vegetation and habitats, to ensure that adverse sedimentation effects will be avoided in these sensitive habitats adjacent to proposed disturbance activities. Therefore, in my view the proposal is consistent with section 6(c) of the Act.

6.2 Section 7

The area of soft-bottom seabed that would be directly affected by the proposed disturbance activities is the most abundant and widespread habitat type within the coastal marine area of Northland. On this basis, the intrinsic value of that ecosystem will be maintained due to the localised footprint of the ecosystem that would be affected and because full recovery of the disturbed area is expected in the short term.

Kaitiakitanga and the ethic of stewardship for ecological values within the study area is demonstrated by Patuharakeke Te Iwi Trust Board Inc. (2014).

Maintenance and enhancement of the quality of the environment (as set out in Section s7 (f) of the Act) would be satisfied in terms of proposed works reducing the likelihood of a significant crude oil spill within the study area, and as a consequence of the considerable efforts that have been made to avoid the areas of significance, and to develop and advance robust, conservatively cast, measures to protect those areas. Minimising the adverse effects on all other marine species and environments also will ensure that quality of the marine environment will be at least maintained in the medium to long term.

The sea run salmon fishery is confined to the South Island and these applications will have no effect on that fishery (which is a relevant matter for consideration under Section 7[h] of the Act).

In terms of trout, brown trout do migrate in the sea from river mouth to river mouth around the New Zealand coastline but they are not generally present north of the Coromandel Peninsula because of warmer water temperatures (McDowall, 1990). Rainbow trout are not common in Northland and do not venture into salt water.

[8] Under the Resource Management (Marine Pollution) Regulations 1998 (reprint as of 28 August 2014) the dumping of dredge material in the Coastal Marine Area is included as a discretionary activity in any regional coastal plan or proposed regional coastal plan and an application for such an activity must identify the sources of contamination and waste prevention strategies that may be used to control that contamination. However, it is considered that these matters have been adequately dealt with under the following sections of the Resource Management Act (1991) and elsewhere in this Assessment of Effects.

As a consequence, the activities proposed by Refining NZ are not expected to impact on that aspect of Section 7(h).

In terms of Section 7(i), based on the latest climate projections for New Zealand (mfe.govt.nz), by the end of this century we are likely to experience:

- higher temperatures – greater increases in the North Island than the South, with the greatest warming in the northeast (although the amount of warming in New Zealand is likely to be lower than the global average),
- rising sea levels,
- more frequent extreme weather events – such as droughts (especially in the east of New Zealand) and floods,
- a change in rainfall patterns – with increased summer rainfall in the north and east of the North Island and increased winter rainfall in many parts of the South Island.

No measureable effects of global warming are expected during the capital dredging programme as it would involve a 6-period within an 80-year projected impact time frame mfe.govt.nz).

However, the term of consent sought for maintenance dredging is 35 years and some subtle changes in terms of rising temperatures, rising sea level, drought / flood frequency and increased summer rainfall might be expected within this time frame. However, any such subtle changes are not expected to have a measureable effect on the effects of the maintenance dredging activities proposed by Refining New Zealand.

6.3 Section 8

It is recognised that the Act requires development of the type proposed to account for the Principles of the Treaty of Waitangi and in this case taonga species such as pipi and flounder.

6.4 Section 15B

Section 15B relates to the discharge of harmful substances (or contaminants) from ships and offshore installations. In terms of ecological matters, sediment plumes created by proposed dredging activities are not expected to contravene matters set out in 15B1(b) (i), (ii) and (iii) of the Act after reasonable mixing.

However, in the case of Section 15B (1) (b) (iv) of the Act, there will be an adverse effect on aquatic life in that surface dwelling benthos and infauna within the dredging footprint will be sacrificed for the project and surface dwelling benthos and infauna at the nominated disposal grounds (1.2 and 3.2) will be buried.

However, the effect is expected to be localised, short term and re-colonisation of disturbed areas is expected to be relatively rapid (6 – 24 months) and compensation measures are proposed to offset these effects (also see Section 2.5.1).

Therefore, this is not expected to constitute a significant adverse effect.

Accordingly, it is considered that the requirements of Section 15B will be met and that this section should not prohibit the grant of resource consents for the project.

6.5 Section 105

(a) The nature of the discharge and the sensitivity of the receiving environment to adverse effects.

These applications involve the placement of clean (uncontaminated) sand and shell with < 6% silt onto similar sediment that occurs within Disposal Areas 1.2 and 3.2 (Tonkin & Taylor 2016C). Benthic communities that are present within the nominated disposal sites can tolerate sediment transport and sediment resuspension that occurs naturally in these habitats in relation to water currents and wave action.

However, they cannot tolerate burial by a significant depth of sediment (> 20 cm) as is proposed during the disposal of dredged sediment in this instance. Re-colonisation of dredged sediment placed in disposal areas is expected to occur relatively quickly so that the effect of displacing benthic communities within these areas will be short term (6 – 24 months, see Coffey 2017A).

Each maintenance dredging event will again displace benthic communities from the footprint of the disposal areas where dredged sediment is placed and the re-colonisation sequence will need to begin again.

(b) The applicant's reasons for the proposed choice.

A combination of project efficiency (addressed by other experts) and sediment supply to nourish Mair Bank that has been described by Tonkin & Taylor (2016D).

(c) Any possible alternative methods of discharge, including discharge into any other receiving environment.

Whilst the stated preference in the RCP is "*to promote land-based disposal of dredging spoil from both capital and maintenance dredging of the coastal marine area, where this better meets the purpose of the Act"* (Policy 22.4 No. 7), benthic communities are expected to re-establish in and on dredged material placed in these areas within a reasonable time frame (6 to 24 months).

Refining N.Z. have sought to identify land-based disposal options where there is a market for dredged material and parties wishing to receive dredged material have the necessary authorisations (Tonkin and Taylor, 2016C).

6.6 Section 107

Section 107 is addressed within the Assessment of Environmental Effects report that is being lodged in support of the Refining NZ's proposal. In summary, however, Section 107 requires that consent for discharges to the CMA shall only be granted where certain water quality and ecology outcomes (as set out in subsections 107(1)(c) to (g) of the Act) are met. The water quality and ecology outcomes (that apply after reasonable mixing in receiving waters) are discussed briefly in the following comments.

Management measures will be required to meet Section 107 (c) requirements in terms of suspended materials and the risk of oil or grease contamination from machinery used to win and dispose of dredged materials. These can be managed by conditions of consent.

In terms of Section 107 (d) a conspicuous change in colour and visual clarity should be confined to a reasonable mixing zone and again can be managed by conditions of consent.

Section 107 (e) is not expected to be an issue due to the low organic matters content of dredged material to be won and disposed of and Section 107 (f) is not applicable in this instance.

There will be an adverse effect on aquatic life (Section 107[g]) in that surface dwelling benthos and infauna within the dredging footprint will be sacrificed for the project and surface dwelling

benthos and infauna at the nominated disposal grounds (1.2 and 3.2) will be buried. However, the effect is expected to be, localised, short-term and re-colonisation of disturbed areas is expected to be relatively rapid (6 – 24 months) and compensation measures are proposed to offset these effects. Therefore, this is not expected to constitute a significant adverse effect.

Accordingly, it is considered that the requirements of S107 will be met and that this section should not prohibit the grant of resource consents for the project.

7.0 Recommended Monitoring

The baseline description of pre-impact community structure by Bioresearches, Kerr and Associates and the Cawthron Institute, within and adjacent to areas that would be disturbed by the proposed dredging programme is considered to be robust. Post-dredging monitoring is required to document any actual changes and effects of the proposed activities.

The situation in terms of potential impacts is less complicated now it has been established that seabed sediments that would be disturbed by proposed works are not contaminated and have a low organic matter content.

The remaining matters that warrant on-going monitoring are:

- a localised, short-term loss of benthic productivity,
- measures to ensure that sediment plumes and associated sedimentation effects from dredging operations do not extend into sensitive communities adjacent to the proposed dredging footprint,
- a benchmark description of seagrass and shellfish communities that are in a current state of flux and need to be described separately from the effects of the proposed RNZ dredging programme, and
- monitoring to identify possible re-colonisation by adventive marine pest species.

7.1 Immediately Prior to Dredging and Disposal

Monitoring would involve a benchmark description of seagrass beds (footprint description and photoquadrats for % cover, health and vigour) and shellfish communities on Mair Bank (as per Pawley (2016). It is appropriate to undertake this immediately prior to commencement of dredging operations because they are known to be in a state of flux and subject to short term change in the absence of proposed disturbance activities.

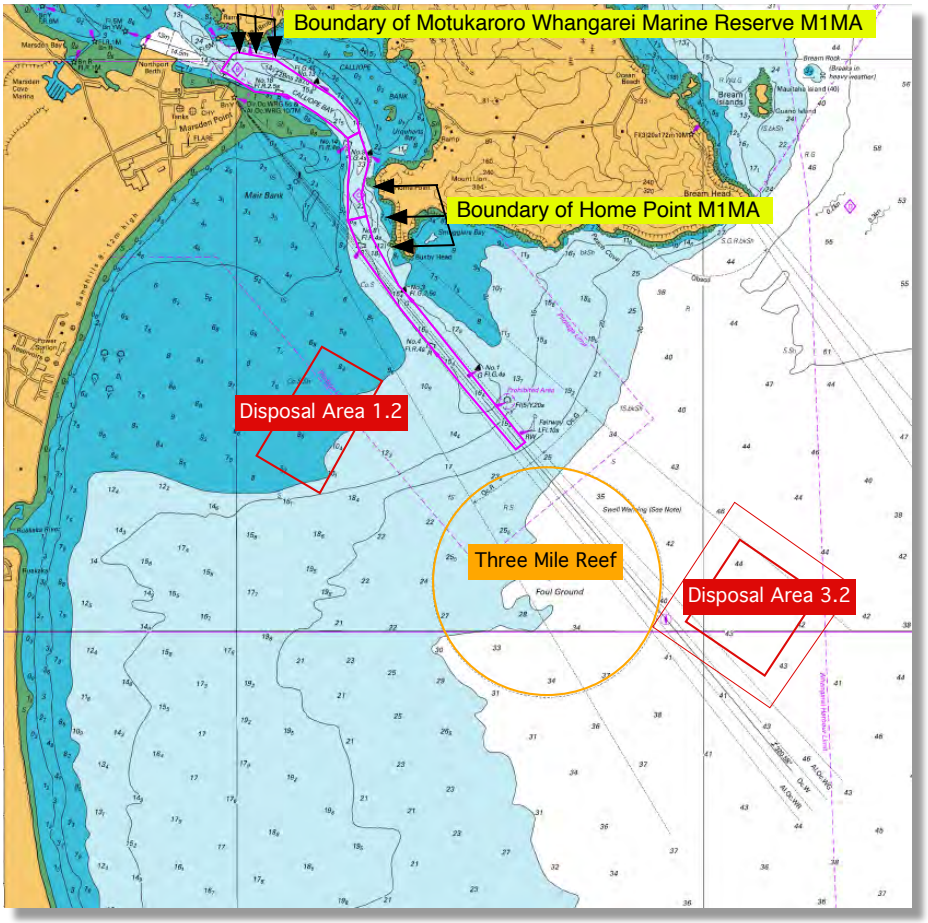
7.2 During Dredging and Disposal

Monitoring would involve the deployment of continuous recording, data transmitting, turbidity meters on the boundary of adjacent reef habitats abeam of where the dredge(s) would be winning dredged material (see Figure 16).

Three would be deployed on the southern boundary of the Motukaroro Marine Reserve and three would be deployed on the western boundary of the Home Point Marine 1 Management Area).

Real time data would be sent to the dredging vessel and a running 6-hour average NTU value (or revisions thereof – see Table 8) would be used to modify (if necessary) engineering and operational measures to meet NTU guidelines for those receiving environments.

Figure 16: Proposed deployment of six fixed, real time, transmitting turbidity metres adjacent to sensitive hard-short receiving environments. Other adjacent receiving environments are to be monitored with hand-held turbidity metres outside a 100m mixing zone at high tide on a daily basis when the dredger is operational.



Turbidity limits / thresholds have been derived that require the following responses in terms of concurrent operational controls on dredging / dredged spoil disposal activities.

- Level 1: the reason for elevated suspended solids concentrations down-current of the operational dredge need to be investigated,
- Level 2: operational changes are required by the dredge to reduce down-current suspended solids concentrations, and
- Level 3: suspended solids concentrations down-current of the operational dredge result in dredge activities being stopped.

In this instance, it is proposed that if a six-hour average turbidity of 20 NTU (average of 360, one-minute real-time records) is exceeded on the boundary of the Motukaroro Island Whangarei Marine Reserve or Home Point due to dredging activities, then dredging activities shall to be modified to ensure the a six-hour average turbidity is reduced to less than 20 NTU (or revisions thereof – see Table 8).

If the one-hour average turbidity of 25 NTU is exceeded on the boundary of the Motukaroro Island Whangarei Marine Reserve or Home Point due to dredging activities, then dredging activities shall stop.

These limits (see Table 8) apply to the boundary of the Motukaroro Island Whangarei Marine Reserve and Home Point. This strategy requires that real time data from turbidity meters on the boundary of the Motukaroro Island Whangarei Marine Reserve or Home Point are

transmitted to the operational dredge and that there are agreed protocols to follow to reduce sediment plumes generated by the dredge if required (for example stop the discharge of decant water, or move away from the boundary of the Motukaroro Island Whangarei Marine Reserve or Home Point).

With regard to other soft-bottomed adjacent communities (see Figure 16), compliance with turbidity thresholds listed in Table 8 (or revisions thereof) would be established with hand-held turbidity meter readings.

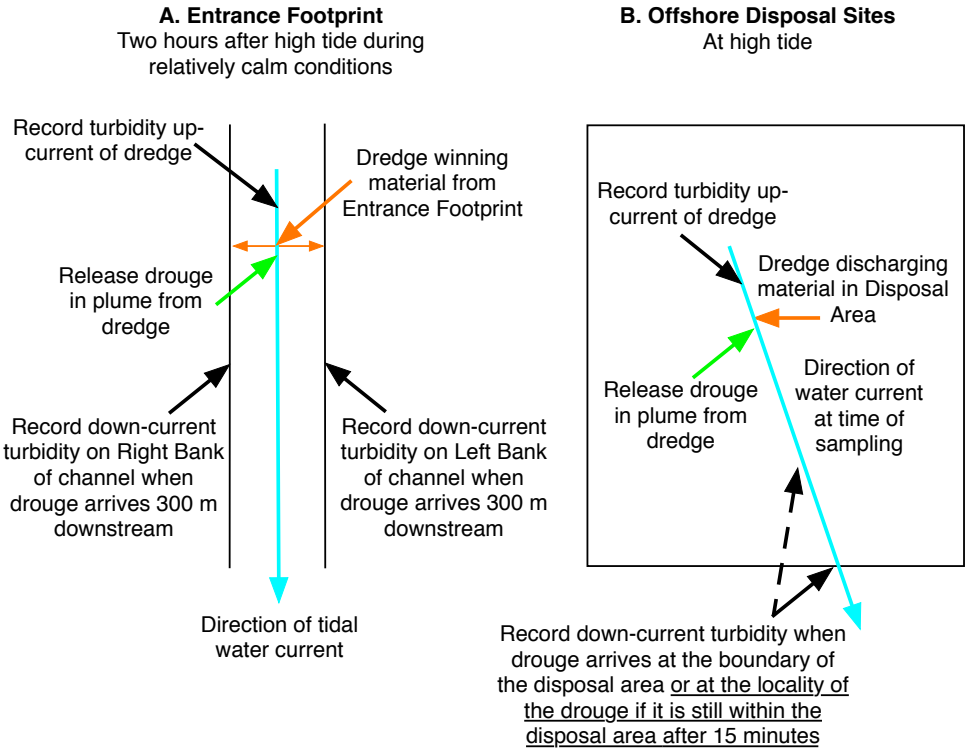
There would two strategies employed with the hand-held turbidity meters.

The first would apply to dredging activities in the entrance channel (see Figure 17A). The second would apply to the disposal areas 1.2 and 3.2 in Bream Bay (see Figure 17B). A drogue (e.g. Dan Bouy) would be used to track the downstream movement of the plume and down-current readings would be taken at the position of the drogue as per Figure 17.

The up-current readings will be used to determine natural background levels of turbidity and the down-current readings will be used to described turbidity increases due to the operation of the dredge (as per Byran et. al., 2014). Turbidity records would be made at a depth of one metre.

It is recommended the readings within the entrance channel are standardised (2 hours into ebb tide during relatively calm conditions) and a mixing zone of 300 m is used to describe turbidity on either bank of the entrance channel as shown in Figure 17A. In the event the drogue enters the boundaries of either of Mair Bank or Calliope Bank, a hand-held turbidity reading would be taken on that boundary (plus records of time and GPS co-ordinates).

Figure 17: Use of hand-held turbidity metre to measure up-current / down-current turbidity when dredge is operating adjacent to soft bottomed habitats (see Figure 16).



In the case of the disposal areas (see Figure 17B), it is recommended sampling is undertaken at high tide and that the down-current reading is taken when the plume (as indicated by the drogue) crosses the boundary of the disposal area (together with records of time and GPS co-ordinates). In the event that the drogue is still within the boundary of the disposal area after

15 minutes, a turbidity reading would be at the position of the drogue (together with records of time and GPS co-ordinates).

Values in Table 8 (or revisions thereof) would be used to assess compliance of dredging activities with turbidity thresholds in soft-bottomed receiving environments and it is envisaged 4 days of data would be used to established compliance / non-compliance on a monthly basis.

The highest turbidity (equivalent to Total Suspended Solids concentration) adopted in Table 8 is 100 NTU for disposal area 1.2 in Bream Bay. This is because Tonkin & Taylor (2016D) have calculated that this depth average concentration of Total Suspended Solids is experienced within disposal area 1.2 for some 10% of the year when waves are 1.5 m high. Clearly therefore, resident benthos present in disposal area 1.2 can tolerate short to medium term exposure to Total Suspended Solids concentration of 100 grams per cubic metre. Similarly, data currently being generated by Elliot (2107), whilst subject to on-going review, has used to inform other changes in Table 8 relative to thresholds originally proposed by Coffey (2016D).

7.3 Post Dredging and Disposal

Benthic ecological surveys post dredging and disposal would involve a repeat of the following.

- The benchmark description of seagrass beds (footprint description and photoquadrats for % cover, health and vigour) and shellfish communities on Mair Bank (as per Pawley (2016) immediately prior to dredging and disposal activities.
- Aspects of the baseline surveys conducted for the AEE immediately after the disturbance events.

These annual repeat (post-dredging and disposal) surveys will be designed to provide ecological information on:

- the recovery of disturbed benthic communities within the dredging footprint,
- the recovery of any affected communities in the immediate surrounds of the dredging footprint (if any adverse effects are described outside of the dredging footprint in the immediate post dredging and disposal monitoring survey),
- the recovery of disturbed benthic communities within the disposal areas,
- the recovery of any affected communities in the immediate surrounds of the spoil disposal footprints (if any adverse effects are described outside of disposal footprints in the immediate post dredging and disposal monitoring survey),

If it is determined that disturbance effects have successfully been limited to the footprint of disturbance activities (on the basis of the immediate post dredging and disposal monitoring survey), then subsequent benthic ecological surveys can be limited to same season follow up surveys for up to three years, or until it has been determined that the affected habitats have recovered. Any longer monitoring period beyond three years will be influenced by anticipated maintenance dredging and disposal disturbances.

However, if the results of the post-dredging and disposal survey find ecological areas adjacent to the dredging footprint have changed as a result of the dredging programme and / or the disposal of dredged material, then a contingency post capital dredging monitoring programme would involve a more detailed control-impact design with both seasonal and temporal components.

In this regard, reference sites have been described for the disposal areas 1.2 and 3.2 (i.e. reference areas 1.2A and 1.2B, and reference areas 3.2A and 3.2B -see Figures 10 and 11) relative to which recovery of soft-bottomed disturbed areas can be gauged. The reef / hard-bottomed areas have necessarily been sampled non-destructively with photoquadrats as they

include a marine reserve and there are ample hard-bottomed photoquadrats logged by Kerr and Associates (2016A) and Kerr and Grace (2016A) relative to which recovery of hard-bottomed disturbed areas can be gauged.

It would also involve a review of ongoing maintenance dredging activities to ensure subsequent dredging activities are confined to disturbance footprints.

8.0 Overall Conclusion

It is confidently expected that dredging activities proposed by Refining NZ can be managed to ensure they have only minor to moderate, localised and short-term effects on benthic communities and water quality at the entrance to Whangarei Harbour.

The material to be removed from the dredging footprint is not contaminated relative to guidelines provided by the Maritime Safety Authority of New Zealand (1999) and contains a low proportion of fines and organic matter (Tonkin & Taylor, 2016D).

Soft-bottomed benthic communities that will be directly disturbed by the proposed dredging programme, will be removed from the proposed dredging footprint and will be effectively buried at offshore disposal sites for dredged materials. There will therefore be a short-term loss of benthic productivity within the dredging and disposal footprints shown in Figure 2.

Soft-bottomed benthic communities adjacent to the dredging and disposal footprints are routinely subject to high turbidity / suspended solids concentrations during high energy wave events (MetOcean Solutions, 2017) and are considered relatively tolerant to sediment plumes that will be generated when winning and disposing of dredged material.

Conversely, there are hard-bottomed reef / rock / boulder communities immediately adjacent to the dredging footprint at the Motukaroro Island Whangarei Marine Reserve and Home Point that are of regional and national significance and that are afforded protection under Policy 11a of the New Zealand Coastal Policy Statement. Adverse sedimentation effects on kelp beds and sponge gardens within these habitats must be avoided rather than remedied or mitigated.

To this end, turbidity limits / thresholds have been derived / are being reviewed (see Table 8) for the boundaries of receiving environments that require the following responses in terms of concurrent operational controls on dredging / dredged spoil disposal activities.

- Level 1: the reason for elevated suspended solids concentrations down-current of the operational dredge need to be investigated,
- Level 2: operational changes are required by the dredge to reduce down-current suspended solids concentrations, and
- Level 3: suspended solids concentrations down-current of the operational dredge result in dredge activities being stopped.

These turbidity thresholds are to be monitored by fixed turbidity meters that telemeter results to the operational barge so it can respond to real time data in the case of sensitive hard-bottomed communities adjacent to the dredging footprint (the Motukaroro Island Whangarei Marine Reserve and at Home Point) in particular.

In the case of the turbidity limits / thresholds that have been derived for the boundaries of the less sensitive soft-bottomed receiving environments adjacent to the dredging and disposal footprints, compliance will be assessed with hand held turbidity meters down-current of the barge on an outgoing (ebb) tide.

Given there is expected to be a localised and short-term loss of benthic productivity within the dredge and disposal areas that amounts to some 4.37 km^2 or 437 hectares, some compensation measures are considered appropriate.

As a compensation measure for this effect, it is recommended that RNZ consider supporting / collaborating with / making a financial contribution to, projects that would enhance the overall health of the harbour or seagrass habitats for example (Coffey and Stewart, 2017).

A monitoring programme is recommended to describe the effects of the dredging programme separately from other temporal ecological changes that are occurring within the study area. The baseline description of pre-impact community structure by Bioresearches, Kerr and Associates and the Cawthron Institute (within and adjacent to areas that would be disturbed by the proposed dredging programme) is considered to be robust in terms of providing a comparison with post impact surveys of the same areas. However, a benchmark description of seagrass and shellfish communities (that are in a current state of flux) needs to be undertaken immediately prior to capital dredging activities.

In summary, it is considered that adverse sedimentation effects can be avoided in sponge garden and kelp bed habitats adjacent to proposed disturbance activities, and should be appropriately avoided, remedied or mitigated in all other adjacent habitats.

Acknowledgements

Much of this report is based on the work of Kerr (2016A), Kerr (2016B), Kerr and Grace (2016A), Kerr and Grace (2016B), Kerr and Grace (2016C), Kerr and Grace (2016D), Kerr and Grace (2016E), West and Don (2015), West and Don (2016A) and West and Don (2016B). I have reviewed the data they have generated and in my opinion, the conclusions they have reached are scientifically defensible and robust.

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Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B.

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institute in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B.

Appendix B: Particle Size and Chemistry for Disposal Area 3.2 (11, 12, 13, 14, 15, 16) Reference Areas 3.2A (23, 24, 24, 25, 26, 27, 28) and 3.2B (29, 30, 31, 32, 33, 34).

Appendix C1: Summary Chemical database for sectioned vibrocore samples collected by Tonkin Taylor and analysed by R.J. Hill Laboratories.

Appendix C2 Amended Laboratory Report, including elutriate testing for Vibrocore sample V19.

Appendix C3 Amended Laboratory Report, including elutriate testing for Vibrocore sample V20.

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

	1.2																													
Taxa	**KER2016INF-47-1**	**KER2016INF-47-2**	**KER2016INF-47-3**	**KER2016INF-47-4**	**KER2016INF-47-5**	**KER2016INF-48-1**	**KER2016INF-48-2**	**KER2016INF-48-3**	**KER2016INF-48-4**	**KER2016INF-48-5**	**KER2016INF-49-1**	**KER2016INF-49-2**	**KER2016INF-49-3**	**KER2016INF-49-4**	**KER2016INF-49-5**	**KER2016INF-50-1**	**KER2016INF-50-2**	**KER2016INF-50-3**	**KER2016INF-50-4**	**KER2016INF-50-5**	**KER2016INF-51-1**	**KER2016INF-51-2**	**KER2016INF-51-3**	**KER2016INF-51-4**	**KER2016INF-51-5**	**KER2016INF-52-1**	**KER2016INF-52-2**	**KER2016INF-52-3**	**KER2016INF-52-4**	**KER2016INF-52-5**
Aglaophamus sp.					1	1	2			1												1					2	1		
Alpheus socialis			1	2																										
Amalda australis	1				1										1															
Amphipoda			2				5		1				1	1			3								1	5	5	7	1	6
Anthozoa																														
Anthuridea							1			3						1														
Anthuridea																														
Armandia maculata									1																					
Asteroidea																														
Barantolla lepte																														
Bivalvia Unid. (juv)				1																										
Bryozoa (encrusting)				1		1	1	2	2	1																				
Caecum digitulum																														
Chaetognatha																								1						
Cirratulidae	1		2				6	1	1	3											5	6	4	14	6	1		2		
Cominella adspersa		1					1																							
Cominella adspersa																														
Cominella glandiformis																														
Copepoda			1			1		2	2		1			2		1	1	1	1		4	5		4	1			1		
Corophiidae																1		1												
Cumacea		1	3	2	1		1	1	1	3		4	2	4				1	2		2	5	3		1					
Cylichna thetidis																														
Decapoda (larvae unid.)																														
Decapoda ident.																	1													
Diasterope grisea																														
Diplodonta zelandica																									1					

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

Divalucina cumingi												1		1																1
Divariscintilla maoria				2		3		1						9								3								
Dorvilleidae																														
Dosinia sp.																	1	1												
Dosinia sp. (Juvenile)			2																											
Dosinia subrosea	1		1				2	3	3	1		2	1								1		1				1	1	1	
Echinocardium cordatum																							1							
Echinoidea	2	1	4	2	1	4	4	19	3	7	13	16	8	2	51	3		1	2	1	21	16	11	3	12	4	6	13	3	2
Edwardsia sp.						1											1													
Epigonichthys hectori																		2	2	1										
Euchone sp.						1			1									2											2	
Eurydice sp.	3	1	1	2		1	5	5			1			2							1		1		1	3	2			
Eurydice sp.																														
Euterebra tristis																				1										
Exosphaeroma chilensis																1														
Exosphaeroma chilensis																														
Exosphaeroma sp.	2	2	4		1	3	1	11	2		3	1	1	8	4						6	6	5	10	4	11	4	11	4	
Exosphaeroma sp.																														
Exosphaeroma sp.																														
Fellaster zelandiae															1			1												
Gastropoda (micro snails)																		1												
Gastropoda Unid. Juv.																														
Goniadidae			2					1	3									3												
Goniadidae																														
Haustoriidae	12	9	6	10	6	14	17	11	15	7	1	1	2					1				2	1							
Hesionidae									1												1									
Hydroides norvegicus																														
Hydrozoa		1	1				1										1					3								
Limnichthys polyactis																														
Lumbrineridae																														
Lysianassidae	3		3	1		1	1	2		1					1	1														
Magelona sp.	1		1		2	5	1	2	2	10			1		1															

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

Maldanidae																														
Munna neozelanica																													1	
Munna neozelanica																														
Myadora antipodum																														
Myllitella vivens vivens						6	1		1	1																				
Mysidacea											1										1	1		1				1		
Natatolana sp.		1					1	1	1		2	2		1				1			1	11	4	4	1	4	3	3	3	2
Nematoda		3	1				1	1	3	3						30		7	3	1	1	1	2	1	7			8	1	
Nemertea	1					1				2							2				2		1		3					
Neoguraleus sp.										1																				
Nereididae sp. A																														
Nucula nitidula																														
Oenonidae																														
Oligochaeta								2										1	1											
Ophiuroidea																														
Ostracoda	1		3	2	1	2	3	1	3	6			1					1			1	2	1	1				1		
Oweniidae																														
Paguridae													6								1									
Paraonidae	2				2	1	1	1	1	1	2	1	1	1	1		1				30	79	56	54	41	5		7	1	3
Phoronida										2																				
Phoxocephalidae	1	1					1	1	1	1											2	3	3	4	3	7	4	7	4	11
Phyllodocidae																1				1										
Polynoidae									1																					
Prionospio sp.	2						1				1																			
Propeamussiidae																														
Pycnogonida																	1													
Sabellidae																1				1										
Serpula sp.																														
Serpulidae																														
Sigalionidae		1			1					1		1										1	1		1					
Sigapatella tenuis																	3	1												
Soletellina nitida																														

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

Sphaeromatidae												2	1				1												
Sphaeromatidae																													
Sphaerosyllis sp.																6			5	5									
Syllidae	2						4	2	1					1		3	3	4	1	1	3	10	4	11	20	2		1		
Tanaidacea								1																					
Tawera spissa						1							1					1		1									1
Travisia sp.			2	2	1		1				2	2									1		2	1					
Waitangi brevirostris											1					1	1	1	4								2	1		

	KER2016INF-47-1	KER2016INF-47-2	KER2016INF-47-3	KER2016INF-47-4	KER2016INF-47-5	KER2016INF-48-1	KER2016INF-48-2	KER2016INF-48-3	KER2016INF-48-4	KER2016INF-48-5	KER2016INF-49-1	KER2016INF-49-2	KER2016INF-49-3	KER2016INF-49-4	KER2016INF-49-5	KER2016INF-50-1	KER2016INF-50-2	KER2016INF-50-3	KER2016INF-50-4	KER2016INF-50-5	KER2016INF-51-1	KER2016INF-51-2	KER2016INF-51-3	KER2016INF-51-4	KER2016INF-51-5	KER2016INF-52-1	KER2016INF-52-2	KER2016INF-52-3	KER2016INF-52-4	KER2016INF-52-5
# taxa	15	11	18	11	11	17	24	21	22	19	11	11	12	11	7	12	13	19	9	9	18	17	17	13	15	9	9	15	10	7
# individuals	35	22	40	27	18	47	63	71	50	55	28	33	26	32	60	50	20	32	21	13	84	155	101	109	103	42	29	65	21	26

average per site	47	48	49	50	51	52
# taxa	13	21	10	12	16	10
# individuals	28	57	36	27	110	37

average per area	Disposal Area 1.2
# taxa	14
# individuals	49

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

	1.2A																													
Taxa	**KER2016INF-53-1**	**KER2016INF-53-2**	**KER2016INF-53-3**	**KER2016INF-53-4**	**KER2016INF-53-5**	**KER2016INF-54-1**	**KER2016INF-54-2**	**KER2016INF-54-3**	**KER2016INF-54-4**	**KER2016INF-54-5**	**KER2016INF-55-1**	**KER2016INF-55-2**	**KER2016INF-55-3**	**KER2016INF-55-4**	**KER2016INF-55-5**	**KER2016INF-56-1**	**KER2016INF-56-2**	**KER2016INF-56-3**	**KER2016INF-56-4**	**KER2016INF-56-5**	**KER2016INF-57-1**	**KER2016INF-57-2**	**KER2016INF-57-3**	**KER2016INF-57-4**	**KER2016INF-57-5**	**KER2016INF-58-1**	**KER2016INF-58-2**	**KER2016INF-58-3**	**KER2016INF-58-4**	**KER2016INF-58-5**
Aglaophamus sp.												1			1	1		1												
Alpheus socialis																														
Amalda australis										1																		1		
Amphipoda	1	2	10	13		3	22	1		20		4	4	10			2				1						1	1		
Anthozoa																		1												
Anthuridea																														
Anthuridea																														
Armandia maculata																									1		1			
Asteroidea					2													1												
Barantolla lepte																														
Bivalvia Unid. (juv)																														
Bryozoa (encrusting)				1																										
Caecum digitulum																														
Chaetognatha																						1								
Cirratulidae	3	3	3	1		2	1			1	3	7	2	2	5		1			1	1		2	2		6	5		5	1
Cominella adspersa																														
Cominella adspersa																	2													
Cominella glandiformis																1														
Copepoda										1																				
Corophiidae																														
Cumacea							1					1							1		1	6			1		4	2		2
Cylichna thetidis																												1		
Decapoda (larvae unid.)					1																									
Decapoda ident.																														
Diasterope grisea																											3	6		1
Diplodonta zelandica																														

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

Divalucina cumingi																														
Divariscintilla maoria																						2								
Dorvilleidae																	1													
Dosinia sp.																														
Dosinia sp. (Juvenile)																														
Dosinia subrosea	2				1	1			3	1				1		1						1		1		1		4	2	
Echinocardium cordatum																												1		
Echinoidea	5	10	14	3	14	17	2	1	3	4	11	3	4	2	5	3	4	6		4		6	1				11	9	4	1
Edwardsia sp.									1		2						3													
Epigonichthys hectori	1														1	3	4	4	2	1										
Euchone sp.	2	17	10	1	29	5		3	4	7	2	12	5	1	64	36	85	10	34	12										
Eurydice sp.			1		1						2						1					2			6	1	2	6	1	3
Eurydice sp.																														
Euterebra tristis																														
Exosphaeroma chilensis							1											1		2							2			
Exosphaeroma chilensis																														
Exosphaeroma sp.																														
Exosphaeroma sp.				1							1			1								2	1	5	3	3	3	2	3	7
Exosphaeroma sp.																														
Fellaster zelandiae																														
Gastropoda (micro snails)															2		2													
Gastropoda Unid. Juv.					2																									
Goniadidae																														
Goniadidae	1					1											3		2	1				1						
Haustoriidae																					2	3		2		3	4	4	8	9
Hesionidae																														
Hydroides norvegicus																														
Hydrozoa																														
Limnichthys polyactis								1		1										1										
Lumbrineridae			1														2			3										
Lysianassidae	2																				3	1	2				1			
Magelona sp.													1								1						1			

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

Maldanidae															2		1													
Munna neozelanica																														
Munna neozelanica																														
Myadora antipodum																							1							
Myllitella vivens vivens																														
Mysidacea							2								1															
Natatolana sp.	1							1	1	1	1		2	2									2	3			1	1	2	1
Nematoda	5	8	2	2	15	3	3	2	2	1	12	5	26	6	14	3	19	11	14	18				6	4	1			3	
Nemertea	2	1							1							1	1	1	1	1									1	
Neoguraleus sp.																														
Nereididae sp. A																2	8	4	12	2										
Nucula nitidula																														
Oenonidae																	2	1												
Oligochaeta																	1	1												
Ophiuroidea																														
Ostracoda		1	1				1				1			1	1	1	1		2		1	2	1		3	5	1	1	5	7
Oweniidae																														
Paguridae						2						1	1	1				1												
Paraonidae	3	3	3	4	7		1				3	6	5	7	6	8	2	1		4	3	12	5	16	8	3	6	14	1	
Phoronida																														
Phoxocephalidae	9	5	10	4	5	2	2		5	4	6	4	4	12	4	2		2	2	3	3	1	3	2	6	2	8	3	14	7
Phyllodocidae															1			1	1											
Polynoidae																														
Prionospio sp.																						1				1			1	
Propeamussiidae																														
Pycnogonida																														
Sabellidae								2			1		2		9	2	3			1										
Serpula sp.								1									1													
Serpulidae													1																	
Sigalionidae	1												1	1												1		1		
Sigapatella tenuis								1				1							1											
Soletellina nitida																						1				1				

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

Sphaeromatidae																														
Sphaeromatidae																														
Sphaerosyllis sp.					4		6	3			1	1	1	12	4	1	4	1	2	1										
Syllidae	13		6	6	1	9	2	6	2	8	14	5	29	10	4	14	13	15	14	10	1	1	3	2	4		2	2		
Tanaidacea																														
Tawera spissa							1											1												
Travisia sp.															1												1			
Waitangi brevirostris			1			1							2						2	1						4				

	KER2016INF-53-1	KER2016INF-53-2	KER2016INF-53-3	KER2016INF-53-4	KER2016INF-53-5	KER2016INF-54-1	KER2016INF-54-2	KER2016INF-54-3	KER2016INF-54-4	KER2016INF-54-5	KER2016INF-55-1	KER2016INF-55-2	KER2016INF-55-3	KER2016INF-55-4	KER2016INF-55-5	KER2016INF-56-1	KER2016INF-56-2	KER2016INF-56-3	KER2016INF-56-4	KER2016INF-56-5	KER2016INF-57-1	KER2016INF-57-2	KER2016INF-57-3	KER2016INF-57-4	KER2016INF-57-5	KER2016INF-58-1	KER2016INF-58-2	KER2016INF-58-3	KER2016INF-58-4	KER2016INF-58-5
# taxa	15	9	12	10	12	11	13	11	9	12	14	13	16	15	17	15	24	19	14	17	10	15	10	10	9	13	18	17	13	10
# individuals	51	50	62	36	82	46	45	22	22	50	60	51	90	69	125	79	166	64	90	66	17	42	21	40	36	32	57	59	50	39

average per site	53	54	55	56	57	58
# taxa	12	11	15	18	11	14
# individuals	56	37	79	93	31	47

average per area	Reference Area 1.2A
# taxa	13
# individuals	57

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

	1.2B																													
Taxa	**KER2016INF-59-1**	**KER2016INF-59-2**	**KER2016INF-59-3**	**KER2016INF-59-4**	**KER2016INF-59-5**	**KER2016INF-60-1**	**KER2016INF-60-2**	**KER2016INF-60-3**	**KER2016INF-60-4**	**KER2016INF-60-5**	**KER2016INF-61-1**	**KER2016INF-61-2**	**KER2016INF-61-3**	**KER2016INF-61-4**	**KER2016INF-61-5**	**KER2016INF-62-1**	**KER2016INF-62-2**	**KER2016INF-62-3**	**KER2016INF-62-4**	**KER2016INF-62-5**	**KER2016INF-63-1**	**KER2016INF-63-2**	**KER2016INF-63-3**	**KER2016INF-63-4**	**KER2016INF-63-5**	**KER2016INF-64-1**	**KER2016INF-64-2**	**KER2016INF-64-3**	**KER2016INF-64-4**	**KER2016INF-64-5**
Aglaophamus sp.				1									1			1				1					1	1				
Alpheus socialis																				1										
Amalda australis																													1	
Amphipoda		2	1			4	4	2	5	3	1		1	1		1		4	1	2		8	1	2	2	2			1	
Anthozoa																					1									
Anthuridea																														
Anthuridea																														
Armandia maculata																														
Asteroidea						1			1				1																	
Barantolla lepte		2																												
Bivalvia Unid. (juv)																					4									
Bryozoa (encrusting)																														
Caecum digitulum					1																									
Chaetognatha																														1
Cirratulidae		1			6			1			6	7	3	1	6	1		1			2	1	2	6	5	7	6	2	1	3
Cominella adspersa																														
Cominella adspersa																														
Cominella glandiformis																														
Copepoda																						1	2					1		2
Corophiidae																														
Cumacea	1					9	2	2	3	9	2	6	2	1	1		2				2	9	2	2	3	4	4	7	3	8
Cylichna thetidis																														
Decapoda (larvae unid.)																														
Decapoda ident.																														
Diasterope grisea													3	1															1	
Diplodonta zelandica																														

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

Divalucina cumingi																31	1		11	1										
Divariscintilla maoria														3		1	2									4				
Dorvilleidae				1																										
Dosinia sp.																														
Dosinia sp. (Juvenile)																														
Dosinia subrosea		1					1			1					1	1	1	1	1	1	4	5	2			3	2	2	4	2
Echinocardium cordatum																									1		1			
Echinoidea	2	6	6		1	8	1	9	3	10	5	42	12	15	3	13	8	3	6	2	3	25	52	1	19	38	20	39	12	35
Edwardsia sp.																						2								
Epigonichthys hectori				1						1																				
Euchone sp.	10	4	1	7	6	2			3		1	2	2		1	2			1											
Eurydice sp.				1						1		1	2	3	3	1					3	14	2	2	1	2	1	4	5	8
Eurydice sp.																														
Euterebra tristis																														
Exosphaeroma chilensis	1	1		3	1				2							31	2		1											
Exosphaeroma chilensis																														
Exosphaeroma sp.																														
Exosphaeroma sp.						2	6	3	3	10	11	19	8	4	3						5	14	11	3	11	10	2	7	2	10
Exosphaeroma sp.																														
Fellaster zelandiae																		1												
Gastropoda (micro snails)												1				1	1													
Gastropoda Unid. Juv.																														
Goniadidae																														
Goniadidae				1												3	3	2	2					2	1	1	1	1	2	
Haustoriidae												1									1		4		1		2		9	1
Hesionidae																														
Hydroides norvegicus													1	1																
Hydrozoa																														
Limnichthys polyactis	1	1																												
Lumbrineridae		1		1													3			1										
Lysianassidae											1										5	4	14	3	2	4	4	2	5	3
Magelona sp.																								2	2	1	1			

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

Maldanidae				8	1											3	1							1					
Munna neozelanica																														
Munna neozelanica																														
Myadora antipodum																														
Myllitella vivens vivens																				1										
Mysidacea												1	2	1												2				
Natatolana sp.							3	1	2	1	3		2	2	1					1					5		1			
Nematoda	4	3	3	10	10	19	1	8	4	1	1	3	1	4	2	18	9		1	1	2	2	5	2	3	2	5	2	2	5
Nemertea											1										2				2					
Neoguraleus sp.																														
Nereididae sp. A				1												2														
Nucula nitidula																2											1			
Oenonidae			1																											
Oligochaeta																		1												
Ophiuroidea																						1	1			1		1		
Ostracoda												1									1	5	1	1	8	1	3		1	4
Oweniidae				1																										
Paguridae																														
Paraonidae			4		4	6	3	11	3	9	6	11	8	5	10						1	3	1	1	5	2	1	2		
Phoronida																														
Phoxocephalidae	5	2	2	1	3	1		2	3	3	1	2	1	4	4			4		1	2	2	3	6	4	2	5	4	2	1
Phyllodocidae																1		1	2											
Polynoidae																														
Prionospio sp.																								1				1	1	
Propeamussiidae				1																										
Pycnogonida																														
Sabellidae	4	7		4	4		5	3	1		1	1	2	1			2			1										
Serpula sp.																														
Serpulidae																														
Sigalionidae								1			1		1						1							1				1
Sigapatella tenuis				2												2														
Soletellina nitida																														

Appendix A1: Synthesised Data for Cawthron Institute ID and Counts for diver cores collected by Kerr and Associates in Disposal Area 1.2 and Reference Areas 1.2A and 1.2B

Sphaeromatidae																														
Sphaeromatidae																														
Sphaerosyllis sp.	12	11	2	16	5	3	4	1	1								2													
Syllidae	7	5	6	8	3	3		2		5	3	2	5	6	2	23	10	8	7	3		1	1	1						1
Tanaidacea																														
Tawera spissa																														
Travisia sp.											1				1														1	1
Waitangi brevirostris	3	3			1			1						1			1		1											

	KER2016INF-59-1	KER2016INF-59-2	KER2016INF-59-3	KER2016INF-59-4	KER2016INF-59-5	KER2016INF-60-1	KER2016INF-60-2	KER2016INF-60-3	KER2016INF-60-4	KER2016INF-60-5	KER2016INF-61-1	KER2016INF-61-2	KER2016INF-61-3	KER2016INF-61-4	KER2016INF-61-5	KER2016INF-62-1	KER2016INF-62-2	KER2016INF-62-3	KER2016INF-62-4	KER2016INF-62-5	KER2016INF-63-1	KER2016INF-63-2	KER2016INF-63-3	KER2016INF-63-4	KER2016INF-63-5	KER2016INF-64-1	KER2016INF-64-2	KER2016INF-64-3	KER2016INF-64-4	KER2016INF-64-5
# taxa	11	15	9	18	13	11	10	14	13	12	16	16	19	16	13	19	15	10	12	12	16	16	16	15	18	19	16	16	17	16
# individuals	50	50	26	68	46	58	30	47	34	54	45	103	56	53	38	138	48	26	35	16	39	97	104	35	72	91	60	77	53	86

average per site	59	60	61	62	63	64
# taxa	13	12	16	14	16	17
# individuals	48	45	59	53	69	73

average per area	Reference Area 1.2B
# taxa	15
# individuals	58

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

	3.2																													
Taxa	11_3_2_ RNZ2016INF001	11_3_2_ RNZ2016INF002	11_3_2_ RNZ2016INF003	11_3_2_ RNZ2016INF004	11_3_2_ RNZ2016INF005	12_3_2_ RNZ2016INF006	12_3_2_ RNZ2016INF007	12_3_2_ RNZ2016INF008	12_3_2_ RNZ2016INF009	12_3_2_ RNZ2016INF010	13_3_2_ RNZ2016INF011	13_3_2_ RNZ2016INF012	13_3_2_ RNZ2016INF013	13_3_2_ RNZ2016INF014	13_3_2_ RNZ2016INF015	14_3_2_ RNZ2016INF016	14_3_2_ RNZ2016INF017	14_3_2_ RNZ2016INF018	14_3_2_ RNZ2016INF019	14_3_2_ RNZ2016INF020	15_3_2_ RNZ2016INF021	15_3_2_ RNZ2016INF022	15_3_2_ RNZ2016INF023	15_3_2_ RNZ2016INF024	15_3_2_ RNZ2016INF025	16_3_2_ RNZ2016INF026	16_3_2_ RNZ2016INF027	16_3_2_ RNZ2016INF028	16_3_2_ RNZ2016INF029	16_3_2_ RNZ2016INF030
Acarina																														
Aglaophamus sp.		1	5	2		1	2	3	1	3	1																			1
Alpheus sp.																														
Amalda northlandica																														
Ampelisca sp.									1																					
Ampharetidae		3		3	1	1					1			1				1			1								
Amphinomidae																														
Amphipoda	5	4	3	2	7	2	1	1	2	2	1	1		2	4	5	5	2		2	1		3	3				2		
Annelida indet.																														
Anthozoa	1																													
Anthuridea	5	2	4	1	2	1			1			1				3	4	3	2	2			1	1						
Aonides trifida																														
Arachnanthus sp.																				1										
Aricidea sp.			2																											
Armandia maculata																														
Ascidiacea																														
Ascidian (orange colonial)																														
Asellota	1		2			1	3												1											
Asteroidea																														
Austrofusus glans					1																									
Austrovenus stutchburyi					1	1																								
Barantolla lepte																														
Bathytoma murdochi																														
Bivalvia Unid.															2															

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Bivalvia Unid. (juv)		1	1	1		3				1																				
Brachyura (juv.)																														
Bryozoa (bushy)																														
Bryozoa (Conical Discoidal)																		1	2	1										
Bryozoa (encrusting)												1	1	1					1			1	1				1			
Callianassidae																														
Capitella sp.											1																			
Capitellidae			1																											
Caprellidae										1							2													
Chaetognatha		1																												
Chrysopetalidae			1																											
Cirolanidae														1																
Cirratulidae	1	3	4	4	2	2	1			2	1				1	1				2	1	1	2	4	2	3		1	1	
Cominella quoyana																														
Copepoda									2							1		1							2					
Corallina (Encrusting Pink)																														
Coralline Paint																														
Corophiidae																	1													
Cossura consimilis	5		2	1	4	2	2	4		3																				
Ctenophora																														
Cumacea	3	4		3		3	1	1		6							1					1								
Cylichna thetidis																														
Cylichnina striata																														
Cypridinodes reticulata									1																					
Diasterope grisea																														
Diplodonta sp.																														
Diplodonta striatula																														
Dorvilleidae			1		1			2			10	1	1	1	1	5		2	4	2		1			5			2	2	1
Ebalia laevis		1								1																				
Echinocardium cordatum								1																						
Echinoidea																														
Edwardsia sp.							1	1							1															

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Ennucula strangei						1																									
Epigonichthys hectori						1	1								1	1	2		1						1						
Euchone sp.				1	1			2	2	1																					
Eunicidae																															
Euphilomedes sp.	4	1	3	2	1				1	3							2	1			1			1	2						
Eurydice sp.																															
Flabelligeridae			1								1		1																		
Gastropoda (rissoid like)																															
Gastropoda (micro snails)																															
Gastrotricha																															
Glyceridae	1	1			1						1	1																			
Goniadidae	1			1		2	2	1	5				1			1	2				5						1		3	
Gonimyrtea concinna																															
Haustoriidae	1		3	5			1							1										1						
Hemichordata						1															2						1	1	1	
Hemichordata (zooids)																												1		
Hesionidae					3				3	1				4						1	1			2					1	
Heteromastus filiformis																						1								
Hiatella arctica																		1												
Hunkydora novozelandica																															
Hydrozoa		1		1																											
Leitoscoloplos kerguelensis																															
Leptochiton inquinatus																															
Leuroleberis zealandica															1																
Limaria orientalis														1																	
Liocarcinus corrugatus																															
Lumbrineridae		1				1		1		1												2									
Lysianassidae	9	1	2	1					2	3				4				7						3		2	1		1		
Magelona dakini																															
Magelona sp.				2							1																				
Maldanidae	27	24	21	30	10	7	2	4	12	11	1	1		2	1	7	1	3		3	1	3									
Munnidae						1																									

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Myadora subrostrata																														
Mysidacea																														
Natantia unid.																														
Natatolana sp.								1																						
Neanthes cricognatha																		1												
Nebaliacea	1						2											1						1						
Nematoda	6	4	3	7	9	10	10	3	12	26	6		1	9	17	4	28	18	5	4	14	6	1	24	7	2		3	5	6
Nematoda sp. A																														
Nemertea	5	3	3	5		6	9	5	2	13	2	1	1	7	1	8	22	3		7	5	4	3	2	4		2	3	2	1
Nereididae																														
Nereididae sp. A											4	3			12	3	6	3	2						3					
Notocallista multistriata							1																							
Notomastus sp.				1					1			1		1		4	1			3		2			2	1	1	1	1	
Nucula nitidula																														
Oligochaeta					1	2	1		1	1	4	2		2		1	6	7	1	2	9	15	21	34	5	8	2	1	2	1
Onuphis aucklandensis	4	9	1			1		1	1		1	1		1		2	3	7	3	2	6	4	2	3	2				2	
Ophichthidae																														
Ophiuroidea	7	3	8	4	2	5	3	4	3	7	1	2			1								1							
Orbiniidae																										1				
Orbiniidae juv.																														
Ostracoda	1			4		2		1	1						1			1			2	1	3	4						
Owenia petersenae	2																													
Oweniidae						8				1												1								
Paguridae																				3										
Paphies australis																														
Paraonidae	6	4	7	6	7	37	25	4	29	24	2		1			3	1	1		1	1	3	1		1				1	2
Paraprionospio sp.	1	1							1																					
Parasterope quadrata																												1		
Pectinaria australis																														
Pennatulacea																														
Philine sp.			1																											
Phoronida		3		1																										

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Phoxocephalidae	2	1	6	2			1	1		1	1			1		1	2			3	3	3	1	3	2		1	1		
Phyllodocidae	1	2				1			1													1		6						
Pilargidae										1																				
Platyhelminthes																														
Pleuromeris zelandica																														
Poecilochaetidae																														
Polydorid		5				1																								
Polynoidae	3	1	2		1	3	4	5	1	6			2							1		1								
Porifera																				1										
Porifera (orange encrusting)																														
Pratulum pulchellum					1																						1			
Prionospio sp.		1	2	1	2	3		1			2		3	9	2	5	10	1	2	14	2			2	2		2	1	2	
Prionospio yuriel	3		2	3		1	2	9	1	1				1	4															
Processa moana												1																		
Pupa affinis																														
Pupa kirki			1				1																							
Retusidae																														
Ruditapes largillierti																														
Rutiderma sp.							1			1										1										
Sabellidae	2	5	1	2		4	1	3	2			1				2	1					2								
Saccella bellula																														
Saccella maxwelli	1				1				1																					
Scalibregmatidae																					1									
Scoloplos cylindrifer								1																						
Scoloplos sp.				1						1	1	1			1									1						
Serpula sp.																														
Serpulidae																				1										
Sigalionidae																	1									1			1	
Sigapatella tenuis																														
Sipuncula																														
Solariella tryphenensis																														
Solemya parkinsoni									1	1																				

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Sphaeromatidae																														
Sphaerosyllis sp.	5	2	2			7	2	3	5	7	3	2		2	1	6	7			4	2		1	3	2	1	1		1	
Spionidae				1																										
Spiophanes kroyeri	14	19	3	7	8	1	2	6	1	3																				
Spiophanes modestus	24	25	19	58	29	42	9	19	21	8			3			6	8				4	1	5	8	1			1	1	
Spirorbidae																				2										
Syllidae	2	1	10	2	1	13	5	8	3	1	2	3		4		5	3			1	4	4	1	4	1	2	4	2	2	5
Tanaidacea	2	1	2	1	1		1		1		1			1			1		2		1		5	2	4	1				1
Terebellidae	6	1	4	2			2					1		2				1			2	1		2	1			1		
Terebellides stroemii										1						1			1											
Terebra circumcincta																														
Thyasiridae	1																													
Travisia olens																								1						
Ungulinidae	1																													
Upogebia sp.															1															
Xenophora neozelanica																		1												
Zeacolpus pagoda pagoda																														

Taxa	**11.1**	**11.2**	**11.3**	**11.4**	**11.5**	**12.1**	**12.2**	**12.3**	**12.4**	**12.5**	**13.1**	**13.2**	**13.3**	**13.4**	**13.5**	**14.1**	**14.2**	**14.3**	**14.4**	**14.5**	**15.1**	**15.2**	**15.3**	**15.4**	**15.5**	**16.1**	**16.2**	**16.3**	**16.4**	**16.5**
# taxa	36	34	34	34	25	35	30	28	32	32	23	18	10	22	18	22	24	22	13	24	22	22	16	23	19	10	11	16	17	8
# individuals	164	140	133	168	98	178	99	96	122	143	49	25	15	58	53	75	120	67	27	64	69	59	52	115	49	22	17	23	29	18
average per site	11					12					13					14					15					16				
# taxa	33					31					18					21					20					12				
# individuals	141					128					40					71					69					22				
average per area	Disposal Area 3.2																													
# taxa	23																													
# individuals	78																													

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

	3.2A																														
Taxa	23_3_2A_RNZ2016INF036	23_3_2A_RNZ2016INF037	23_3_2A_RNZ2016INF038	23_3_2A_RNZ2016INF039	23_3_2A_RNZ2016INF040	24_3_2A_RNZ2016INF041	24_3_2A_RNZ2016INF042	24_3_2A_RNZ2016INF043	24_3_2A_RNZ2016INF044	24_3_2A_RNZ2016INF045	25_3_2A_RNZ2016INF046	25_3_2A_RNZ2016INF047	25_3_2A_RNZ2016INF048	25_3_2A_RNZ2016INF049	25_3_2A_RNZ2016INF050	26_3_2A_RNZ2016INF051	26_3_2A_RNZ2016INF052	26_3_2A_RNZ2016INF053	26_3_2A_RNZ2016INF054	26_3_2A_RNZ2016INF055	27_3_2A_RNZ2016INF056	27_3_2A_RNZ2016INF057	27_3_2A_RNZ2016INF058	27_3_2A_RNZ2016INF059	27_3_2A_RNZ2016INF060	28_3_2A_RNZ2016INF061	28_3_2A_RNZ2016INF062	28_3_2A_RNZ2016INF063	28_3_2A_RNZ2016INF064	28_3_2A_RNZ2016INF065
Acarina															1															
Aglaophamus sp.																												1		
Alpheus sp.																														
Amalda northlandica																														
Ampelisca sp.																														
Ampharetidae	1	2	1		2							1	1				2	1			1	4	1		2		2	1		
Amphinomidae																						1								1
Amphipoda	1		2	1				1	1	12	5		3	1	6	14	8	1	3	1		2	3	4		1	3	7	1	3
Annelida indet.																						3				1	2	2		
Anthozoa																														
Anthuridea	1	1	1		1		1						2	1	1		1					1	1				2	1	1	
Aonides trifida																			2									1		
Arachnanthus sp.																														
Aricidea sp.			3			2	2	1		1		2							1			1								
Armandia maculata																														
Ascidiacea																														
Ascidian (orange colonial)																												1		
Asellota																2												1		
Asteroidea																														
Austrofusus glans																														
Austrovenus stutchburyi								1																						
Barantolla lepte					1																									
Bathytoma murdochi																														
Bivalvia Unid.																														

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Bivalvia Unid. (juv)																1														
Brachyura (juv.)																														
Bryozoa (bushy)																1														
Bryozoa (Conical Discoida	9	3	3	2	4	2	2	12	6	9	2	10	3	5	14	1						1								
Bryozoa (encrusting)															1	1	1			1	1					1				
Callianassidae																														
Capitella sp.																														
Capitellidae																														
Caprellidae										3																				
Chaetognatha																														
Chrysopetalidae																														
Cirolanidae	1				1																									
Cirratulidae			1			1	4	2	4		4	1		1	5	2						5	1		2		2	1		4
Cominella quoyana																														
Copepoda								1		1			1	1	2	1	3	1	1	1				1	3		1	1		
Corallina (Encrusting Pink)																												1		
Coralline Paint																													1	
Corophiidae																														
Cossura consimilis																														
Ctenophora									7			1		1					1		2	1	1	1				2	1	
Cumacea			2	1												3	3	1	1		1				1			1	1	
Cylichna thetidis																														
Cylichnina striata																														
Cypridinodes reticulata																												1		
Diasterope grisea										1																				
Diplodonta sp.																														
Diplodonta striatula																														
Dorvilleidae					1						1	1			1							1	5		1					
Ebalia laevis																			1											
Echinocardium cordatum																														
Echinoidea																											1			
Edwardsia sp.																														

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Ennucula strangei														1																
Epigonichthys hectori	1														1	1		1								1				
Euchone sp.																									1					
Eunicidae																														
Euphilomedes sp.			1		1								1		1		1													
Eurydice sp.									1								1	2	1			1			2			1		
Flabelligeridae			1													1	3	1				1					1			
Gastropoda (rissoid like)																			1											
Gastropoda (micro snails)																												1		
Gastrotricha																														
Glyceridae																								2				1		
Goniadidae	1		2	4	1			1													1						1			
Gonimyrtea concinna																														
Haustoriidae				1										1	1	1			3											
Hemichordata		1	9		2					1			1												1					
Hemichordata (zooids)	1																							1			3	4	1	
Hesionidae			1					1								1	1		1		1			1	1		2			
Heteromastus filiformis	1		1																											
Hiatella arctica																														
Hunkydora novozelandica																														
Hydrozoa																														
Leitoscoloplos kerguelensis																														
Leptochiton inquinatus																	1								1			2		
Leuroleberis zealandica																														
Limaria orientalis																												2		
Liocarcinus corrugatus																														
Lumbrineridae									1			1					1	1									1			
Lysianassidae			2						4						2							1		1				1		
Magelona dakini																														
Magelona sp.						1							1										1							
Maldanidae	9				5	1		4		3	2	3	6	1	2		4	1	1		1	2			1		1	1		3
Munnidae										1																				

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Myadora subrostrata																														
Mysidacea																														
Natantia unid.																														
Natatolana sp.																														
Neanthes cricognatha																														
Nebaliacea																														
Nematoda	3	9	5		10	3	1	1	6	4	2	8	6	22	19	6	19	14	12	39	18	25	10	19	37		20	27	20	14
Nematoda sp. A				1				2			2			3	1	1	1	3		1										
Nemertea	3	2	1	1	4			1			6	4	3	4	1	1	10		1		2	1	5		3			1		2
Nereididae																							4				16		19	
Nereididae sp. A		1	1	6	1		1		2					1	1	7	13	5	8	12	2	6						12		5
Notocallista multistriata																														
Notomastus sp.	1				2				1				2	2		1			1		1	5	1		2		2			1
Nucula nitidula	1																													1
Oligochaeta	1	7	1	1	5			1	4	1	1	3	2	2		2		14	3		2	3	1	2	2			1		1
Onuphis aucklandensis		1			4							2						1			1	1	1							
Ophichthidae			1																											
Ophiuroidea					2			2		2							3				2						1		1	
Orbiniidae																												1		
Orbiniidae juv.																														
Ostracoda	1							1	2		1	1		1		1					1	1						2		
Owenia petersenae																														1
Oweniidae	1				1							1					2													
Paguridae			1																1											
Paphies australis																			1											
Paraonidae	1		5		3		1	1	2	3	1	3		1								1	1							
Paraprionospio sp.																														
Parasterope quadrata					1									1														1		1
Pectinaria australis																														
Pennatulacea																														
Philine sp.													1		1												1			
Phoronida																														

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Phoxocephalidae		1		1					1						1		1	1	3				1							1
Phyllodocidae												1			1		1												1		
Pilargidae																														
Platyhelminthes																														
Pleuromeris zelandica																														
Poecilochaetidae																												1		
Polydorid																									1					
Polynoidae																2		1				1				1				
Porifera																	1													
Porifera (orange encrusting)																											1		1	
Pratulum pulchellum																								1	1					
Prionospio sp.	2	4	7	8	1	1	2	1		1		2	2	1	6	4	1	2	2			7		1	5		4	5		4
Prionospio yuriel																														
Processa moana						1		1									1										1			1
Pupa affinis																														
Pupa kirki																														
Retusidae																														
Ruditapes largillierti																														
Rutiderma sp.																														
Sabellidae		1	1						1	1												1								
Saccella bellula																														
Saccella maxwelli																														
Scalibregmatidae																														
Scoloplos cylindrifer																														
Scoloplos sp.				1											2	1	1	1			1	1				1	1			
Serpula sp.																														
Serpulidae																														
Sigalionidae									1																		1		1	
Sigapatella tenuis																												1		
Sipuncula																						1								
Solariella tryphenensis																														
Solemya parkinsoni																														

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Sphaeromatidae				1																		1			1					
Sphaerosyllis sp.	2	1	9	19	4		1		1		3		4	8	5	4	7	8	4			4	2	6	6		10	13		6
Spionidae																														
Spiophanes kroyeri																														
Spiophanes modestus				1								1																		
Spirorbidae																														
Syllidae		4	3	4	7	1	1	4	5	3	4	7	1	2	3	1	1	1				9		1	4		2	3		6
Tanaidacea		1			3					1	1		1	8	4	1	3	3	4	2	1	1		1	1			3		1
Terebellidae	1	2		1				1	1	1	3						2	1				2						1		1
Terebellides stroemii																														
Terebra circumcincta																														
Thyasiridae																														
Travisia olens																														
Ungulinidae																														
Upogebia sp.																														
Xenophora neozelanica																														
Zeacolpus pagoda pagoda										1		1																		

	23.1	23.2	23.3	23.4	23.5	24.1	24.2	24.3	24.4	24.5	25.1	25.2	25.3	25.4	25.5	26.1	26.2	26.3	26.4	26.5	27.1	27.2	27.3	27.4	27.5	28.1	28.2	28.3	28.4	28.5
Taxa																														
# taxa	21	16	25	17	24	9	10	20	19	19	15	20	18	22	25	26	29	22	23	7	17	32	16	14	22	6	24	38	10	20
# individuals	43	41	65	54	67	13	16	40	51	50	38	54	41	69	83	62	97	65	57	57	39	96	39	42	79	6	81	109	47	58
average per site			23					24					25					26					27					28		
# taxa			21					15					20					21					20					20		
# individuals			54					34					57					68					59					60		
average per area																														
# taxa																														
# individuals																														

Reference Area 3.2A

# taxa	20
# individuals	55

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

	3.2B																													
Taxa	29_3_2B_RNZ2016INF066	29_3_2B_RNZ2016INF067	29_3_2B_RNZ2016INF068	29_3_2B_RNZ2016INF069	29_3_2B_RNZ2016INF070	30_3_2B_RNZ2016INF071	30_3_2B_RNZ2016INF072	30_3_2B_RNZ2016INF073	30_3_2B_RNZ2016INF074	30_3_2B_RNZ2016INF075	31_3_2B_RNZ2016INF076	31_3_2B_RNZ2016INF077	31_3_2B_RNZ2016INF078	31_3_2B_RNZ2016INF079	31_3_2B_RNZ2016INF080	32_3_2B_RNZ2016INF081	32_3_2B_RNZ2016INF082	32_3_2B_RNZ2016INF083	32_3_2B_RNZ2016INF084	32_3_2B_RNZ2016INF085	33_3_2B_RNZ2016INF086	33_3_2B_RNZ2016INF087	33_3_2B_RNZ2016INF088	33_3_2B_RNZ2016INF089	33_3_2B_RNZ2016INF090	34_3_2B_RNZ2016INF091	34_3_2B_RNZ2016INF092	34_3_2B_RNZ2016INF093	34_3_2B_RNZ2016INF094	34_3_2B_RNZ2016INF095
Acarina		1																												
Aglaophamus sp.	2				1	3					2				2	1	1		1								1			1
Alpheus sp.																			1	1										
Amalda northlandica																								1	1			1	1	
Ampelisca sp.					1													1			1		1		1		1			1
Ampharetidae	1		1			2	2	1	1		1										1		2	2	1	2	1		3	3
Amphinomidae						1																								
Amphipoda	4	1	4	6		1	14	13	7	6	10	1	1	8	3		2	1	2	1		8	2		1	3		2	2	3
Annelida indet.								1	2																					
Anthozoa																														
Anthuridea	2	1	3			2	6	2	2	1	2			1	1	1	2	2	1	4	1	1		1	2	1		2		
Aonides trifida																														
Arachnanthus sp.							1																							
Aricidea sp.	1		2	2		1					1							2								1				
Armandia maculata																														
Ascidiacea							2			2																				
Ascidian (orange colonial)																														
Asellota										1																				
Asteroidea				1										1																
Austrofusus glans						1					1								1											
Austrovenus stutchburyi																														
Barantolla lepte																	1													
Bathytoma murdochi																													1	
Bivalvia Unid.																														

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Bivalvia Unid. (juv)									2				1			1									1						
Brachyura (juv.)											1																				
Bryozoa (bushy)																															
Bryozoa (Conical Discoidal)		1											1																		
Bryozoa (encrusting)										1							1		1			1						1			
Callianassidae				1																											
Capitella sp.																															
Capitellidae							1																1		2						
Caprellidae																															
Chaetognatha																															
Chrysopetalidae																															
Cirolanidae																															
Cirratulidae		1	4	2	1		4	2	2	2	2	2		3	1			2						1			3			1
Cominella quoyana																									1						
Copepoda																2	1	1	2	8											
Corallina (Encrusting Pink)																															
Coralline Paint										1																					
Corophiidae																															
Cossura consimilis						4																									
Ctenophora					1						1		1							1										10
Cumacea	1		1			2	3		1		3		1		2		1	3			2	3			1	1		1		1
Cylichna thetidis																											1				
Cylichnina striata																								1	1						
Cypridinodes reticulata		1											1																		
Diasterope grisea									1			1								1	1			1	1					1	
Diplodonta sp.				2								1						1				1	5				1	1			
Diplodonta striatula			1		1																										
Dorvilleidae		1			1		6	2	2	8		1								1											
Ebalia laevis																															
Echinocardium cordatum																															
Echinoidea	1																														
Edwardsia sp.		1							1		1	1			2																

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Ennucula strangei																															
Epigonichthys hectori		1			1		1		3											1											
Euchone sp.						1															1				1						
Eunicidae	1					1	1																								
Euphilomedes sp.						2						1		3		2		1										3		2	
Eurydice sp.																															
Flabelligeridae						1	1				1										1	1									
Gastropoda (rissoid like)						1																									
Gastropoda (micro snails)																															
Gastrotricha																				1											
Glyceridae					1																										
Goniadidae			1				1	1	4		2			1	1	2		1				2	1	1	1	1	1	1	1		
Gonimyrtea concinna		1	1																					1							
Haustoriidae		1			1	1		2	2				2			3		2		3	3		3			3		1			
Hemichordata		1								1		1									1										
Hemichordata (zooids)																															
Hesionidae			1									1			1							1			1						
Heteromastus filiformis																															
Hiatella arctica																															
Hunkydora novozelandica																											1				
Hydrozoa		1																													
Leitoscoloplos kerguelensis													1							1											
Leptochiton inquinatus							1													1											
Leuroleberis zealandica																															
Limaria orientalis																				1											
Liocarcinus corrugatus																															
Lumbrineridae			1																		1				1	1					
Lysianassidae		4	1		1	1			1				3			2		3		1			5	5	9	8	4	14	1	9	
Magelona dakini																		1													
Magelona sp.									1				1		1																
Maldanidae	75	18	85	52	7	40	3	1		3	25	3	4	2	26	33	33	67	18	1	45	2	5		2	5	1	3	3	3	
Munnidae							1	1									1													1	

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Myadora subrostrata																					1									
Mysidacea					2																									
Natantia unid.						2										1														
Natatolana sp.																														
Neanthes cricognatha					1																									
Nebaliacea						1																			1	1				
Nematoda	5	8	7	1	4	4	4	16	15	1		28	1		3				1	11		1	7	4	8	1	2	2	1	3
Nematoda sp. A																														
Nemertea	9	6	1	1		6	9	3	2	9	1	9		1	1		1	1	1	3	1		1		1				1	1
Nereididae																1														
Nereididae sp. A																														
Notocallista multistriata	1																			1										
Notomastus sp.							2	1	2	3	1												1						1	
Nucula nitidula	1				2	2										3	1		1					5		1	1			
Oligochaeta	1				1			3	3																					
Onuphis aucklandensis	21	4	9	3	2	8	1	2	9	1	4			2	2	5	3	2	1	1	5	2	2	7	1	2	3	4	4	1
Ophichthidae																														
Ophiuroidea						3	2									1		1	2		1									
Orbiniidae	3														2				1											
Orbiniidae juv.																										2				
Ostracoda		1		4	2			1	7		3		3			2						2	4	21	21	24	31	15	33	1
Owenia petersenae	1				4	3	1	1	1														1							
Oweniidae																														
Paguridae						2																								
Paphies australis																														
Paraonidae				2	4	3	2	1	3	1	1			3			1	1	1	1		3	2		1		1	1	1	
Paraprionospio sp.						1							1						1		1									
Parasterope quadrata																														
Pectinaria australis	1											1					1	1												
Pennatulacea																								1						
Philine sp.				1				1											1											
Phoronida	4			9				1	3			1		1	10			3	10	1	7	1		1	1	2		7	3	1

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Phoxocephalidae	4	2	14	5	8	5	3	2	7	1	1		13	7	1	8	5	5	4	10	4	5	7	13	28	6	1	4	8	9
Phyllodocidae	3			2	1			1	5			1		1				1		1			2	1			2		2	1
Pilargidae																														
Platyhelminthes	1														1															
Pleuromeris zelandica		1																				1		1						
Poecilochaetidae																														
Polydorid	2		3	2																1		1								
Polynoidae																		1	1											
Porifera																														
Porifera (orange encrusting)																														
Pratulum pulchellum			1				1																							
Prionospio sp.	1	2	4	1	4	3	3	12	4	4	2		8	7				1	9	11		2	4	4	3	2	1		1	2
Prionospio yuriel						1																								
Processa moana																1														
Pupa affinis																		1	1		1									
Pupa kirki																														
Retusidae																														
Ruditapes largillierti							1																							
Rutiderma sp.								1								1														
Sabellidae		2		5	1	5	10	1	2	5	1	2	1			2	1	1	1	1	6	1	1		2	1	1	3		1
Saccella bellula																				1										
Saccella maxwelli				1																										
Scalibregmatidae																														
Scoloplos cylindrifer																														
Scoloplos sp.				1	4						1		2	1																
Serpula sp.				1			1			3														1						
Serpulidae																														
Sigalionidae					1			1																						
Sigapatella tenuis																														
Sipuncula																														
Solariella tryphenensis									1																					
Solemya parkinsoni																	1													

Appendix A2: Synthesised Data for Cawthron Institute ID and Counts for grab samples collected Cawthron Institue in Disposal Area 3.2 and Reference Areas 3.2A and 3.2B

Sphaeromatidae																														
Sphaerosyllis sp.	3	1		1	1	2	1	10	2	2		2	2				1	1	1			1	2						2	
Spionidae																														
Spiophanes kroyeri	5		1	4	3	8							1	1			3				1				1					
Spiophanes modestus	32	1	9	29	26	28	4	2	62	1	11	31		78	16	1	1	27	5	5	3	9	16		38	5	3	6	13	8
Spirorbidae							1																							
Syllidae	5	4	3			4	6	5	5	18	3						3	1			2	1	2	1		3	1	1		
Tanaidacea				2	3	2	5	2		1	1				1	1	2		1	3				1		1	1	2	5	7
Terebellidae	1	2	2	1	2	1	1	1	1	1	1	1	1						1			4		6	3	8	2	4	4	3
Terebellides stroemii			1				1		1												1					2			4	
Terebra circumcincta											1																			
Thyasiridae																														
Travisia olens																					1	1								
Ungulinidae																														
Upogebia sp.																														
Xenophora neozelanica																														
Zeacolpus pagoda pagoda	1						1																		1					

Taxa	**29.1**	**29.2**	**29.3**	**29.4**	**29.5**	**30.1**	**30.2**	**30.3**	**30.4**	**30.5**	**31.1**	**31.2**	**31.3**	**31.4**	**31.5**	**32.1**	**32.2**	**32.3**	**32.4**	**32.5**	**33.1**	**33.2**	**33.3**	**33.4**	**33.5**	**34.1**	**34.2**	**34.3**	**34.4**	**34.5**
# taxa	30	27	25	27	31	38	37	31	34	24	28	19	20	18	19	21	22	29	27	29	24	25	23	23	31	25	23	22	22	24
# individuals	193	69	161	142	93	159	108	94	167	77	85	89	49	122	77	74	67	136	71	78	92	56	77	81	138	87	65	79	95	74
average per site			29					30					31					32					33					34		
# taxa			28					33					21					26					25					23		
# individuals			132					121					84					85					89					80		
average per area																Reference Area 3.2B														
# taxa																26														
# individuals																99														

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ANALYSIS REPORT

Client:	Cawthron Institute (Nelson)	**Lab No:**	1578823	SPv2
Contact:	Deanna Elvines	**Date Registered:**	05-May-2016	
	C/- Cawthron Institute (Nelson)	**Date Reported:**	02-Jun-2016	
	Private Bag 2	**Quote No:**	76487	
	Nelson Mail Centre	**Order No:**		
	Nelson 7042	**Client Reference:**	Sediment Analyses	
		Add. Client Ref:	RNZ	
		Submitted By:	Olivia Johnston	

Amended Report

This report replaces an earlier report issued on the 20 May 2016 at 2:18 pm
At the client's request, organic analyses have been added to four samples.

Sample Type: Sediment

Sample Name:		RNZ2016SED001 11_3.2	RNZ2016SED002 12_3.2	RNZ2016SED003 13_3.2	RNZ2016SED004 14_3.2	RNZ2016SED005 15_3.2
Lab Number:		1578823.1	1578823.2	1578823.3	1578823.4	1578823.5
Individual Tests						
Particle size analysis*		See attached report	See attached report	See attached report	See attached report	See attached report
Total Recoverable Silver	mg/kg dry wt	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	3.3	4	6	6.3	4.9
Total Recoverable Cadmium	mg/kg dry wt	0.032	0.038	0.012	< 0.010	< 0.010
Total Recoverable Chromium	mg/kg dry wt	14.5	15.0	6.7	6.4	5.7
Total Recoverable Copper	mg/kg dry wt	1.4	1.8	0.8	0.6	0.5
Total Recoverable Lead	mg/kg dry wt	2.7	2.8	1.32	1.23	1.05
Total Recoverable Mercury	mg/kg dry wt	0.013	0.016	< 0.010	< 0.010	< 0.010
Total Recoverable Nickel	mg/kg dry wt	5.6	7.5	4.8	3.3	4.0
Total Recoverable Zinc	mg/kg dry wt	14.7	15.5	8.1	7.0	6.4

Sample Name:		RNZ2016SED006 16_3.2	RNZ2016SED007 19_2.2	RNZ2016SED008 23_3.2A	RNZ2016SED009 24_3.2A	RNZ2016SED010 25_3.2A
Lab Number:		1578823.6	1578823.7	1578823.8	1578823.9	1578823.10
Individual Tests						
Particle size analysis*		See attached report	See attached report	See attached report	See attached report	See attached report
Total Recoverable Silver	mg/kg dry wt	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	4.5	3.5	7.2	5.0	6.8
Total Recoverable Cadmium	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	0.012
Total Recoverable Chromium	mg/kg dry wt	4.3	7.3	5.6	4.3	4.9
Total Recoverable Copper	mg/kg dry wt	0.5	0.4	0.7	0.4	0.6
Total Recoverable Lead	mg/kg dry wt	0.96	1.06	1.33	0.99	1.20
Total Recoverable Mercury	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Total Recoverable Nickel	mg/kg dry wt	3.4	2.0	4.2	3.9	5.0
Total Recoverable Zinc	mg/kg dry wt	5.2	8.9	6.4	5.2	6.8

Sample Name:	RNZ2016SED011 26_3.2A	RNZ2016SED012 27_3.2A	RNZ2016SED013 28_3.2A	RNZ2016SED014 29_3.2B	RNZ2016SED015 30_3.2B
Lab Number:	1578823.11	1578823.12	1578823.13	1578823.14	1578823.15

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The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Sediment						
Sample Name:		RNZ2016SED011 26_3.2A	RNZ2016SED012 27_3.2A	RNZ2016SED013 28_3.2A	RNZ2016SED014 29_3.2B	RNZ2016SED015 30_3.2B
Lab Number:		1578823.11	1578823.12	1578823.13	1578823.14	1578823.15
Individual Tests						
Particle size analysis*		See attached report	See attached report	See attached report	See attached report	See attached report
Total Recoverable Silver	mg/kg dry wt	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	6.8	5.3	5	5.5	5.7
Total Recoverable Cadmium	mg/kg dry wt	0.010	< 0.010	0.012	0.018	0.013
Total Recoverable Chromium	mg/kg dry wt	5.6	4.7	4.4	16.6	7.9
Total Recoverable Copper	mg/kg dry wt	0.6	0.7	0.7	1.0	0.6
Total Recoverable Lead	mg/kg dry wt	1.36	1.24	1.47	2.1	1.36
Total Recoverable Mercury	mg/kg dry wt	< 0.010	0.013	< 0.010	< 0.010	< 0.010
Total Recoverable Nickel	mg/kg dry wt	4.8	5.1	5.9	5.2	4.5
Total Recoverable Zinc	mg/kg dry wt	6.0	6.4	5.8	13.4	7.1

Sample Name:		RNZ2016SED016 31_3.2B	RNZ2016SED017 32_3.2B	RNZ2016SED018 33_3.2B	RNZ2016SED019 34_3.2B	RNZ2016SED061 14_3.2
Lab Number:		1578823.16	1578823.17	1578823.18	1578823.19	1578823.23
Individual Tests						
Dry Matter	g/100g as rcvd	-	-	-	-	81
Particle size analysis*		See attached report	See attached report	See attached report	See attached report	-
Total Recoverable Silver	mg/kg dry wt	< 0.02	< 0.02	< 0.02	< 0.02	-
Total Organic Carbon*	g/100g dry wt	-	-	-	-	< 0.13
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	5.1	5	4.9	4.2	-
Total Recoverable Cadmium	mg/kg dry wt	0.015	0.030	< 0.010	0.010	-
Total Recoverable Chromium	mg/kg dry wt	13.9	21	10.0	9.1	-
Total Recoverable Copper	mg/kg dry wt	0.8	1.6	0.6	0.5	-
Total Recoverable Lead	mg/kg dry wt	2.2	3.3	1.49	1.33	-
Total Recoverable Mercury	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	-
Total Recoverable Nickel	mg/kg dry wt	4.4	8.0	4.0	3.8	-
Total Recoverable Zinc	mg/kg dry wt	12.3	18.9	8.4	8.0	-
Organochlorine Pesticides Trace in Soil						
Aldrin	mg/kg dry wt	-	-	-	-	< 0.0010
alpha-BHC	mg/kg dry wt	-	-	-	-	< 0.0010
beta-BHC	mg/kg dry wt	-	-	-	-	< 0.0010
delta-BHC	mg/kg dry wt	-	-	-	-	< 0.0010
gamma-BHC (Lindane)	mg/kg dry wt	-	-	-	-	< 0.0010
cis-Chlordane	mg/kg dry wt	-	-	-	-	< 0.0010
trans-Chlordane	mg/kg dry wt	-	-	-	-	< 0.0010
2,4'-DDD	mg/kg dry wt	-	-	-	-	< 0.0010
4,4'-DDD	mg/kg dry wt	-	-	-	-	< 0.0010
2,4'-DDE	mg/kg dry wt	-	-	-	-	< 0.0010
4,4'-DDE	mg/kg dry wt	-	-	-	-	< 0.0010
2,4'-DDT	mg/kg dry wt	-	-	-	-	< 0.0010
4,4'-DDT	mg/kg dry wt	-	-	-	-	< 0.0010
Total DDT Isomers	mg/kg dry wt	-	-	-	-	< 0.006
Dieldrin	mg/kg dry wt	-	-	-	-	< 0.0010
Endosulfan I	mg/kg dry wt	-	-	-	-	< 0.0010
Endosulfan II	mg/kg dry wt	-	-	-	-	< 0.0010
Endosulfan sulphate	mg/kg dry wt	-	-	-	-	< 0.0010
Endrin	mg/kg dry wt	-	-	-	-	< 0.0010
Endrin aldehyde	mg/kg dry wt	-	-	-	-	< 0.0010
Endrin ketone	mg/kg dry wt	-	-	-	-	< 0.0010
Heptachlor	mg/kg dry wt	-	-	-	-	< 0.0010
Heptachlor epoxide	mg/kg dry wt	-	-	-	-	< 0.0010
Hexachlorobenzene	mg/kg dry wt	-	-	-	-	< 0.0010

Sample Type: Sediment						
Sample Name:		RNZ2016SED016 31_3.2B	RNZ2016SED017 32_3.2B	RNZ2016SED018 33_3.2B	RNZ2016SED019 34_3.2B	RNZ2016SED061 14_3.2
Lab Number:		1578823.16	1578823.17	1578823.18	1578823.19	1578823.23
Organochlorine Pesticides Trace in Soil						
Methoxychlor	mg/kg dry wt	-	-	-	-	< 0.0010
Total Chlordane [(cis+trans)* 100/42]	mg/kg dry wt	-	-	-	-	< 0.002
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Acenaphthene	mg/kg dry wt	-	-	-	-	< 0.002
Acenaphthylene	mg/kg dry wt	-	-	-	-	< 0.002
Anthracene	mg/kg dry wt	-	-	-	-	< 0.002
Benzo[a]anthracene	mg/kg dry wt	-	-	-	-	< 0.002
Benzo[a]pyrene (BAP)	mg/kg dry wt	-	-	-	-	< 0.002
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	-	-	-	-	< 0.002
Benzo[g,h,i]perylene	mg/kg dry wt	-	-	-	-	< 0.002
Benzo[k]fluoranthene	mg/kg dry wt	-	-	-	-	< 0.002
Chrysene	mg/kg dry wt	-	-	-	-	< 0.002
Dibenzo[a,h]anthracene	mg/kg dry wt	-	-	-	-	< 0.002
Fluoranthene	mg/kg dry wt	-	-	-	-	< 0.002
Fluorene	mg/kg dry wt	-	-	-	-	< 0.002
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	-	-	-	-	< 0.002
Naphthalene	mg/kg dry wt	-	-	-	-	< 0.012
Phenanthrene	mg/kg dry wt	-	-	-	-	< 0.005
Pyrene	mg/kg dry wt	-	-	-	-	< 0.002
Polychlorinated Biphenyls Trace in Soil						
PCB-18	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-28	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-31	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-44	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-49	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-52	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-60	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-77	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-81	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-86	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-101	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-105	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-110	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-114	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-118	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-121	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-123	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-126	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-128	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-138	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-141	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-149	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-151	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-153	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-156	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-157	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-159	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-167	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-169	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-170	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-180	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-189	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-194	mg/kg dry wt	-	-	-	-	< 0.0010

Sample Type: Sediment						
Sample Name:		RNZ2016SED016 31_3.2B	RNZ2016SED017 32_3.2B	RNZ2016SED018 33_3.2B	RNZ2016SED019 34_3.2B	RNZ2016SED061 14_3.2
Lab Number:		1578823.16	1578823.17	1578823.18	1578823.19	1578823.23
Polychlorinated Biphenyls Trace in Soil						
PCB-206	mg/kg dry wt	-	-	-	-	< 0.0010
PCB-209	mg/kg dry wt	-	-	-	-	< 0.0010
Total PCB (Sum of 35 congeners)	mg/kg dry wt	-	-	-	-	< 0.04
Tributyl Tin Trace in Soil samples by GCMS						
Dibutyltin (as Sn)	mg/kg dry wt	-	-	-	-	< 0.005
Monobutyltin (as Sn)	mg/kg dry wt	-	-	-	-	< 0.007
Tributyltin (as Sn)	mg/kg dry wt	-	-	-	-	< 0.004
Triphenyltin (as Sn)	mg/kg dry wt	-	-	-	-	< 0.003
Total Petroleum Hydrocarbons in Soil						
C7 - C9	mg/kg dry wt	-	-	-	-	< 8
C10 - C14	mg/kg dry wt	-	-	-	-	< 20
C15 - C36	mg/kg dry wt	-	-	-	-	< 40
Total hydrocarbons (C7 - C36)	mg/kg dry wt	-	-	-	-	< 70

Sample Name:		RNZ2016SED062 15_3.2	RNZ2016SED066 24_3.2A	RNZ2016SED071 29_3.2B		
Lab Number:		1578823.24	1578823.28	1578823.33		
Individual Tests						
Dry Matter	g/100g as rcvd	80	80	76	-	-
Total Organic Carbon*	g/100g dry wt	< 0.13	< 0.13	0.16	-	-
Organochlorine Pesticides Trace in Soil						
Aldrin	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
alpha-BHC	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
beta-BHC	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
delta-BHC	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
gamma-BHC (Lindane)	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
cis-Chlordane	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
trans-Chlordane	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
2,4'-DDD	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
4,4'-DDD	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
2,4'-DDE	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
4,4'-DDE	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
2,4'-DDT	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
4,4'-DDT	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Total DDT Isomers	mg/kg dry wt	< 0.006	< 0.006	< 0.006	-	-
Dieldrin	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Endosulfan I	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Endosulfan II	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Endosulfan sulphate	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Endrin	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Endrin aldehyde	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Endrin ketone	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Heptachlor	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Heptachlor epoxide	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Hexachlorobenzene	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Methoxychlor	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Total Chlordane [(cis+trans)* 100/42]	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Acenaphthene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Acenaphthylene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Anthracene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Benzo[a]anthracene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-

Sample Type: Sediment						
Sample Name:		RNZ2016SED06215_3.2	RNZ2016SED06624_3.2A	RNZ2016SED07129_3.2B		
Lab Number:		1578823.24	1578823.28	1578823.33		
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Benzo[g,h,i]perylene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Benzo[k]fluoranthene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Chrysene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Fluoranthene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Fluorene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Naphthalene	mg/kg dry wt	< 0.012	< 0.012	< 0.013	-	-
Phenanthrene	mg/kg dry wt	< 0.005	< 0.006	< 0.006	-	-
Pyrene	mg/kg dry wt	< 0.002	< 0.002	< 0.002	-	-
Polychlorinated Biphenyls Trace in Soil						
PCB-18	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-28	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-31	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-44	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-49	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-52	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-60	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-77	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-81	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-86	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-101	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-105	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-110	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-114	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-118	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-121	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-123	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-126	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-128	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-138	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-141	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-149	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-151	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-153	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-156	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-157	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-159	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-167	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-169	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-170	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-180	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-189	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-194	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-206	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
PCB-209	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	-	-
Total PCB (Sum of 35 congeners)	mg/kg dry wt	< 0.04	< 0.04	< 0.04	-	-
Tributyl Tin Trace in Soil samples by GCMS						
Dibutyltin (as Sn)	mg/kg dry wt	< 0.005	< 0.005	< 0.005	-	-
Monobutyltin (as Sn)	mg/kg dry wt	< 0.007	< 0.007	< 0.007	-	-
Tributyltin (as Sn)	mg/kg dry wt	< 0.004	< 0.004	< 0.004	-	-
Triphenyltin (as Sn)	mg/kg dry wt	< 0.003	< 0.003	< 0.003	-	-

Sample Type: Sediment						
Sample Name:		RNZ2016SED062 15_3.2	RNZ2016SED066 24_3.2A	RNZ2016SED071 29_3.2B		
Lab Number:		1578823.24	1578823.28	1578823.33		
Total Petroleum Hydrocarbons in Soil						
C7 - C9	mg/kg dry wt	< 9	< 9	< 9	-	-
C10 - C14	mg/kg dry wt	< 20	< 20	< 20	-	-
C15 - C36	mg/kg dry wt	< 40	< 40	< 40	-	-
Total hydrocarbons (C7 - C36)	mg/kg dry wt	< 70	< 70	< 70	-	-

Analyst's Comments

The detection limit for Naphthalene and Phenanthrene was raised due to an elevated blank level found during the analysis.

Appendix No.1 - Particle Size Report - 1578823

Appendix No.2 - Particle Size Report - 1578823

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-19, 23-24, 28, 33
Organochlorine/Polychlorinated biphenyls Trace in Soil	Sonication extraction, SPE cleanup, GC & GC-MS analysis. Tested on dried sample	0.0010 - 0.02 mg/kg dry wt	23-24, 28, 33
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-19
Polycyclic Aromatic Hydrocarbons Trace in Soil	Sonication extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C. Tested on as received sample [KBIs:5784,4273,2695]	0.002 - 0.010 mg/kg dry wt	23-24, 28, 33
Tributyl Tin Trace in Soil samples by GCMS	Solvent extraction, ethylation, SPE cleanup, GC-MS SIM analysis. Tested on dried sample	0.003 - 0.007 mg/kg dry wt	23-24, 28, 33
Total Petroleum Hydrocarbons in Soil	Sonication extraction in DCM, Silica cleanup, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines. Tested on as received sample [KBIs:5786,2805,10734]	8 - 60 mg/kg dry wt	23-24, 28, 33
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. US EPA 3550. (Free water removed before analysis).	0.10 g/100g as rcvd	23-24, 28, 33
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-19
Particle size analysis*	Malvern Laser Sizer particle size analysis. Subcontracted to Earth Sciences Department, Waikato University, Hamilton.	-	1-19
Total Recoverable Silver	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.02 mg/kg dry wt	1-19
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	23-24, 28, 33

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental

Samples were sieved at 2mm and particles below 2mm were analysed using the Malvern Lasersizer.
Below are the proportions above and below 2mm

Sample No	% > 2mm	%< 2mm
1578823.3	22.5	77.5
1578823.4	3.1	96.9
1578823.5	4.6	95.4
1578823.6	10.7	89.3
1578823.7	1.1	98.9
1578823.8	7.2	92.8
1578823.1	8.6	91.4
1578823.11	20.9	79.1
1578823.12	23.5	76.5
1578823.13	24.0	76.0
1578823.15	12.7	87.3

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Result Analysis Report

Sample Name:
1578823.1

SOP Name:
Sediment

Measured:
Wednesday, 18 May 2016 2:44:32 p.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Wednesday, 18 May 2016 2:44:34 p.m.

Sample bulk lot ref:
2016084/1

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0.2

Size range:
0.020 to 2000.000 um

Obscuration:
25.51 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.536 %

Result Emulation:
Off

Concentration:
0.1097 %Vol

Span :
2.127

Uniformity:
0.684

Result units:
Volume

Specific Surface Area:
0.253 m²/g

Surface Weighted Mean D[3,2]:
23.720 um

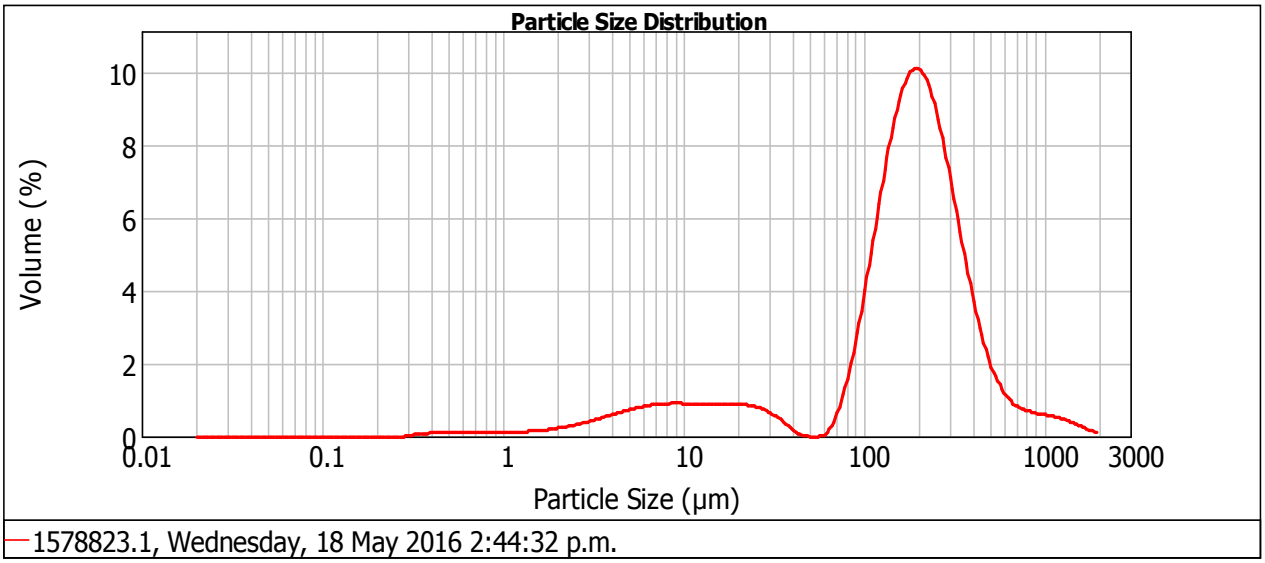
Vol. Weighted Mean D[4,3]:
224.507 um

Standard Deviation
212.633 um

---

d(0.1): 13.723 um **d(0.5):** 184.500 um **d(0.9):** 406.138 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	1.53	44.000	15.25	149.000	36.62	500.000	93.83	1680.000	99.82
0.060	0.00	3.900	3.18	53.000	15.26	177.000	47.27	590.000	95.56	2000.000	100.00
0.120	0.00	7.800	6.67	63.000	15.28	210.000	58.58	710.000	96.77		
0.240	0.00	10.000	8.14	74.000	15.71	250.000	69.57	840.000	97.58		
0.490	0.27	15.600	10.74	88.000	17.43	300.000	79.29	1000.000	98.30		
0.700	0.56	31.000	14.48	105.000	21.28	350.000	85.61	1190.000	98.94		
0.980	0.83	37.000	15.05	125.000	27.64	420.000	90.78	1410.000	99.45		

Operator notes:

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Result Analysis Report

Sample Name:
1578823.2

SOP Name:
Sediment

Measured:
Wednesday, 18 May 2016 2:49:47 p.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Wednesday, 18 May 2016 2:49:49 p.m.

Sample bulk lot ref:
2016084/2

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0.2

Size range:
0.020 to 2000.000 um

Obscuration:
18.76 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.558 %

Result Emulation:
Off

Concentration:
0.0451 %Vol

Span :
3.043

Uniformity:
0.966

Result units:
Volume

Specific Surface Area:
0.43 m²/g

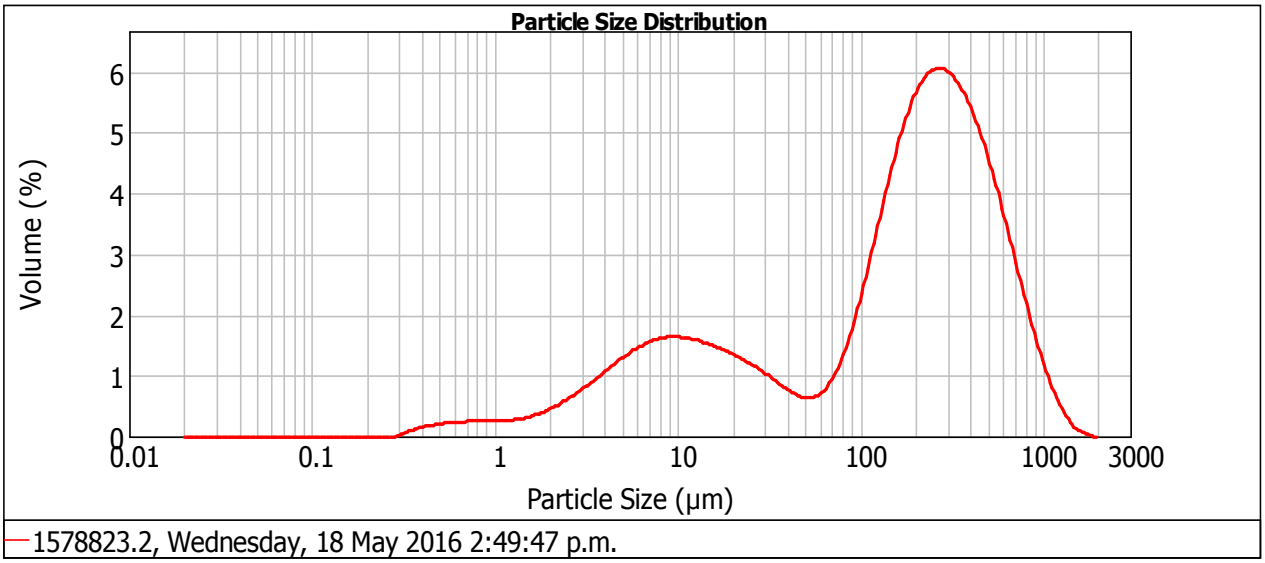
Surface Weighted Mean D[3,2]:
13.938 um

Vol. Weighted Mean D[4,3]:
252.039 um

Standard Deviation
252.12 um

---

d(0.1): 6.232 um **d(0.5):** 192.796 um **d(0.9):** 592.985 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	2.94	44.000	27.20	149.000	41.54	500.000	85.33	1680.000	99.98
0.060	0.00	3.900	6.09	53.000	28.00	177.000	46.99	590.000	89.87	2000.000	100.00
0.120	0.00	7.800	12.27	63.000	28.75	210.000	53.16	710.000	93.90		
0.240	0.00	10.000	14.92	74.000	29.68	250.000	59.92	840.000	96.55		
0.490	0.41	15.600	19.52	88.000	31.20	300.000	67.14	1000.000	98.37		
0.700	0.95	31.000	25.27	105.000	33.58	350.000	73.10	1190.000	99.38		
0.980	1.49	37.000	26.34	125.000	36.99	420.000	79.70	1410.000	99.85		

Operator notes:

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Hamilton, New Zealand

Result Analysis Report

Sample Name:
1578823.3

SOP Name:

Measured:
Wednesday, 18 May 2016 3:06:08 p.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Wednesday, 18 May 2016 3:06:09 p.m.

Sample bulk lot ref:
2016084/3

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
9.15 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.700 %

Result Emulation:
Off

Concentration:
0.1008 %Vol

Span :
1.863

Uniformity:
0.5

Result units:
Volume

Specific Surface Area:
0.0775 m²/g

Surface Weighted Mean D[3,2]:
77.374 um

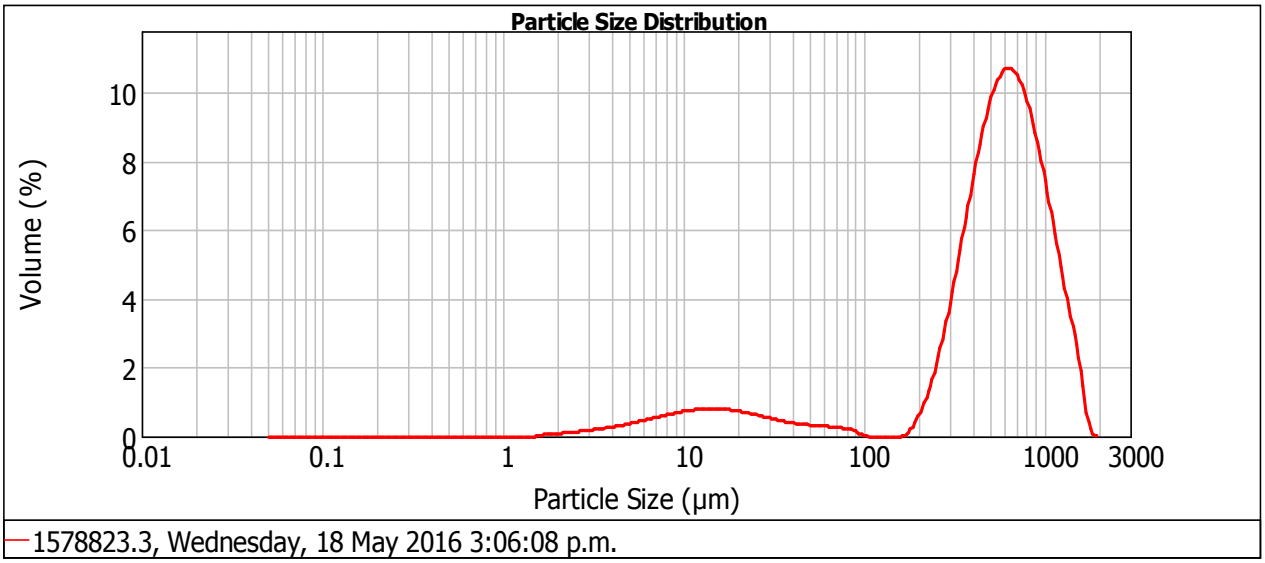
Vol. Weighted Mean D[4,3]:
617.198 um

Standard Deviation
369.036 um

---

d(0.1): 41.755 um **d(0.5):** 580.502 um **d(0.9):** 1123.321 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.10	44.000	10.13	149.000	11.51	500.000	40.02	1680.000	99.82
0.060	0.00	3.900	0.80	53.000	10.54	177.000	11.51	590.000	51.13	2000.000	100.00
0.120	0.00	7.800	2.71	63.000	10.89	210.000	11.98	710.000	64.05		
0.240	0.00	10.000	3.79	74.000	11.18	250.000	13.49	840.000	75.07		
0.490	0.00	15.600	6.06	88.000	11.43	300.000	16.89	1000.000	84.78		
0.700	0.00	31.000	9.13	105.000	11.51	350.000	21.67	1190.000	92.19		
0.980	0.00	37.000	9.68	125.000	11.51	420.000	29.86	1410.000	97.05		

Operator notes:

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Result Analysis Report

Sample Name:
1578823.4

SOP Name:

Measured:
Wednesday, 18 May 2016 3:56:54 p.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Wednesday, 18 May 2016 3:56:56 p.m.

Sample bulk lot ref:
2016084/4

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
13.11 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.894 %

Result Emulation:
Off

Concentration:
0.6562 %Vol

Span :
1.260

Uniformity:
0.387

Result units:
Volume

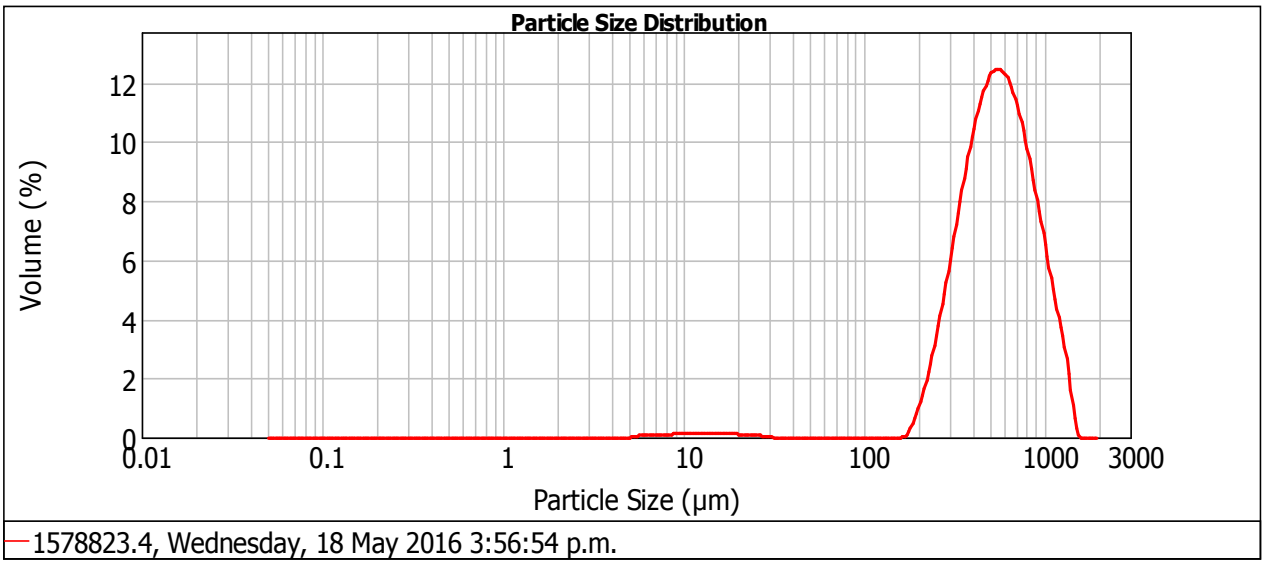
Specific Surface Area:
0.018 m²/g

Surface Weighted Mean D[3,2]:
333.807 um

Vol. Weighted Mean D[4,3]:
603.367 um

Standard Deviation
274.189 um

d(0.1): 300.504 um **d(0.5):** 552.885 um **d(0.9):** 997.288 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	1.20	149.000	1.20	500.000	41.85	1680.000	100.00
0.060	0.00	3.900	0.00	53.000	1.20	177.000	1.20	590.000	55.30	2000.000	100.00
0.120	0.00	7.800	0.19	63.000	1.20	210.000	1.97	710.000	69.74		
0.240	0.00	10.000	0.38	74.000	1.20	250.000	4.52	840.000	81.03		
0.490	0.00	15.600	0.79	88.000	1.20	300.000	9.94	1000.000	90.12		
0.700	0.00	31.000	1.20	105.000	1.20	350.000	17.12	1190.000	96.25		
0.980	0.00	37.000	1.20	125.000	1.20	420.000	28.60	1410.000	99.71		

Operator notes:

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Result Analysis Report

Sample Name:
1578823.5

SOP Name:

Measured:
Wednesday, 18 May 2016 4:02:53 p.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Wednesday, 18 May 2016 4:02:55 p.m.

Sample bulk lot ref:
2016084/5

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
19.07 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.304 %

Result Emulation:
Off

Concentration:
0.3821 %Vol

Span :
1.456

Uniformity:
0.461

Result units:
Volume

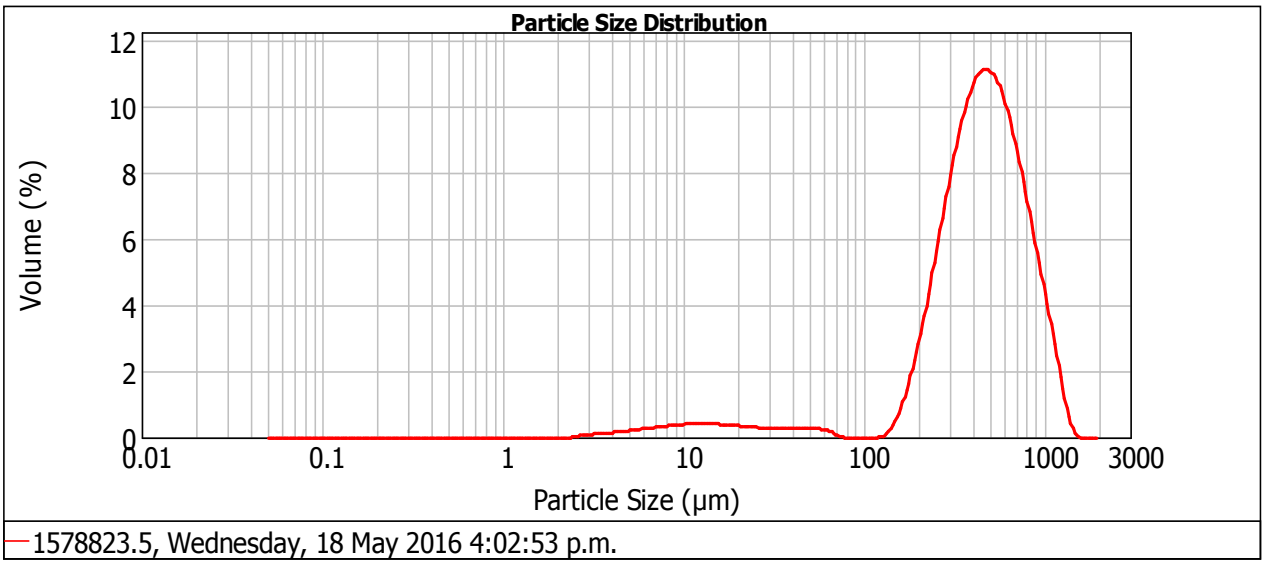
Specific Surface Area:
0.0456 m²/g

Surface Weighted Mean D[3,2]:
131.618 um

Vol. Weighted Mean D[4,3]:
497.639 um

Standard Deviation
270.118 um

d(0.1): 209.672 um **d(0.5):** 456.274 um **d(0.9):** 874.222 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	5.29	149.000	6.25	500.000	56.67	1680.000	100.00
0.060	0.00	3.900	0.27	53.000	5.65	177.000	7.35	590.000	68.36	2000.000	100.00
0.120	0.00	7.800	1.33	63.000	5.93	210.000	10.03	710.000	79.94		
0.240	0.00	10.000	1.93	74.000	6.07	250.000	14.99	840.000	88.34		
0.490	0.00	15.600	3.13	88.000	6.07	300.000	22.92	1000.000	94.65		
0.700	0.00	31.000	4.63	105.000	6.07	350.000	31.74	1190.000	98.55		
0.980	0.00	37.000	4.96	125.000	6.07	420.000	44.03	1410.000	99.95		

Operator notes:

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Result Analysis Report

Sample Name:
1578823.6

SOP Name:

Measured:
Wednesday, 18 May 2016 4:07:50 p.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Wednesday, 18 May 2016 4:07:52 p.m.

Sample bulk lot ref:
2016084/6

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
14.78 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.509 %

Result Emulation:
Off

Concentration:
0.5627 %Vol

Span :
1.197

Uniformity:
0.378

Result units:
Volume

Specific Surface Area:
0.0237 m²/g

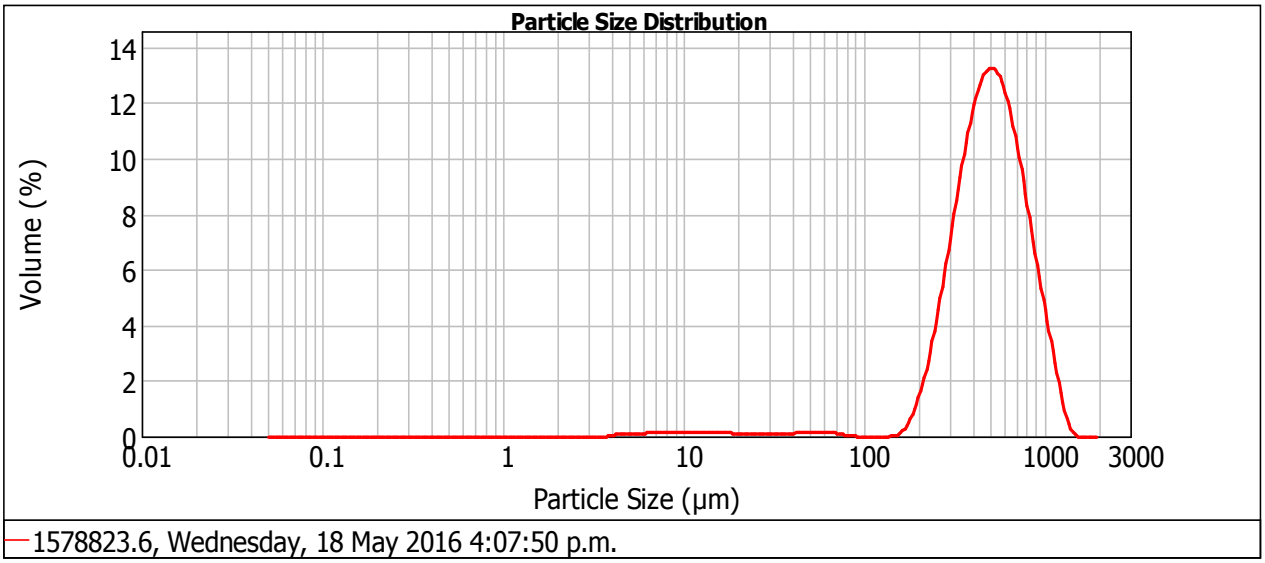
Surface Weighted Mean D[3,2]:
252.960 um

Vol. Weighted Mean D[4,3]:
539.538 um

Standard Deviation
242.384 um

---

d(0.1): 276.201 um **d(0.5):** 501.305 um **d(0.9):** 876.095 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	1.84	149.000	2.40	500.000	49.77	1680.000	100.00
0.060	0.00	3.900	0.00	53.000	2.03	177.000	2.58	590.000	63.96	2000.000	100.00
0.120	0.00	7.800	0.46	63.000	2.22	210.000	3.74	710.000	78.09		
0.240	0.00	10.000	0.72	74.000	2.36	250.000	6.91	840.000	88.01		
0.490	0.00	15.600	1.20	88.000	2.40	300.000	13.40	1000.000	94.98		
0.700	0.00	31.000	1.63	105.000	2.40	350.000	21.85	1190.000	98.87		
0.980	0.00	37.000	1.71	125.000	2.40	420.000	35.06	1410.000	99.98		

Operator notes:

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Result Analysis Report

Sample Name:
1578823.7

SOP Name:

Measured:
Wednesday, 18 May 2016 4:17:06 p.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Wednesday, 18 May 2016 4:17:08 p.m.

Sample bulk lot ref:
2016084/7

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
14.37 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.697 %

Result Emulation:
Off

Concentration:
0.8625 %Vol

Span :
1.322

Uniformity:
0.406

Result units:
Volume

Specific Surface Area:
0.0152 m²/g

Surface Weighted Mean D[3,2]:
393.714 um

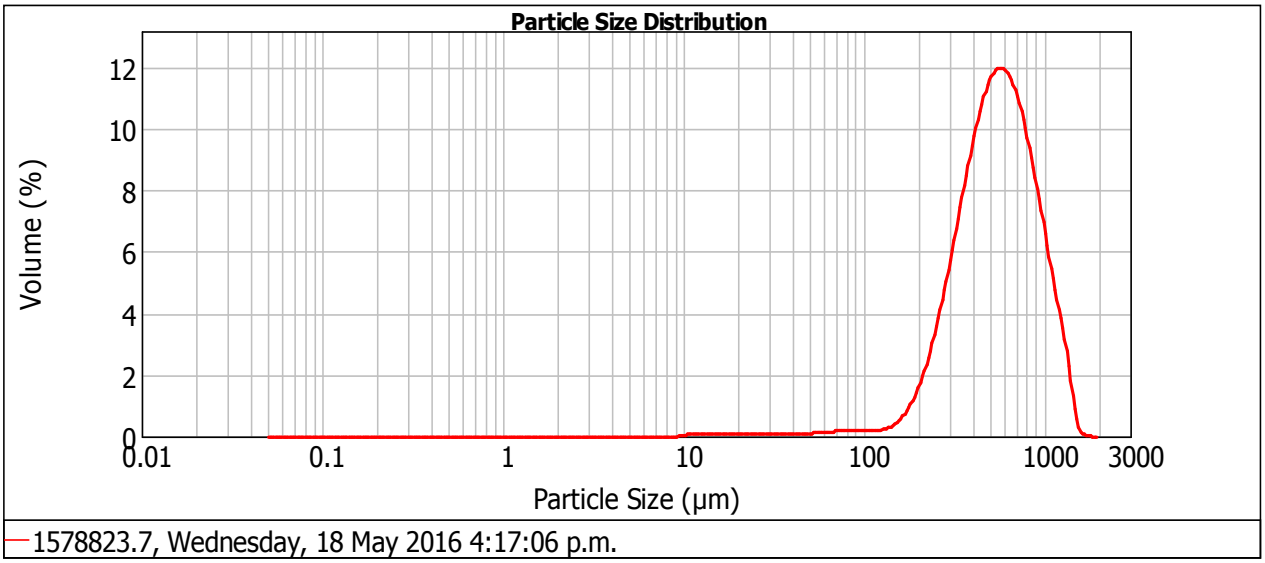
Vol. Weighted Mean D[4,3]:
599.922 um

Standard Deviation
286.183 um

---

d(0.1): 278.011 um **d(0.5):** 551.799 um **d(0.9):** 1007.495 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	0.74	149.000	2.08	500.000	42.39	1680.000	99.99
0.060	0.00	3.900	0.00	53.000	0.86	177.000	2.77	590.000	55.25	2000.000	100.00
0.120	0.00	7.800	0.00	63.000	1.01	210.000	4.26	710.000	69.34		
0.240	0.00	10.000	0.00	74.000	1.17	250.000	7.21	840.000	80.55		
0.490	0.00	15.600	0.23	88.000	1.37	300.000	12.55	1000.000	89.67		
0.700	0.00	31.000	0.59	105.000	1.56	350.000	19.28	1190.000	95.91		
0.980	0.00	37.000	0.66	125.000	1.76	420.000	29.95	1410.000	99.48		

Operator notes:

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Result Analysis Report

Sample Name:
1578823.8

SOP Name:

Measured:
Wednesday, 18 May 2016 4:21:49 p.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Wednesday, 18 May 2016 4:21:51 p.m.

Sample bulk lot ref:
2016084/8

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
16.54 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.464 %

Result Emulation:
Off

Concentration:
0.5503 %Vol

Span :
1.251

Uniformity:
0.398

Result units:
Volume

Specific Surface Area:
0.0273 m²/g

Surface Weighted Mean D[3,2]:
219.393 um

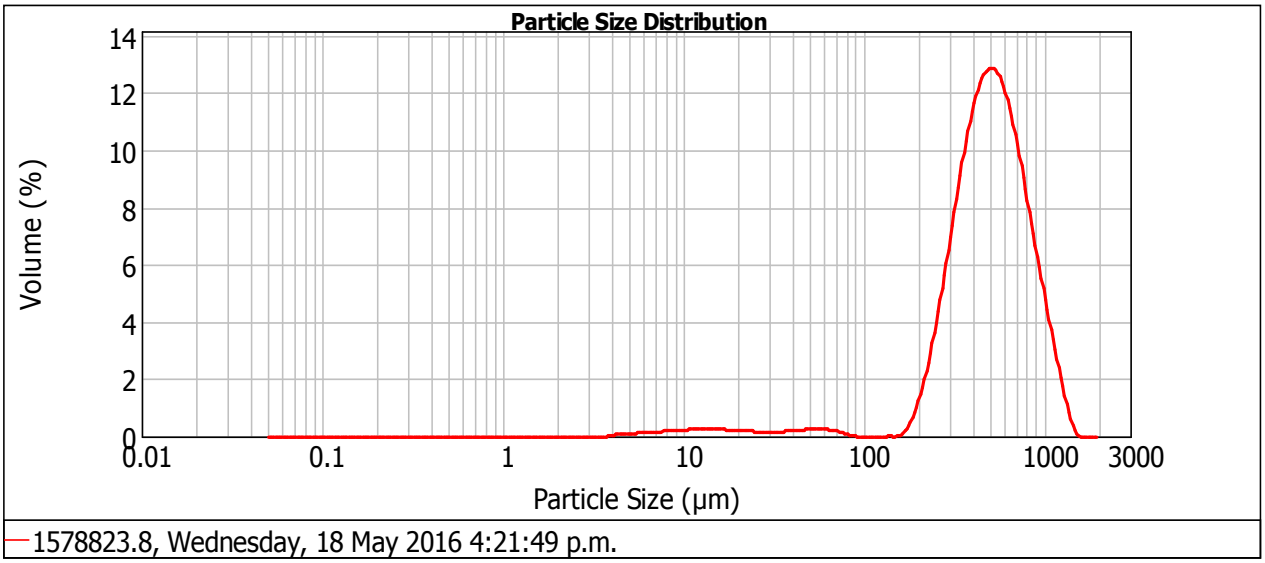
Vol. Weighted Mean D[4,3]:
542.916 um

Standard Deviation
257.675 um

---

d(0.1): 270.110 um **d(0.5):** 502.601 um **d(0.9):** 898.772 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	2.82	149.000	3.68	500.000	49.56	1680.000	100.00
0.060	0.00	3.900	0.00	53.000	3.11	177.000	3.78	590.000	63.33	2000.000	100.00
0.120	0.00	7.800	0.53	63.000	3.39	210.000	4.79	710.000	77.08		
0.240	0.00	10.000	0.85	74.000	3.60	250.000	7.77	840.000	86.88		
0.490	0.00	15.600	1.55	88.000	3.68	300.000	14.07	1000.000	94.00		
0.700	0.00	31.000	2.41	105.000	3.68	350.000	22.33	1190.000	98.24		
0.980	0.00	37.000	2.60	125.000	3.68	420.000	35.24	1410.000	99.91		

Operator notes:

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Result Analysis Report

Sample Name:
1578823.9

SOP Name:

Measured:
Wednesday, 18 May 2016 4:26:31 p.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Wednesday, 18 May 2016 4:26:33 p.m.

Sample bulk lot ref:
2016084/9

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
9.42 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.565 %

Result Emulation:
Off

Concentration:
0.6571 %Vol

Span :
1.087

Uniformity:
0.337

Result units:
Volume

Specific Surface Area:
0.0128 m²/g

Surface Weighted Mean D[3,2]:
467.557 um

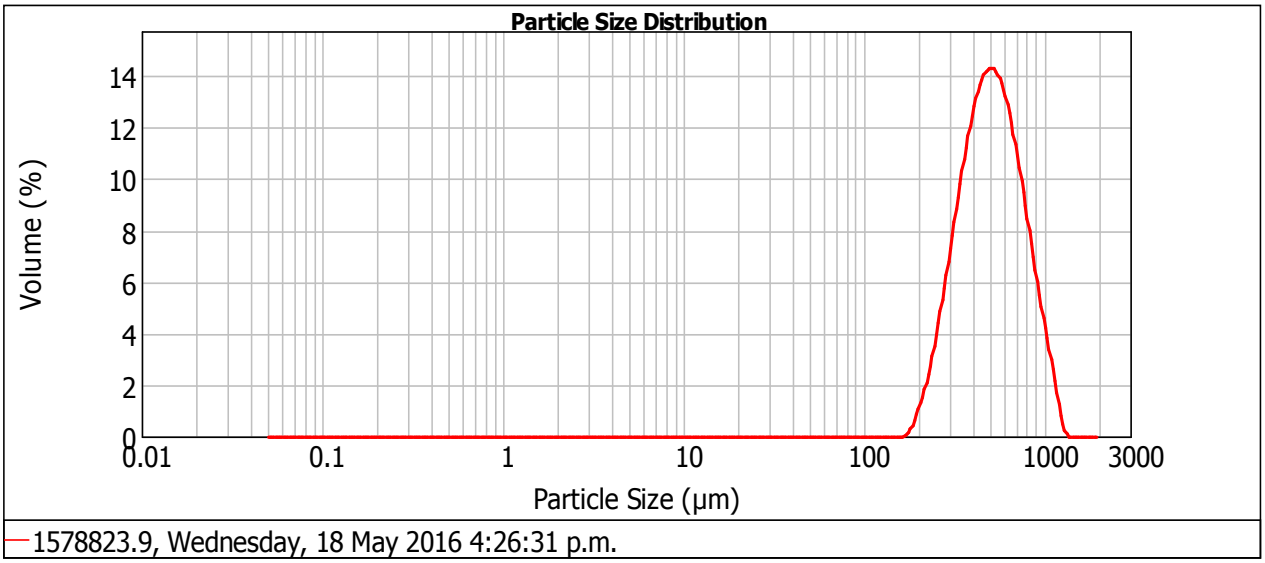
Vol. Weighted Mean D[4,3]:
544.858 um

Standard Deviation
214.469 um

---

d(0.1): 299.850 um **d(0.5):** 506.214 um **d(0.9):** 850.290 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	0.00	149.000	0.00	500.000	48.84	1680.000	100.00
0.060	0.00	3.900	0.00	53.000	0.00	177.000	0.00	590.000	64.14	2000.000	100.00
0.120	0.00	7.800	0.00	63.000	0.00	210.000	0.78	710.000	79.15		
0.240	0.00	10.000	0.00	74.000	0.00	250.000	3.60	840.000	89.39		
0.490	0.00	15.600	0.00	88.000	0.00	300.000	10.02	1000.000	96.19		
0.700	0.00	31.000	0.00	105.000	0.00	350.000	18.82	1190.000	99.62		
0.980	0.00	37.000	0.00	125.000	0.00	420.000	32.94	1410.000	100.00		

Operator notes:

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MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
1578823.10

SOP Name:

Measured:
Wednesday, 18 May 2016 4:30:56 p.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Wednesday, 18 May 2016 4:30:57 p.m.

Sample bulk lot ref:
2016084/10

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
10.97 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.738 %

Result Emulation:
Off

Concentration:
0.7666 %Vol

Span :
1.284

Uniformity:
0.395

Result units:
Volume

Specific Surface Area:
0.0129 m²/g

Surface Weighted Mean D[3,2]:
464.788 um

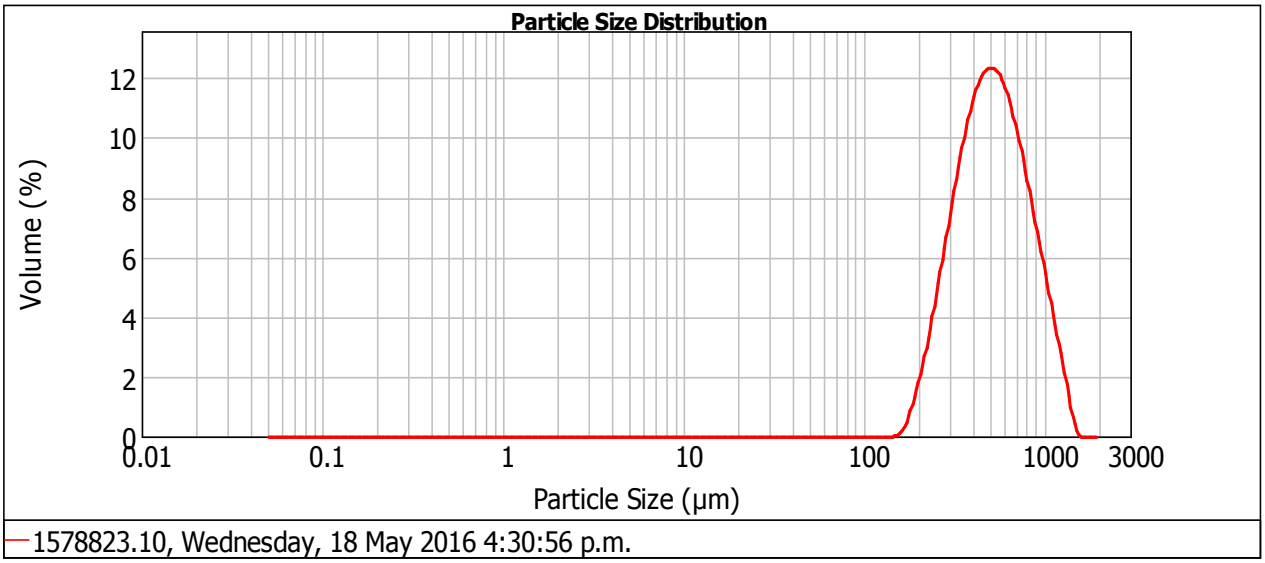
Vol. Weighted Mean D[4,3]:
568.054 um

Standard Deviation
258.201 um

---

d(0.1): 282.648 um **d(0.5):** 513.233 um **d(0.9):** 941.694 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	0.00	149.000	0.00	500.000	47.89	1680.000	100.00
0.060	0.00	3.900	0.00	53.000	0.00	177.000	0.21	590.000	61.11	2000.000	100.00
0.120	0.00	7.800	0.00	63.000	0.00	210.000	1.76	710.000	74.58		
0.240	0.00	10.000	0.00	74.000	0.00	250.000	5.58	840.000	84.61		
0.490	0.00	15.600	0.00	88.000	0.00	300.000	12.70	1000.000	92.37		
0.700	0.00	31.000	0.00	105.000	0.00	350.000	21.31	1190.000	97.42		
0.980	0.00	37.000	0.00	125.000	0.00	420.000	34.10	1410.000	99.83		

Operator notes:

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MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
1578823.11

SOP Name:
Sediment

Measured:
Thursday, 19 May 2016 10:54:50 a.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Thursday, 19 May 2016 10:54:52 a.m.

Sample bulk lot ref:
2016084/11

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0.2

Size range:
0.020 to 2000.000 um

Obscuration:
13.15 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.566 %

Result Emulation:
Off

Concentration:
0.4583 %Vol

Span :
1.336

Uniformity:
0.418

Result units:
Volume

Specific Surface Area:
0.0255 m²/g

Surface Weighted Mean D[3,2]:
235.629 um

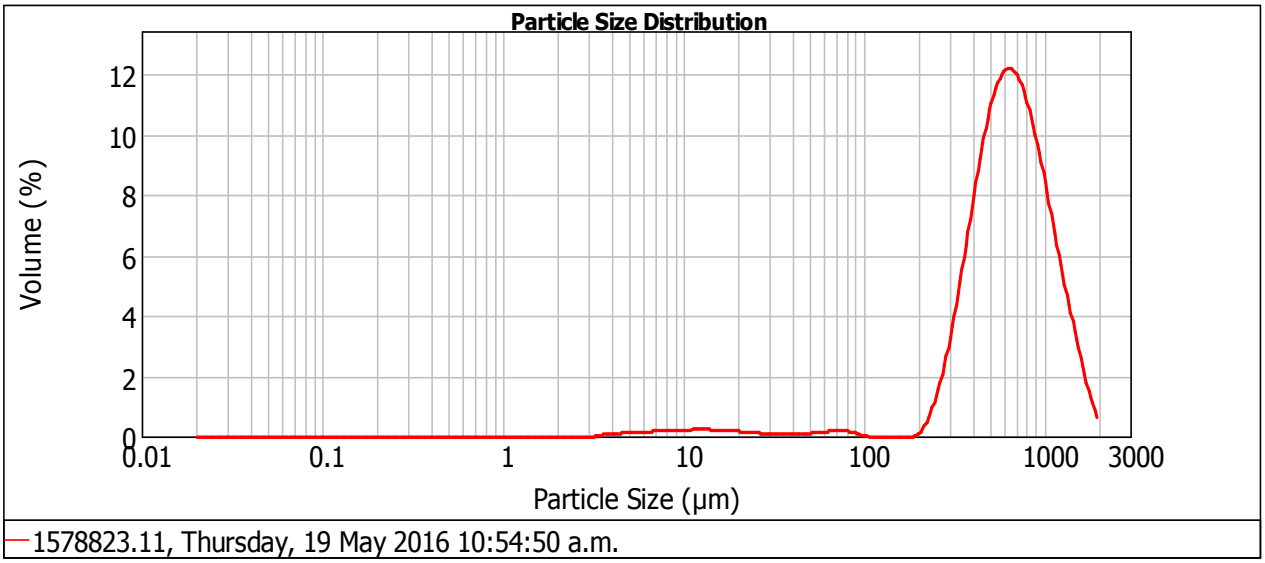
Vol. Weighted Mean D[4,3]:
711.266 um

Standard Deviation
354.533 um

---

d(0.1): 341.801 um **d(0.5):** 645.893 um **d(0.9):** 1204.965 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	2.46	149.000	3.18	500.000	30.24	1680.000	98.61
0.060	0.00	3.900	0.06	53.000	2.58	177.000	3.18	590.000	42.78	2000.000	100.00
0.120	0.00	7.800	0.68	63.000	2.74	210.000	3.20	710.000	57.52		
0.240	0.00	10.000	1.01	74.000	2.92	250.000	3.95	840.000	70.07		
0.490	0.00	15.600	1.64	88.000	3.12	300.000	6.49	1000.000	81.09		
0.700	0.00	31.000	2.31	105.000	3.18	350.000	10.82	1190.000	89.50		
0.980	0.00	37.000	2.39	125.000	3.18	420.000	19.15	1410.000	95.14		

Operator notes:

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Result Analysis Report

Sample Name:
1578823.12

SOP Name:

Measured:
Thursday, 19 May 2016 11:05:42 a.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Thursday, 19 May 2016 11:05:43 a.m.

Sample bulk lot ref:
2016084/12

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
12.82 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.547 %

Result Emulation:
Off

Concentration:
0.8829 %Vol

Span :
1.371

Uniformity:
0.424

Result units:
Volume

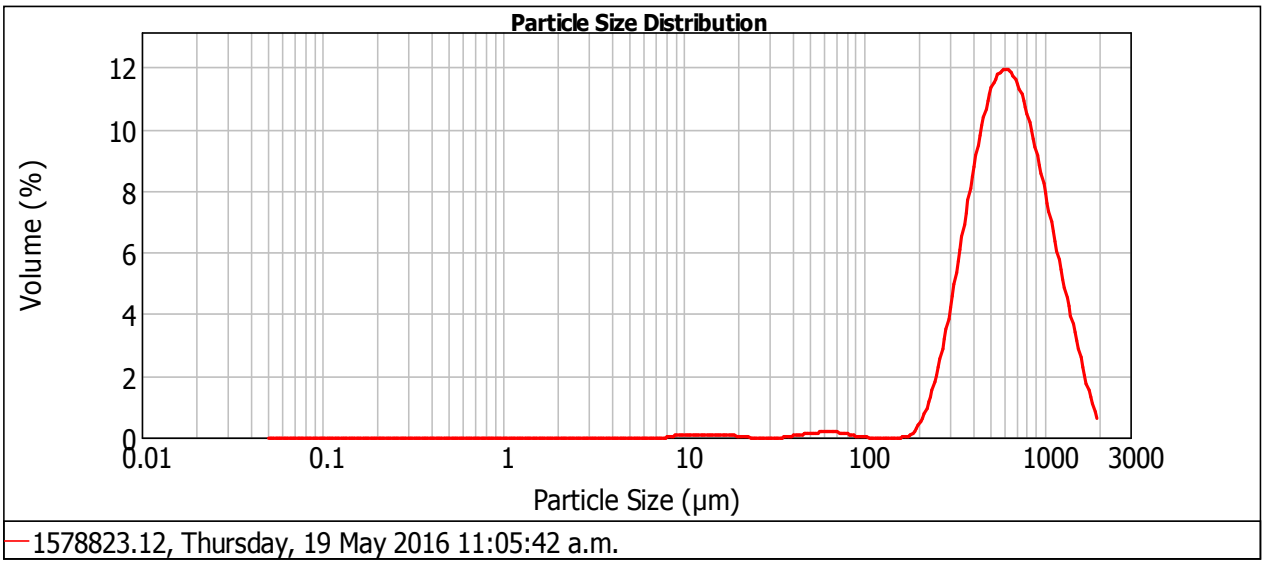
Specific Surface Area:
0.0131 m²/g

Surface Weighted Mean D[3,2]:
456.590 um

Vol. Weighted Mean D[4,3]:
703.268 um

Standard Deviation
347.045 um

d(0.1): 336.765 um **d(0.5):** 627.155 um **d(0.9):** 1196.701 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	0.49	149.000	1.15	500.000	32.61	1680.000	98.61
0.060	0.00	3.900	0.00	53.000	0.63	177.000	1.15	590.000	45.22	2000.000	100.00
0.120	0.00	7.800	0.00	63.000	0.82	210.000	1.41	710.000	59.55		
0.240	0.00	10.000	0.08	74.000	1.00	250.000	2.74	840.000	71.47		
0.490	0.00	15.600	0.31	88.000	1.12	300.000	6.24	1000.000	81.84		
0.700	0.00	31.000	0.44	105.000	1.15	350.000	11.55	1190.000	89.78		
0.980	0.00	37.000	0.44	125.000	1.15	420.000	20.92	1410.000	95.21		

Operator notes:

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MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
1578823.13

SOP Name:

Measured:
Thursday, 19 May 2016 11:10:11 a.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Thursday, 19 May 2016 11:10:13 a.m.

Sample bulk lot ref:
2016084/13

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
13.52 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.478 %

Result Emulation:
Off

Concentration:
0.7557 %Vol

Span :
1.330

Uniformity:
0.416

Result units:
Volume

Specific Surface Area:
0.0162 m²/g

Surface Weighted Mean D[3,2]:
370.921 um

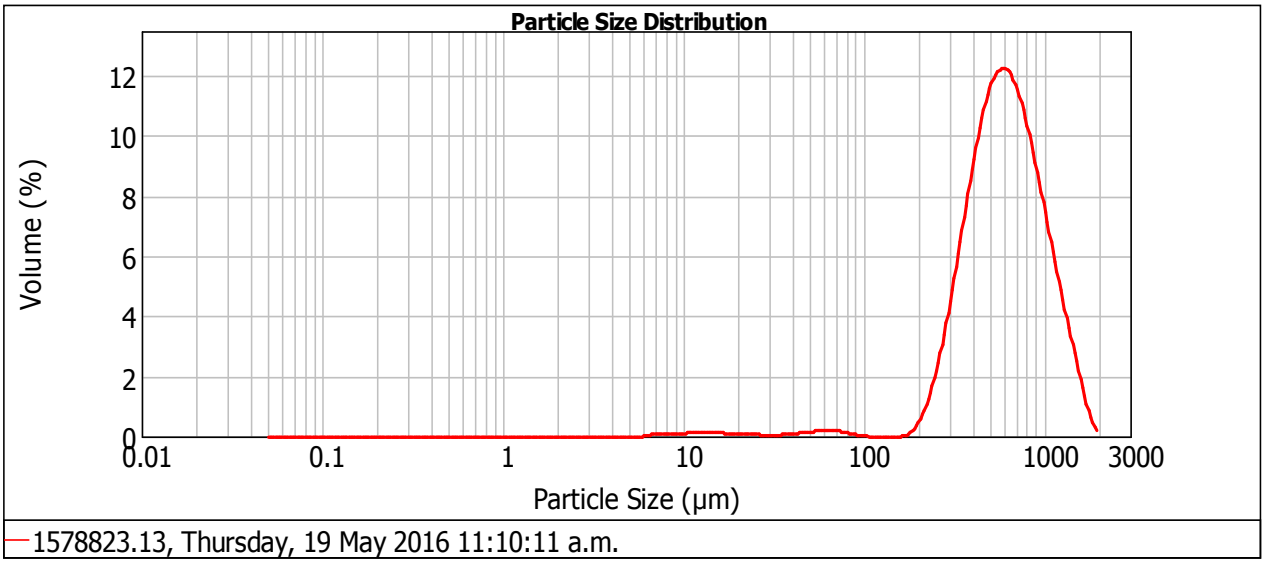
Vol. Weighted Mean D[4,3]:
669.388 um

Standard Deviation
325.739 um

---

d(0.1): 325.265 um **d(0.5):** 603.555 um **d(0.9):** 1128.137 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	1.09	149.000	1.82	500.000	35.11	1680.000	99.38
0.060	0.00	3.900	0.00	53.000	1.26	177.000	1.82	590.000	48.17	2000.000	100.00
0.120	0.00	7.800	0.11	63.000	1.46	210.000	2.14	710.000	62.77		
0.240	0.00	10.000	0.27	74.000	1.65	250.000	3.60	840.000	74.63		
0.490	0.00	15.600	0.61	88.000	1.79	300.000	7.36	1000.000	84.62		
0.700	0.00	31.000	0.93	105.000	1.82	350.000	12.99	1190.000	91.98		
0.980	0.00	37.000	0.98	125.000	1.82	420.000	22.88	1410.000	96.75		

Operator notes:

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MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
1578823.14

SOP Name:

Measured:
Thursday, 19 May 2016 11:14:36 a.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Thursday, 19 May 2016 11:14:38 a.m.

Sample bulk lot ref:
2016084/14

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
17.73 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.358 %

Result Emulation:
Off

Concentration:
0.1548 %Vol

Span :
1.767

Uniformity:
0.484

Result units:
Volume

Specific Surface Area:
0.103 m²/g

Surface Weighted Mean D[3,2]:
58.320 um

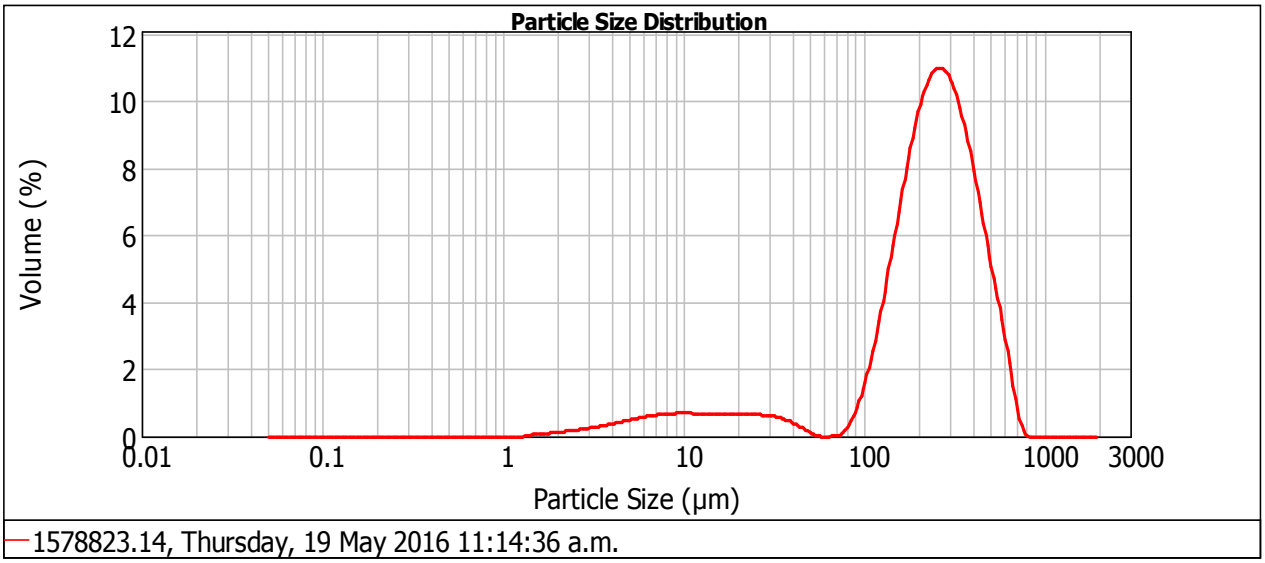
Vol. Weighted Mean D[4,3]:
260.070 um

Standard Deviation
150.393 um

---

d(0.1): 35.054 um **d(0.5):** 244.077 um **d(0.9):** 466.285 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.21	44.000	10.65	149.000	21.21	500.000	92.64	1680.000	100.00
0.060	0.00	3.900	1.18	53.000	10.86	177.000	29.30	590.000	97.30	2000.000	100.00
0.120	0.00	7.800	3.57	63.000	10.86	210.000	39.63	710.000	99.84		
0.240	0.00	10.000	4.68	74.000	10.87	250.000	51.71	840.000	100.00		
0.490	0.00	15.600	6.65	88.000	11.16	300.000	64.74	1000.000	100.00		
0.700	0.00	31.000	9.54	105.000	12.51	350.000	75.02	1190.000	100.00		
0.980	0.00	37.000	10.18	125.000	15.63	420.000	85.29	1410.000	100.00		

Operator notes:

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MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
1578823.15

SOP Name:

Measured:
Thursday, 19 May 2016 11:19:06 a.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Thursday, 19 May 2016 11:19:08 a.m.

Sample bulk lot ref:
2016084/15

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
12.24 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.579 %

Result Emulation:
Off

Concentration:
0.5384 %Vol

Span :
1.338

Uniformity:
0.43

Result units:
Volume

Specific Surface Area:
0.0204 m²/g

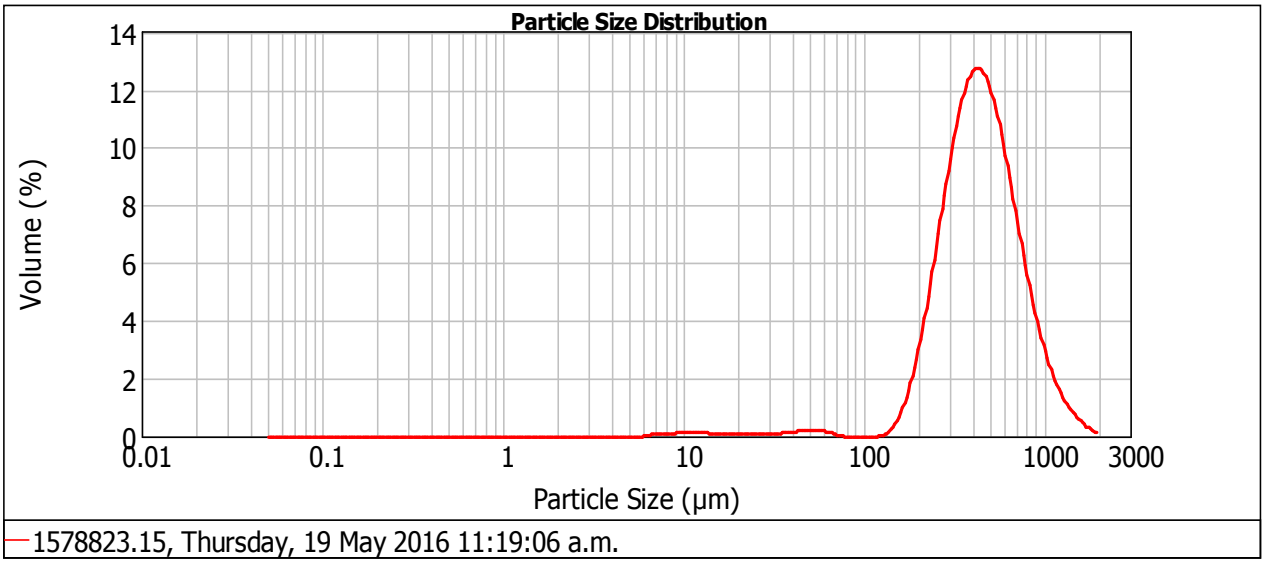
Surface Weighted Mean D[3,2]:
293.653 um

Vol. Weighted Mean D[4,3]:
495.997 um

Standard Deviation
261.343 um

d(0.1): 241.464 um **d(0.5):** 438.561 um **d(0.9):** 828.058 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	1.29	149.000	2.00	500.000	60.75	1680.000	99.74
0.060	0.00	3.900	0.00	53.000	1.53	177.000	3.02	590.000	72.95	2000.000	100.00
0.120	0.00	7.800	0.12	63.000	1.74	210.000	5.78	710.000	83.68		
0.240	0.00	10.000	0.30	74.000	1.84	250.000	11.38	840.000	90.47		
0.490	0.00	15.600	0.64	88.000	1.84	300.000	20.87	1000.000	94.98		
0.700	0.00	31.000	0.99	105.000	1.84	350.000	31.62	1190.000	97.61		
0.980	0.00	37.000	1.12	125.000	1.84	420.000	46.38	1410.000	99.01		

Operator notes:

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MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
1578823.16

SOP Name:

Measured:
Thursday, 19 May 2016 11:23:36 a.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Thursday, 19 May 2016 11:23:38 a.m.

Sample bulk lot ref:
2016084/16

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
16.54 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.324 %

Result Emulation:
Off

Concentration:
0.1483 %Vol

Span :
1.820

Uniformity:
0.504

Result units:
Volume

Specific Surface Area:
0.0998 m²/g

Surface Weighted Mean D[3,2]:
60.102 um

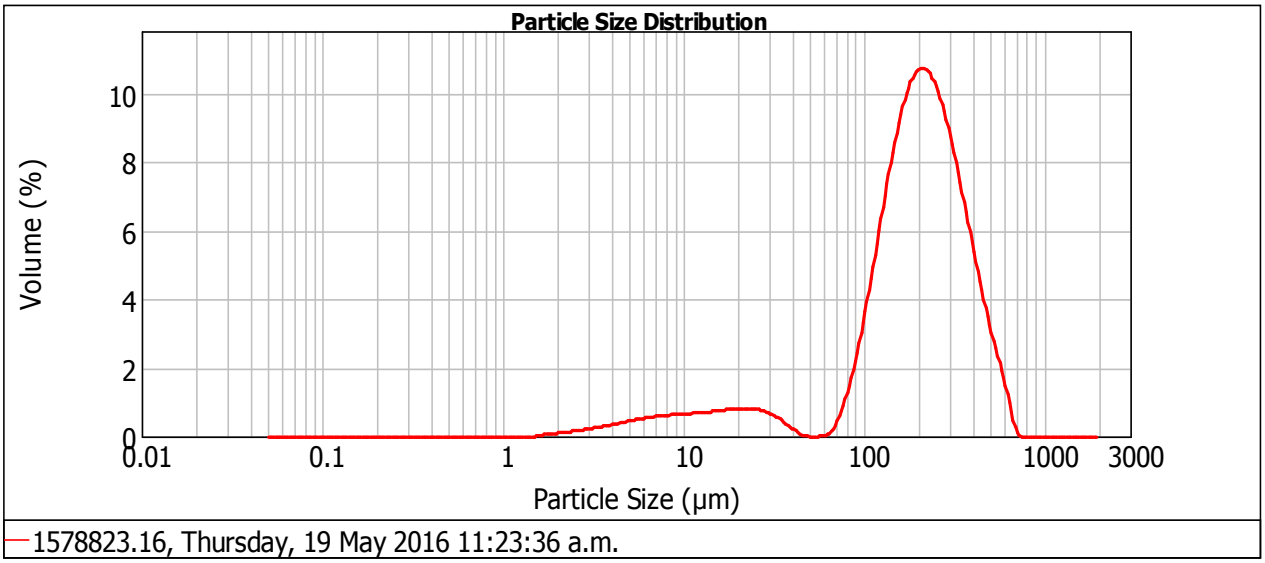
Vol. Weighted Mean D[4,3]:
220.858 um

Standard Deviation
132.261 um

---

d(0.1): 33.480 um **d(0.5):** 202.248 um **d(0.9):** 401.599 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.10	44.000	10.56	149.000	30.17	500.000	96.22	1680.000	100.00
0.060	0.00	3.900	0.97	53.000	10.57	177.000	40.83	590.000	98.92	2000.000	100.00
0.120	0.00	7.800	3.16	63.000	10.58	210.000	52.65	710.000	100.00		
0.240	0.00	10.000	4.19	74.000	10.84	250.000	64.75	840.000	100.00		
0.490	0.00	15.600	6.22	88.000	12.23	300.000	76.23	1000.000	100.00		
0.700	0.00	31.000	9.70	105.000	15.63	350.000	84.30	1190.000	100.00		
0.980	0.00	37.000	10.31	125.000	21.52	420.000	91.55	1410.000	100.00		

Operator notes:

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MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
1578823.17

SOP Name:

Measured:
Thursday, 19 May 2016 11:28:16 a.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Thursday, 19 May 2016 11:28:18 a.m.

Sample bulk lot ref:
2016084/17

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
17.91 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.322 %

Result Emulation:
Off

Concentration:
0.0998 %Vol

Span :
2.766

Uniformity:
0.831

Result units:
Volume

Specific Surface Area:
0.175 m²/g

Surface Weighted Mean D[3,2]:
34.326 um

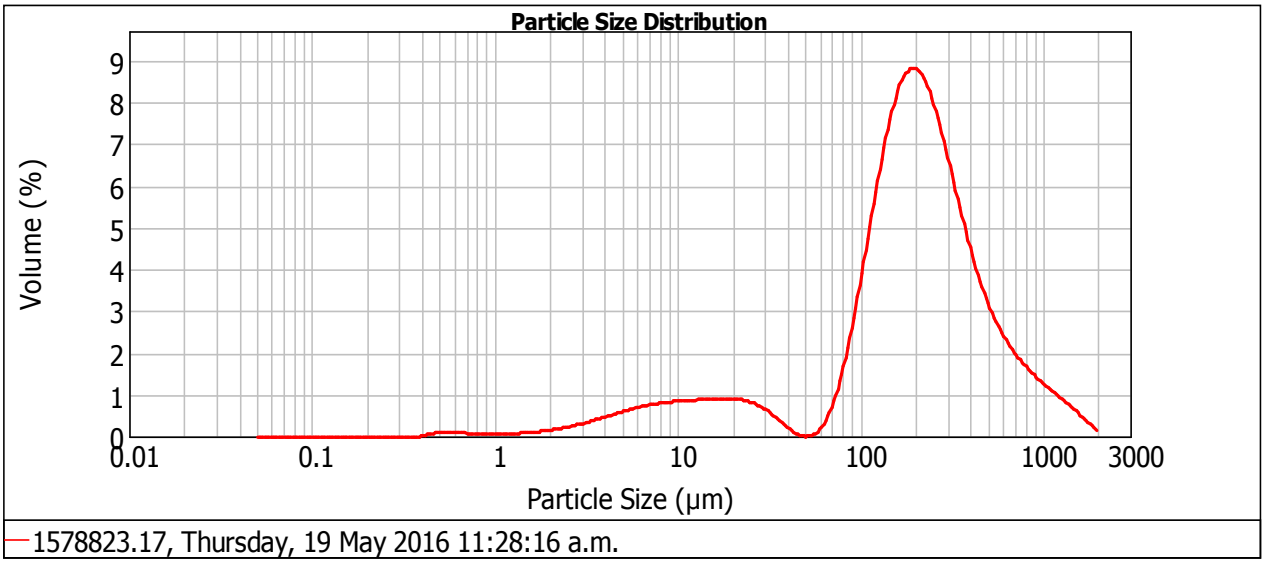
Vol. Weighted Mean D[4,3]:
272.203 um

Standard Deviation
269.3 um

---

d(0.1): 19.024 um **d(0.5):** 199.216 um **d(0.9):** 570.033 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.85	44.000	13.41	149.000	33.81	500.000	87.53	1680.000	99.68
0.060	0.00	3.900	2.08	53.000	13.43	177.000	43.19	590.000	90.58	2000.000	100.00
0.120	0.00	7.800	4.97	63.000	13.54	210.000	53.04	710.000	93.25		
0.240	0.00	10.000	6.30	74.000	14.17	250.000	62.68	840.000	95.19		
0.490	0.08	15.600	8.83	88.000	16.04	300.000	71.51	1000.000	96.81		
0.700	0.27	31.000	12.60	105.000	19.81	350.000	77.66	1190.000	98.09		
0.980	0.43	37.000	13.17	125.000	25.74	420.000	83.38	1410.000	99.03		

Operator notes:

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MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name:
1578823.18

SOP Name:

Measured:
Thursday, 19 May 2016 11:33:13 a.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Thursday, 19 May 2016 11:33:15 a.m.

Sample bulk lot ref:
2016084/18

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
18.67 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.331 %

Result Emulation:
Off

Concentration:
0.5671 %Vol

Span :
1.194

Uniformity:
0.377

Result units:
Volume

Specific Surface Area:
0.0305 m²/g

Surface Weighted Mean D[3,2]:
196.500 um

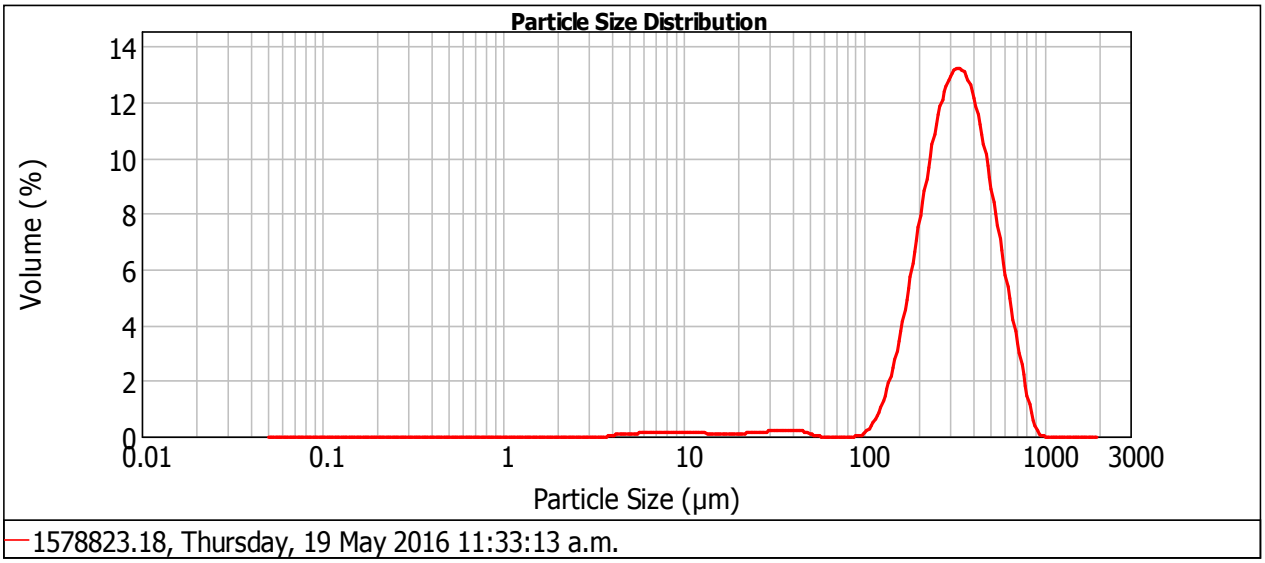
Vol. Weighted Mean D[4,3]:
351.329 um

Standard Deviation
156.885 um

---

d(0.1): 179.187 um **d(0.5):** 326.989 um **d(0.9):** 569.467 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	2.14	149.000	5.11	500.000	83.08	1680.000	100.00
0.060	0.00	3.900	0.00	53.000	2.32	177.000	9.56	590.000	91.55	2000.000	100.00
0.120	0.00	7.800	0.49	63.000	2.32	210.000	17.09	710.000	97.43		
0.240	0.00	10.000	0.73	74.000	2.32	250.000	28.15	840.000	99.73		
0.490	0.00	15.600	1.09	88.000	2.32	300.000	42.60	1000.000	100.00		
0.700	0.00	31.000	1.67	105.000	2.38	350.000	55.89	1190.000	100.00		
0.980	0.00	37.000	1.91	125.000	3.02	420.000	70.97	1410.000	100.00		

Operator notes:

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Hamilton, New Zealand

Result Analysis Report

Sample Name:
1578823.19

SOP Name:

Measured:
Thursday, 19 May 2016 11:38:41 a.m.

Sample Source & type:

Measured by:
rodgers

Analysed:
Thursday, 19 May 2016 11:38:43 a.m.

Sample bulk lot ref:
2016084/19

Result Source:
Measurement

Particle Name:
Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.500

Absorption:
0.2

Size range:
0.050 to 2000.000 um

Obscuration:
16.54 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.374 %

Result Emulation:
Off

Concentration:
0.4830 %Vol

Span :
1.284

Uniformity:
0.414

Result units:
Volume

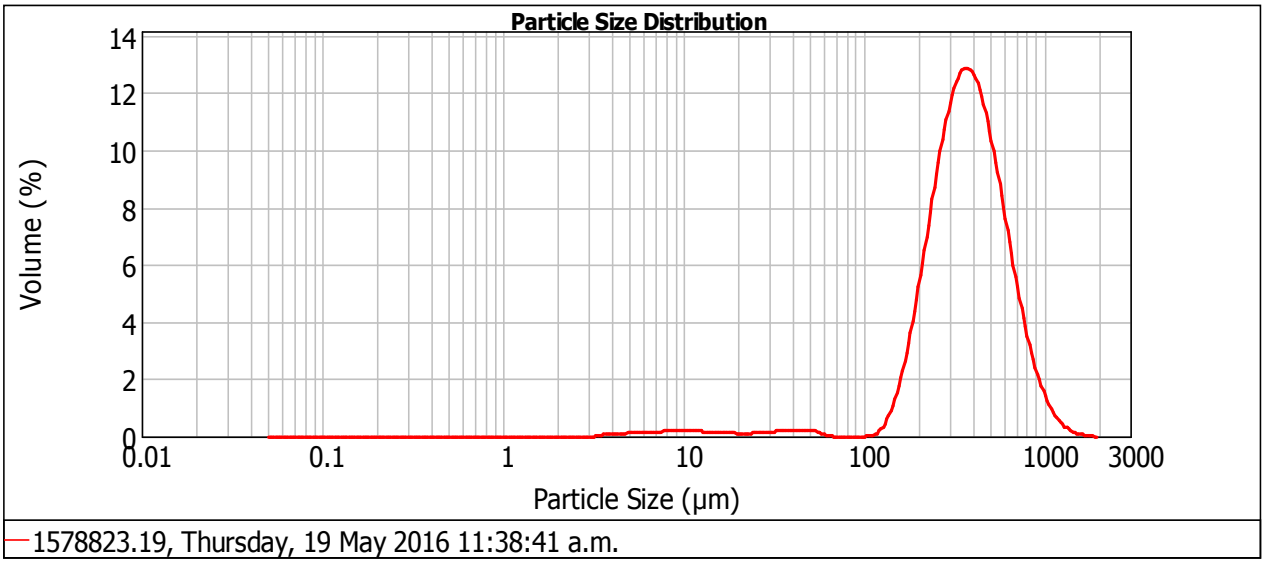
Specific Surface Area:
0.0312 m²/g

Surface Weighted Mean D[3,2]:
192.288 um

Vol. Weighted Mean D[4,3]:
412.727 um

Standard Deviation
208.666 um

d(0.1): 203.166 um **d(0.5):** 373.485 um **d(0.9):** 682.542 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	2.000	0.00	44.000	2.48	149.000	3.74	500.000	73.14	1680.000	99.98
0.060	0.00	3.900	0.06	53.000	2.75	177.000	6.18	590.000	83.36	2000.000	100.00
0.120	0.00	7.800	0.65	63.000	2.88	210.000	11.22	710.000	91.43		
0.240	0.00	10.000	0.95	74.000	2.88	250.000	19.71	840.000	95.89		
0.490	0.00	15.600	1.45	88.000	2.88	300.000	32.10	1000.000	98.37		
0.700	0.00	31.000	2.01	105.000	2.88	350.000	44.53	1190.000	99.49		
0.980	0.00	37.000	2.23	125.000	2.95	420.000	59.80	1410.000	99.89		

Operator notes:

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V 1	V 1	V 1	V 1	V 1A	V 1A	V 1A	V 1A	V 1A	V 2	V 2	V 2	V 2
Sample Type: Sediment	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B
Sample Name:	27/02/16	27/02/16	27/02/16	27/02/16	27/02/16	27/02/16	27/02/16	27/02/16	27/02/16	28/02/16	28/02/16	28/02/16	28/02/16
Lab Number:	1545303.1	1545303.3	1545303.4	1545303.5	1545303.7	1545303.8	1545303.1	1545303.11	1545303.13	1545223.1	1545223.2	1545223.4	1545223.5
Dry Matter (g/100g as rcvd)	79	-	79	-	80	-	83	-	-	86	-	85	-
Total Organic Carbon (g/100g dry wt)	-	< 0.13	-	< 0.13	-	< 0.05	-	< 0.05	< 0.13	-	< 0.05	-	< 0.05
Antifouling cobiocides in sediment samples by LCMSMS													
Diuron	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010	-	-	< 0.010	-	< 0.010	-
Irgarol	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010	-	-	< 0.010	-	< 0.010	-
Isoproturon	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010	-	-	< 0.010	-	< 0.010	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg													
Total Recoverable Arsenic	-	3.4	-	3.5	-	2.2	-	2.2	2.5	-	2.4	-	2.2
Total Recoverable Cadmium	-	< 0.010	-	0.011	-	< 0.010	-	< 0.010	0.013	-	< 0.010	-	< 0.010
Total Recoverable Chromium	-	8.9	-	11.4	-	6.9	-	7.2	5.9	-	7.5	-	18.2
Total Recoverable Copper	-	0.5	-	0.6	-	0.7	-	0.7	0.4	-	0.4	-	0.5
Total Recoverable Lead	-	1.12	-	1.4	-	1.07	-	1.56	0.81	-	0.91	-	1.43
Total Recoverable Mercury	-	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010	< 0.010	-	< 0.010	-	< 0.010
Total Recoverable Nickel	-	1.9	-	2.5	-	1.6	-	1.8	1.9	-	2.1	-	8.7
Total Recoverable Zinc	-	9.1	-	11.7	-	8.1	-	8.5	5.7	-	9.3	-	6.2
Polycyclic Aromatic Hydrocarbons Screening in Soil													
Acenaphthene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Acenaphthylene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Anthracene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Benzo[a]anthracene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Benzo[a]pyrene (BAP)	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Benzo[g,h,i]perylene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Benzo[k]fluoranthene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Chrysene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Dibenzo[a,h]anthracene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V 1	V 1	V 1	V 1	V 1A	V 1A	V 1A	V 1A	V 1A	V 2	V 2	V 2	V 2
Sample Type: Sediment	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B
Fluoranthene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Fluorene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Indeno(1,2,3-c,d)pyrene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Naphthalene	< 0.14	-	< 0.14	-	< 0.14	-	< 0.13	-	-	< 0.13	-	< 0.13	-
Phenanthrene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Pyrene	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-	< 0.03	-	< 0.03	-
Haloethers in SVOC Soil Samples by GC-MS													
Bis(2-chloroethoxy) methane	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Bis(2-chloroethyl)ether	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Bis(2-chloroisopropyl)ether	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
4-Bromophenyl phenyl ether	< 0.4	-	-	-	< 0.4	-	-	-	-	< 0.4	-	-	-
4-Chlorophenyl phenyl ether	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Nitrogen containing compounds in SVOC Soil Samples by GC-MS													
2,4-Dinitrotoluene	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
2,6-Dinitrotoluene	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Nitrobenzene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
N-Nitrosodi-n-propylamine	< 0.7	-	-	-	< 0.7	-	-	-	-	< 0.7	-	-	-
N-Nitrosodiphenylamine + Diphenylamine	< 0.7	-	-	-	< 0.7	-	-	-	-	< 0.7	-	-	-
Organochlorine Pesticides in SVOC Soil Samples by GC-MS													
Aldrin	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
alpha-BHC	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
beta-BHC	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
delta-BHC	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
gamma-BHC (Lindane)	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
4,4'-DDD	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
4,4'-DDE	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
4,4'-DDT	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Dieldrin	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V 1	V 1	V 1	V 1	V 1A	V 1A	V 1A	V 1A	V 1A	V 2	V 2	V 2	V 2
Sample Type: Sediment	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B
Endosulfan I	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Endosulfan II	< 2	-	-	-	< 2	-	-	-	-	< 2	-	-	-
Endosulfan sulphate	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Endrin	< 0.7	-	-	-	< 0.7	-	-	-	-	< 0.7	-	-	-
Endrin ketone	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Heptachlor	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Heptachlor epoxide	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Hexachlorobenzene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS													
Acenaphthene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Acenaphthylene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Anthracene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Benzo[a]anthracene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Benzo[a]pyrene (BAP)	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Benzo[g,h,i]perylene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Benzo[k]fluoranthene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
1&2-Chloronaphthalene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Chrysene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Dibenzo[a,h]anthracene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Fluoranthene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Fluorene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Indeno(1,2,3-c,d)pyrene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
2-Methylnaphthalene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Naphthalene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Phenanthrene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Pyrene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Phenols in SVOC Soil Samples by GC-MS													

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V 1	V 1	V 1	V 1	V 1A	V 1A	V 1A	V 1A	V 1A	V 2	V 2	V 2	V 2
Sample Type: Sediment	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B
4-Chloro-3-methylphenol	< 5	-	-	-	< 5	-	-	-	-	< 5	-	-	-
2-Chlorophenol	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
2,4-Dichlorophenol	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
2,4-Dimethylphenol	< 3	-	-	-	< 3	-	-	-	-	< 3	-	-	-
3 & 4-Methylphenol (m- + p-cresol)	< 3	-	-	-	< 3	-	-	-	-	< 3	-	-	-
2-Methylphenol (o-Cresol)	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
2-Nitrophenol	< 5	-	-	-	< 5	-	-	-	-	< 5	-	-	-
Pentachlorophenol (PCP)	< 30	-	-	-	< 30	-	-	-	-	< 30	-	-	-
Phenol	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
2,4,5-Trichlorophenol	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
2,4,6-Trichlorophenol	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Plasticisers in SVOC Soil Samples by GC-MS													
Bis(2-ethylhexyl)phthalate	< 5	-	-	-	< 5	-	-	-	-	< 5	-	-	-
Butylbenzylphthalate	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Di(2-ethylhexyl)adipate	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Diethylphthalate	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Dimethylphthalate	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Di-n-butylphthalate	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Di-n-octylphthalate	< 1.0	-	-	-	< 1.0	-	-	-	-	< 1.0	-	-	-
Other Halogenated compounds in SVOC Soil Samples by GC-MS													
1,2-Dichlorobenzene	< 0.7	-	-	-	< 0.7	-	-	-	-	< 0.7	-	-	-
1,3-Dichlorobenzene	< 0.7	-	-	-	< 0.7	-	-	-	-	< 0.7	-	-	-
1,4-Dichlorobenzene	< 0.7	-	-	-	< 0.7	-	-	-	-	< 0.7	-	-	-
Hexachlorobutadiene	< 0.7	-	-	-	< 0.7	-	-	-	-	< 0.7	-	-	-
Hexachloroethane	< 0.7	-	-	-	< 0.7	-	-	-	-	< 0.7	-	-	-
1,2,4-Trichlorobenzene	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Other compounds in SVOC Soil Samples by GC-MS													
Benzyl alcohol	< 10	-	-	-	< 10	-	-	-	-	< 10	-	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V 1	V 1	V 1	V 1	V 1A	V 1A	V 1A	V 1A	V 1A	V 2	V 2	V 2	V 2
Sample Type: Sediment	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B
Carbazole	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Dibenzofuran	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Isophorone	< 0.5	-	-	-	< 0.5	-	-	-	-	< 0.5	-	-	-
Tributyl Tin Trace in Soil samples by GCMS													
Dibutyltin (as Sn)	< 0.005	-	< 0.005	-	< 0.005	-	< 0.005	-	-	< 0.005	-	< 0.005	-
Monobutyltin (as Sn)	< 0.007	-	< 0.007	-	< 0.007	-	< 0.007	-	-	< 0.007	-	< 0.007	-
Tributyltin (as Sn)	< 0.004	-	< 0.004	-	< 0.004	-	< 0.004	-	-	< 0.004	-	0.004	-
Triphenyltin (as Sn)	< 0.003	-	< 0.003	-	< 0.003	-	< 0.003	-	-	< 0.003	-	< 0.003	-
Total Petroleum Hydrocarbons in Soil													
C7 - C9	< 9	-	< 9	-	< 9	-	< 8	-	-	< 8	-	< 8	-
C10 - C14	< 20	-	< 20	-	< 20	-	< 20	-	-	< 20	-	< 20	-
C15 - C36	< 40	-	< 40	-	< 40	-	< 40	-	-	< 40	-	< 40	-
Total hydrocarbons (C7 - C36)	< 70	-	< 70	-	< 70	-	< 70	-	-	< 70	-	< 70	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V 2	V3	V3	V3	V3	V3	V5	V5	V5	V5	V5	V6	V6
Sample Type: Sediment	1.0-1.7m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.4m A	0-0.5m A	0-0.5m B 2
Sample Name:	28/02/16	25/02/16	25/02/16	25/02/16	25/02/16	25/02/16	27/02/16	27/02/16	27/02/16	27/02/16	27/02/16	28/02/16	8/02/16
Lab Number:	1545223.7	1544110.37	1544110.38	1544110.4	1544110.41	1544110.43	1545303.16	1545303.17	1545303.19	1545303.2	1545303.22	1545237.1	1545237.2
Dry Matter (g/100g as rcvd)	-	73	-	71	-	-	85	-	84	-	-	82	-
Total Organic Carbon (g/100g dry wt)	0.05	-	0.25	-	0.6	< 0.13	-	< 0.13	-	< 0.13	< 0.13	-	< 0.13
Antifouling cobiocides in sediment samples by LCMSMS													
Diuron	-	< 0.010	-	< 0.010	-	-	< 0.010	-	< 0.010	-	-	< 0.010	-
Irgarol	-	< 0.010	-	< 0.010	-	-	< 0.010	-	< 0.010	-	-	< 0.010	-
Isoproturon	-	< 0.010	-	< 0.010	-	-	< 0.010	-	< 0.010	-	-	< 0.010	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg													
Total Recoverable Arsenic	2.6	-	5.3	-	5.5	2.3	-	2.4	-	2.2	2	-	2.3
Total Recoverable Cadmium	0.022	-	< 0.10	-	0.162	0.011	-	0.022	-	0.021	0.029	-	0.03
Total Recoverable Chromium	11.2	-	13.6	-	16.9	5.1	-	6.2	-	5.9	6.2	-	6.3
Total Recoverable Copper	0.5	-	1.3	-	1.7	0.3	-	0.6	-	0.4	0.4	-	0.5
Total Recoverable Lead	0.77	-	2.1	-	2.8	0.83	-	1.18	-	0.8	0.84	-	1.01
Total Recoverable Mercury	< 0.010	-	< 0.010	-	< 0.010	< 0.010	-	< 0.010	-	< 0.010	< 0.010	-	0.011
Total Recoverable Nickel	5.2	-	4.1	-	5.6	1.7	-	2.9	-	2.8	2.8	-	2.7
Total Recoverable Zinc	5.8	-	12.6	-	15.8	5.2	-	6.8	-	4.9	5.1	-	6.4
Polycyclic Aromatic Hydrocarbons Screening in Soil													
Acenaphthene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Acenaphthylene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Anthracene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Benzo[a]anthracene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Benzo[a]pyrene (BAP)	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Benzo[g,h,i]perylene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Benzo[k]fluoranthene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Chrysene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Dibenzo[a,h]anthracene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V 2	V3	V3	V3	V3	V3	V5	V5	V5	V5	V5	V6	V6
Sample Type: Sediment	1.0-1.7m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.4m A	0-0.5m A	0-0.5m B 2
Fluoranthene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Fluorene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Indeno(1,2,3-c,d)pyrene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Naphthalene	-	< 0.15	-	< 0.16	-	-	< 0.13	-	< 0.13	-	-	< 0.14	-
Phenanthrene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Pyrene	-	< 0.03	-	< 0.04	-	-	< 0.03	-	< 0.03	-	-	< 0.03	-
Haloethers in SVOC Soil Samples by GC-MS													
Bis(2-chloroethoxy) methane	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Bis(2-chloroethyl)ether	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Bis(2-chloroisopropyl)ether	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
4-Bromophenyl phenyl ether	-	< 0.4	-	-	-	-	< 0.4	-	-	-	-	< 0.4	-
4-Chlorophenyl phenyl ether	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Nitrogen containing compounds in SVOC Soil Samples by GC-MS													
2,4-Dinitrotoluene	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
2,6-Dinitrotoluene	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Nitrobenzene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
N-Nitrosodi-n-propylamine	-	< 0.8	-	-	-	-	< 0.7	-	-	-	-	< 0.7	-
N-Nitrosodiphenylamine + Diphenylamine	-	< 0.8	-	-	-	-	< 0.7	-	-	-	-	< 0.7	-
Organochlorine Pesticides in SVOC Soil Samples by GC-MS													
Aldrin	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
alpha-BHC	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
beta-BHC	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
delta-BHC	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
gamma-BHC (Lindane)	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
4,4'-DDD	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
4,4'-DDE	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
4,4'-DDT	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Dieldrin	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V 2	V3	V3	V3	V3	V3	V5	V5	V5	V5	V5	V6	V6
Sample Type: Sediment	1.0-1.7m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.4m A	0-0.5m A	0-0.5m B 2
Endosulfan I	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Endosulfan II	-	< 2	-	-	-	-	< 2	-	-	-	-	< 2	-
Endosulfan sulphate	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Endrin	-	< 0.8	-	-	-	-	< 0.7	-	-	-	-	< 0.7	-
Endrin ketone	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Heptachlor	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Heptachlor epoxide	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Hexachlorobenzene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS													
Acenaphthene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Acenaphthylene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Anthracene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Benzo[a]anthracene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Benzo[a]pyrene (BAP)	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Benzo[g,h,i]perylene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Benzo[k]fluoranthene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
1&2-Chloronaphthalene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Chrysene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Dibenzo[a,h]anthracene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Fluoranthene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Fluorene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Indeno(1,2,3-c,d)pyrene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
2-Methylnaphthalene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Naphthalene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Phenanthrene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Pyrene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Phenols in SVOC Soil Samples by GC-MS													

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V 2	V3	V3	V3	V3	V3	V5	V5	V5	V5	V5	V6	V6
Sample Type: Sediment	1.0-1.7m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.4m A	0-0.5m A	0-0.5m B 2
4-Chloro-3-methylphenol	-	< 5	-	-	-	-	< 5	-	-	-	-	< 5	-
2-Chlorophenol	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
2,4-Dichlorophenol	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
2,4-Dimethylphenol	-	< 3	-	-	-	-	< 3	-	-	-	-	< 3	-
3 & 4-Methylphenol (m- + p-cresol)	-	< 3	-	-	-	-	< 3	-	-	-	-	< 3	-
2-Methylphenol (o-Cresol)	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
2-Nitrophenol	-	< 5	-	-	-	-	< 5	-	-	-	-	< 5	-
Pentachlorophenol (PCP)	-	< 30	-	-	-	-	< 30	-	-	-	-	< 30	-
Phenol	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
2,4,5-Trichlorophenol	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
2,4,6-Trichlorophenol	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Plasticisers in SVOC Soil Samples by GC-MS													
Bis(2-ethylhexyl)phthalate	-	< 5	-	-	-	-	< 5	-	-	-	-	< 5	-
Butylbenzylphthalate	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Di(2-ethylhexyl)adipate	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Diethylphthalate	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Dimethylphthalate	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Di-n-butylphthalate	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Di-n-octylphthalate	-	< 1.0	-	-	-	-	< 1.0	-	-	-	-	< 1.0	-
Other Halogenated compounds in SVOC Soil Samples by GC-MS													
1,2-Dichlorobenzene	-	< 0.8	-	-	-	-	< 0.7	-	-	-	-	< 0.7	-
1,3-Dichlorobenzene	-	< 0.8	-	-	-	-	< 0.7	-	-	-	-	< 0.7	-
1,4-Dichlorobenzene	-	< 0.8	-	-	-	-	< 0.7	-	-	-	-	< 0.7	-
Hexachlorobutadiene	-	< 0.8	-	-	-	-	< 0.7	-	-	-	-	< 0.7	-
Hexachloroethane	-	< 0.8	-	-	-	-	< 0.7	-	-	-	-	< 0.7	-
1,2,4-Trichlorobenzene	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Other compounds in SVOC Soil Samples by GC-MS													
Benzyl alcohol	-	< 10	-	-	-	-	< 10	-	-	-	-	< 10	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V 2	V3	V3	V3	V3	V3	V5	V5	V5	V5	V5	V6	V6
Sample Type: Sediment	1.0-1.7m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.4m A	0-0.5m A	0-0.5m B 2
Carbazole	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Dibenzofuran	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Isophorone	-	< 0.5	-	-	-	-	< 0.5	-	-	-	-	< 0.5	-
Tributyl Tin Trace in Soil samples by GCMS													
Dibutyltin (as Sn)	-	< 0.005	-	< 0.005	-	-	< 0.005	-	< 0.005	-	-	< 0.005	-
Monobutyltin (as Sn)	-	< 0.007	-	< 0.007	-	-	< 0.007	-	< 0.007	-	-	< 0.007	-
Tributyltin (as Sn)	-	< 0.004	-	< 0.004	-	-	< 0.004	-	< 0.004	-	-	< 0.004	-
Triphenyltin (as Sn)	-	< 0.003	-	< 0.003	-	-	< 0.003	-	< 0.003	-	-	< 0.003	-
Total Petroleum Hydrocarbons in Soil													
C7 - C9	-	< 9	-	< 10	-	-	< 8	-	< 8	-	-	< 8	-
C10 - C14	-	< 20	-	< 20	-	-	< 20	-	< 20	-	-	< 20	-
C15 - C36	-	< 40	-	< 40	-	-	< 40	-	< 40	-	-	< 40	-
Total hydrocarbons (C7 - C36)	-	< 70	-	< 70	-	-	< 70	-	< 70	-	-	< 70	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V6	V6	V6	V7	V7	V8	V8	V8	V8	V8	V10	V10	V10
Sample Type: Sediment	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0.5-1.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A
Sample Name:	28/02/16	28/02/16	28/02/16	26/02/16	26/02/16	28/02/16	28/02/16	28/02/16	28/02/16	28/02/16	26/02/16	26/02/16	26/02/16
Lab Number:	1545237.4	1545237.5	1545237.7	1544819.1	1544819.4	1546141.1	1546141.2	1546141.4	1546141.5	1546141.7	1545199.1	1545199.2	1545199.4
Dry Matter (g/100g as rcvd)	80	-	-	81	85	-	79	-	81	-	89	-	84
Total Organic Carbon (g/100g dry wt)	-	0.18	0.23			0.14	-	0.11	-	0.12	-	< 0.13	-
Antifouling cobiocides in sediment samples by LCMSMS													
Diuron	< 0.010	-	-			-	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010
Irgarol	< 0.010	-	-			-	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010
Isoproturon	< 0.010	-	-			-	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg													
Total Recoverable Arsenic	-	5.3	6.6			3.2	-	3.9	-	3.8	-	2	-
Total Recoverable Cadmium	-	0.083	0.05			0.023	-	0.022	-	0.034	-	< 0.010	-
Total Recoverable Chromium	-	10	13.5			9.3	-	10.1	-	12.6	-	11.4	-
Total Recoverable Copper	-	1.4	1.7			0.9	-	0.8	-	0.8	-	0.5	-
Total Recoverable Lead	-	1.7	2.3			1.76	-	1.73	-	1.62	-	0.57	-
Total Recoverable Mercury	-	< 0.010	0.011			< 0.010	-	< 0.010	-	< 0.010	-	< 0.010	-
Total Recoverable Nickel	-	4.2	5.4			3	-	3	-	4.7	-	5.8	-
Total Recoverable Zinc	-	11	14.7			10.4	-	11.3	-	11.1	-	4.4	-
Polycyclic Aromatic Hydrocarbons Screening in Soil													
Acenaphthene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Acenaphthylene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Anthracene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Benzo[a]anthracene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Benzo[a]pyrene (BAP)	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Benzo[b]fluoranthene + Benzo[j]fluoranthene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Benzo[g,h,i]perylene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Benzo[k]fluoranthene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Chrysene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Dibenzo[a,h]anthracene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V6	V6	V6	V7	V7	V8	V8	V8	V8	V8	V10	V10	V10
Sample Type: Sediment	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0.5-1.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A
Fluoranthene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Fluorene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Indeno(1,2,3-c,d)pyrene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Naphthalene	< 0.14	-	-	< 0.14	< 0.13	-	< 0.14	-	< 0.14	-	< 0.12	-	< 0.13
Phenanthrene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Pyrene	< 0.03	-	-	< 0.03	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03
Haloethers in SVOC Soil Samples by GC-MS													
Bis(2-chloroethoxy) methane	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Bis(2-chloroethyl)ether	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Bis(2-chloroisopropyl)ether	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
4-Bromophenyl phenyl ether	-	-	-			-	< 0.4	-	-	-	< 0.3	-	-
4-Chlorophenyl phenyl ether	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Nitrogen containing compounds in SVOC Soil Samples by GC-MS													
2,4-Dinitrotoluene	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
2,6-Dinitrotoluene	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Nitrobenzene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
N-Nitrosodi-n-propylamine	-	-	-			-	< 0.7	-	-	-	< 0.6	-	-
N-Nitrosodiphenylamine + Diphenylamine	-	-	-			-	< 0.7	-	-	-	< 0.6	-	-
Organochlorine Pesticides in SVOC Soil Samples by GC-MS													
Aldrin	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
alpha-BHC	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
beta-BHC	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
delta-BHC	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
gamma-BHC (Lindane)	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
4,4'-DDD	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
4,4'-DDE	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
4,4'-DDT	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Dieldrin	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V6	V6	V6	V7	V7	V8	V8	V8	V8	V8	V10	V10	V10
Sample Type: Sediment	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0.5-1.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A
Endosulfan I	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Endosulfan II	-	-	-			-	< 2	-	-	-	< 2	-	-
Endosulfan sulphate	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Endrin	-	-	-			-	< 0.7	-	-	-	< 0.6	-	-
Endrin ketone	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Heptachlor	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Heptachlor epoxide	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Hexachlorobenzene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS													
Acenaphthene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Acenaphthylene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Anthracene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Benzo[a]anthracene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Benzo[a]pyrene (BAP)	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Benzo[g,h,i]perylene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Benzo[k]fluoranthene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
1&2-Chloronaphthalene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Chrysene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Dibenzo[a,h]anthracene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Fluoranthene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Fluorene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Indeno(1,2,3-c,d)pyrene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
2-Methylnaphthalene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Naphthalene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Phenanthrene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Pyrene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Phenols in SVOC Soil Samples by GC-MS													

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V6	V6	V6	V7	V7	V8	V8	V8	V8	V8	V10	V10	V10
Sample Type: Sediment	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0.5-1.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A
4-Chloro-3-methylphenol	-	-	-			-	< 5	-	-	-	< 5	-	-
2-Chlorophenol	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
2,4-Dichlorophenol	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
2,4-Dimethylphenol	-	-	-			-	< 3	-	-	-	< 3	-	-
3 & 4-Methylphenol (m- + p-cresol)	-	-	-			-	< 3	-	-	-	< 3	-	-
2-Methylphenol (o-Cresol)	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
2-Nitrophenol	-	-	-			-	< 5	-	-	-	< 5	-	-
Pentachlorophenol (PCP)	-	-	-			-	< 30	-	-	-	< 30	-	-
Phenol	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
2,4,5-Trichlorophenol	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
2,4,6-Trichlorophenol	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Plasticisers in SVOC Soil Samples by GC-MS													
Bis(2-ethylhexyl)phthalate	-	-	-			-	< 5	-	-	-	< 5	-	-
Butylbenzylphthalate	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Di(2-ethylhexyl)adipate	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Diethylphthalate	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Dimethylphthalate	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Di-n-butylphthalate	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Di-n-octylphthalate	-	-	-			-	< 1.0	-	-	-	< 1.0	-	-
Other Halogenated compounds in SVOC Soil Samples by GC-MS													
1,2-Dichlorobenzene	-	-	-			-	< 0.7	-	-	-	< 0.6	-	-
1,3-Dichlorobenzene	-	-	-			-	< 0.7	-	-	-	< 0.6	-	-
1,4-Dichlorobenzene	-	-	-			-	< 0.7	-	-	-	< 0.6	-	-
Hexachlorobutadiene	-	-	-			-	< 0.7	-	-	-	< 0.6	-	-
Hexachloroethane	-	-	-			-	< 0.7	-	-	-	< 0.6	-	-
1,2,4-Trichlorobenzene	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Other compounds in SVOC Soil Samples by GC-MS													
Benzyl alcohol	-	-	-			-	< 10	-	-	-	< 10	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V6	V6	V6	V7	V7	V8	V8	V8	V8	V8	V10	V10	V10
Sample Type: Sediment	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0.5-1.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A
Carbazole	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Dibenzofuran	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Isophorone	-	-	-			-	< 0.5	-	-	-	< 0.5	-	-
Tributyl Tin Trace in Soil samples by GCMS													
Dibutyltin (as Sn)	< 0.005	-	-	< 0.005	< 0.005	-	< 0.005	-	< 0.005	-	< 0.005	-	< 0.005
Monobutyltin (as Sn)	< 0.007	-	-	< 0.007	< 0.007	-	< 0.007	-	< 0.007	-	< 0.007	-	< 0.007
Tributyltin (as Sn)	< 0.004	-	-	< 0.004	< 0.004	-	< 0.004	-	< 0.004	-	< 0.004	-	< 0.004
Triphenyltin (as Sn)	< 0.003	-	-	< 0.003	< 0.003	-	< 0.003	-	< 0.003	-	< 0.003	-	< 0.003
Total Petroleum Hydrocarbons in Soil													
C7 - C9	< 9	-	-	< 8	< 8	-	< 8	-	< 8	-	< 8	-	< 8
C10 - C14	< 20	-	-	< 20	< 20	-	< 20	-	< 20	-	< 20	-	< 20
C15 - C36	< 40	-	-	< 40	< 40	-	< 40	-	< 40	-	< 40	-	< 40
Total hydrocarbons (C7 - C36)	< 70	-	-	< 70	< 70	-	< 70	-	< 70	-	< 70	-	< 70

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V10	V10	V12	V12	V12	V12	V12	V13	V13	V13	V13		V13
Sample Type: Sediment	0.5-1.0m B	1.0-1.6m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B 2	1.0-2.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-2.7m A
Sample Name:	26/02/16	26/02/16	26/02/16	26/02/16	26/02/16	6/02/16	26/02/16	25/02/16	25/02/16	25/02/16	25/02/16	25/02/16	25/02/16
Lab Number:	1545199.5	1545199.7	1545290.3	1545290.4	1545290.6	1545290.7	1545290.9	1544110.1	1544110.2	1544110.4	1544110.5	1544110.7	1544110.1
Dry Matter (g/100g as rcvd)	-	-	85	-	89	-	-	-	87	-	88	-	-
Total Organic Carbon (g/100g dry wt)	< 0.13	< 0.13	-	< 0.13	-	< 0.13	< 0.13	< 0.13	-	< 0.13	-	< 0.13	< 0.13
Antifouling cobiocides in sediment samples by LCMSMS													
Diuron	-	-	< 0.010	-	< 0.010	-	-	-	< 0.010	-	< 0.010	-	-
Irgarol	-	-	< 0.010	-	< 0.010	-	-	-	< 0.010	-	< 0.010	-	-
Isoproturon	-	-	< 0.010	-	< 0.010	-	-	-	< 0.010	-	< 0.010	-	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg													
Total Recoverable Arsenic	1.9	1.6	-	1.8	-	1.8	2.5	< 2	-	< 2	-	< 1.9	< 1.9
Total Recoverable Cadmium	< 0.010	0.012	-	< 0.010	-	< 0.010	0.029	< 0.010	-	< 0.010	-	0.01	< 0.010
Total Recoverable Chromium	4.1	7.4	-	3.7	-	3.2	7.6	3.9	-	3	-	4.3	7
Total Recoverable Copper	0.3	0.4	-	0.4	-	0.2	0.6	0.3	-	0.3	-	0.3	0.3
Total Recoverable Lead	0.57	0.75	-	0.57	-	0.5	1.09	0.6	-	0.52	-	0.62	0.52
Total Recoverable Mercury	0.018	0.01	-	< 0.010	-	< 0.010	< 0.010	< 0.010	-	< 0.010	-	< 0.010	< 0.010
Total Recoverable Nickel	1.8	3.3	-	1.6	-	2.1	3.5	1.9	-	2.5	-	2	2.8
Total Recoverable Zinc	4.1	7.4	-	4.4	-	4.2	8.9	4.4	-	3.8	-	4.5	4.7
Polycyclic Aromatic Hydrocarbons Screening in Soil													
Acenaphthene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Acenaphthylene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Anthracene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Benzo[a]anthracene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Benzo[a]pyrene (BAP)	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Benzo[g,h,i]perylene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Benzo[k]fluoranthene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Chrysene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Dibenzo[a,h]anthracene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V10	V10	V12	V12	V12	V12	V12	V13	V13	V13	V13		V13
Sample Type: Sediment	0.5-1.0m B	1.0-1.6m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B 2	1.0-2.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-2.7m A
Fluoranthene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Fluorene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Indeno(1,2,3-c,d)pyrene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Naphthalene	-	-	< 0.13	-	< 0.13	-	-	-	< 0.13	-	< 0.13	-	-
Phenanthrene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Pyrene	-	-	< 0.03	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-
Haloethers in SVOC Soil Samples by GC-MS													
Bis(2-chloroethoxy) methane	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Bis(2-chloroethyl)ether	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Bis(2-chloroisopropyl)ether	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
4-Bromophenyl phenyl ether	-	-	< 0.4	-	-	-	-	-	< 0.4	-	-	-	-
4-Chlorophenyl phenyl ether	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Nitrogen containing compounds in SVOC Soil Samples by GC-MS													
2,4-Dinitrotoluene	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
2,6-Dinitrotoluene	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Nitrobenzene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
N-Nitrosodi-n-propylamine	-	-	< 0.7	-	-	-	-	-	< 0.7	-	-	-	-
N-Nitrosodiphenylamine + Diphenylamine	-	-	< 0.7	-	-	-	-	-	< 0.7	-	-	-	-
Organochlorine Pesticides in SVOC Soil Samples by GC-MS													
Aldrin	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
alpha-BHC	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
beta-BHC	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
delta-BHC	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
gamma-BHC (Lindane)	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
4,4'-DDD	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
4,4'-DDE	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
4,4'-DDT	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Dieldrin	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-

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	V10	V10	V12	V12	V12	V12	V12	V13	V13	V13	V13		V13
Sample Type: Sediment	0.5-1.0m B	1.0-1.6m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B 2	1.0-2.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-2.7m A
Endosulfan I	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Endosulfan II	-	-	< 2	-	-	-	-	-	< 2	-	-	-	-
Endosulfan sulphate	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Endrin	-	-	< 0.7	-	-	-	-	-	< 0.7	-	-	-	-
Endrin ketone	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Heptachlor	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Heptachlor epoxide	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Hexachlorobenzene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS													
Acenaphthene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Acenaphthylene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Anthracene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Benzo[a]anthracene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Benzo[a]pyrene (BAP)	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Benzo[g,h,i]perylene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Benzo[k]fluoranthene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
1&2-Chloronaphthalene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Chrysene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Dibenzo[a,h]anthracene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Fluoranthene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Fluorene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
2-Methylnaphthalene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Naphthalene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Phenanthrene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Pyrene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Phenols in SVOC Soil Samples by GC-MS													

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	V10	V10	V12	V12	V12	V12	V12	V13	V13	V13	V13		V13
Sample Type: Sediment	0.5-1.0m B	1.0-1.6m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B 2	1.0-2.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-2.7m A
4-Chloro-3-methylphenol	-	-	< 5	-	-	-	-	-	< 5	-	-	-	-
2-Chlorophenol	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
2,4-Dichlorophenol	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
2,4-Dimethylphenol	-	-	< 3	-	-	-	-	-	< 3	-	-	-	-
3 & 4-Methylphenol (m- + p-cresol)	-	-	< 3	-	-	-	-	-	< 3	-	-	-	-
2-Methylphenol (o-Cresol)	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
2-Nitrophenol	-	-	< 5	-	-	-	-	-	< 5	-	-	-	-
Pentachlorophenol (PCP)	-	-	< 30	-	-	-	-	-	< 30	-	-	-	-
Phenol	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
2,4,5-Trichlorophenol	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
2,4,6-Trichlorophenol	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Plasticisers in SVOC Soil Samples by GC-MS													
Bis(2-ethylhexyl)phthalate	-	-	< 5	-	-	-	-	-	< 5	-	-	-	-
Butylbenzylphthalate	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Di(2-ethylhexyl)adipate	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Diethylphthalate	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Dimethylphthalate	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Di-n-butylphthalate	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Di-n-octylphthalate	-	-	< 1.0	-	-	-	-	-	< 1.0	-	-	-	-
Other Halogenated compounds in SVOC Soil Samples by GC-MS													
1,2-Dichlorobenzene	-	-	< 0.7	-	-	-	-	-	< 0.7	-	-	-	-
1,3-Dichlorobenzene	-	-	< 0.7	-	-	-	-	-	< 0.7	-	-	-	-
1,4-Dichlorobenzene	-	-	< 0.7	-	-	-	-	-	< 0.7	-	-	-	-
Hexachlorobutadiene	-	-	< 0.7	-	-	-	-	-	< 0.7	-	-	-	-
Hexachloroethane	-	-	< 0.7	-	-	-	-	-	< 0.7	-	-	-	-
1,2,4-Trichlorobenzene	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Other compounds in SVOC Soil Samples by GC-MS													
Benzyl alcohol	-	-	< 10	-	-	-	-	-	< 10	-	-	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
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	V10	V10	V12	V12	V12	V12	V12	V13	V13	V13	V13		V13
Sample Type: Sediment	0.5-1.0m B	1.0-1.6m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B 2	1.0-2.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-2.7m A
Carbazole	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Dibenzofuran	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Isophorone	-	-	< 0.5	-	-	-	-	-	< 0.5	-	-	-	-
Tributyl Tin Trace in Soil samples by GCMS													
Dibutyltin (as Sn)	-	-	< 0.005	-	< 0.005	-	-	-	< 0.005	-	< 0.005	-	-
Monobutyltin (as Sn)	-	-	< 0.007	-	< 0.007	-	-	-	< 0.007	-	< 0.007	-	-
Tributyltin (as Sn)	-	-	< 0.004	-	< 0.004	-	-	-	< 0.004	-	< 0.004	-	-
Triphenyltin (as Sn)	-	-	< 0.003	-	< 0.003	-	-	-	< 0.003	-	< 0.003	-	-
Total Petroleum Hydrocarbons in Soil													
C7 - C9	-	-	< 8	-	< 8	-	-	-	< 8	-	< 8	-	-
C10 - C14	-	-	< 20	-	< 20	-	-	-	< 20	-	< 20	-	-
C15 - C36	-	-	< 40	-	< 40	-	-	-	< 40	-	< 40	-	-
Total hydrocarbons (C7 - C36)	-	-	< 70	-	< 70	-	-	-	< 70	-	< 70	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
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	V14	V14	V14	V14	V14	V14	V15	V15	V15	V15	V15	V15	V16
Sample Type: Sediment	0.0-0.5m B	0.0-0.5m A	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-3.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-3.0m A	0-0.5m A
Sample Name:	25/02/16	25/02/16	25/02/16	25/02/16	Feb-2016 12:0	25/02/16	25/02/16	25/02/16	25/02/16	25/02/16	25/02/16	25/02/16	23/02/16
Lab Number:	1544110.13	1544110.14	1544110.16	1544110.17	1544110.19	1544110.22	1544110.25	1544110.26	1544110.28	1544110.29	1544110.31	1544110.34	1543364.1
Dry Matter (g/100g as rcvd)	73	-	-	81	-	-	-	86	-	88	-	-	84
Total Organic Carbon (g/100g dry wt)	-	< 0.13	< 0.13	-	< 0.13	< 0.13	< 0.13	-	< 0.13	-	< 0.13	< 0.13	0.17
Antifouling cobiocides in sediment samples by LCMSMS													
Diuron	< 0.010	-	-	< 0.010	-	-	-	< 0.010	-	< 0.010	-	-	< 0.010
Irgarol	< 0.010	-	-	< 0.010	-	-	-	< 0.010	-	< 0.010	-	-	< 0.010
Isoproturon	< 0.010	-	-	< 0.010	-	-	-	< 0.010	-	< 0.010	-	-	< 0.010
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg													
Total Recoverable Arsenic	-	5	3	-	2.3	< 2	2.1	-	2.2	-	< 2	2	3.8
Total Recoverable Cadmium	-	0.024	0.014	-	0.081	0.025	0.015	-	0.014	-	< 0.010	< 0.010	< 0.02
Total Recoverable Chromium	-	8.8	5.4	-	7.1	8.8	4.4	-	4.3	-	3.6	4.2	8.5
Total Recoverable Copper	-	1.6	0.6	-	0.8	1.8	0.6	-	0.4	-	0.3	< 0.2	1.3
Total Recoverable Lead	-	1.76	0.96	-	1.05	1.11	1.12	-	0.9	-	0.53	0.49	1.61
Total Recoverable Mercury	-	< 0.010	< 0.010	-	< 0.010	< 0.010	< 0.010	-	< 0.010	-	< 0.010	< 0.010	0.02
Total Recoverable Nickel	-	5.2	3.3	-	3.7	4.9	3.1	-	2.1	-	2.1	2	5.9
Total Recoverable Zinc	-	9.5	5.3	-	6.2	6.8	6.3	-	5.1	-	3.8	3.4	9.1
Polycyclic Aromatic Hydrocarbons Screening in Soil													
Acenaphthene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Acenaphthylene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Anthracene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Benzo[a]anthracene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Benzo[a]pyrene (BAP)	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Benzo[b]fluoranthene + Benzo[j]fluoranthene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Benzo[g,h,i]perylene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Benzo[k]fluoranthene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Chrysene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Dibenzo[a,h]anthracene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
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	V14	V14	V14	V14	V14	V14	V15	V15	V15	V15	V15	V15	V16
Sample Type: Sediment	0.0-0.5m B	0.0-0.5m A	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-3.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-3.0m A	0-0.5m A
Fluoranthene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Fluorene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Indeno(1,2,3-c,d)pyrene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Naphthalene	< 0.15	-	-	< 0.14	-	-	-	< 0.13	-	< 0.13	-	-	< 0.13
Phenanthrene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Pyrene	< 0.03	-	-	< 0.03	-	-	-	< 0.03	-	< 0.03	-	-	< 0.03
Haloethers in SVOC Soil Samples by GC-MS													
Bis(2-chloroethoxy) methane	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Bis(2-chloroethyl)ether	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Bis(2-chloroisopropyl)ether	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
4-Bromophenyl phenyl ether	< 0.4	-	-	-	-	-	-	< 0.4	-	-	-	-	< 0.4
4-Chlorophenyl phenyl ether	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Nitrogen containing compounds in SVOC Soil Samples by GC-MS													
2,4-Dinitrotoluene	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
2,6-Dinitrotoluene	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Nitrobenzene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
N-Nitrosodi-n-propylamine	< 0.8	-	-	-	-	-	-	< 0.7	-	-	-	-	< 0.7
N-Nitrosodiphenylamine + Diphenylamine	< 0.8	-	-	-	-	-	-	< 0.7	-	-	-	-	< 0.7
Organochlorine Pesticides in SVOC Soil Samples by GC-MS													
Aldrin	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
alpha-BHC	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
beta-BHC	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
delta-BHC	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
gamma-BHC (Lindane)	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
4,4'-DDD	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
4,4'-DDE	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
4,4'-DDT	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Dieldrin	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V14	V14	V14	V14	V14	V14	V15	V15	V15	V15	V15	V15	V16
Sample Type: Sediment	0.0-0.5m B	0.0-0.5m A	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-3.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-3.0m A	0-0.5m A
Endosulfan I	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Endosulfan II	< 2	-	-	-	-	-	-	< 2	-	-	-	-	< 2
Endosulfan sulphate	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Endrin	< 0.8	-	-	-	-	-	-	< 0.7	-	-	-	-	< 0.7
Endrin ketone	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Heptachlor	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Heptachlor epoxide	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Hexachlorobenzene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS													
Acenaphthene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Acenaphthylene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Anthracene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Benzo[a]anthracene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Benzo[a]pyrene (BAP)	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Benzo[b]fluoranthene + Benzo[j]fluoranthene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Benzo[g,h,i]perylene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Benzo[k]fluoranthene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
1&2-Chloronaphthalene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Chrysene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Dibenzo[a,h]anthracene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Fluoranthene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Fluorene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Indeno(1,2,3-c,d)pyrene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
2-Methylnaphthalene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Naphthalene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Phenanthrene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Pyrene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Phenols in SVOC Soil Samples by GC-MS													

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V14	V14	V14	V14	V14	V14	V15	V15	V15	V15	V15	V15	V16
Sample Type: Sediment	0.0-0.5m B	0.0-0.5m A	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-3.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-3.0m A	0-0.5m A
4-Chloro-3-methylphenol	< 5	-	-	-	-	-	-	< 5	-	-	-	-	< 5
2-Chlorophenol	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
2,4-Dichlorophenol	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
2,4-Dimethylphenol	< 3	-	-	-	-	-	-	< 3	-	-	-	-	< 3
3 & 4-Methylphenol (m- + p-cresol)	< 3	-	-	-	-	-	-	< 3	-	-	-	-	< 3
2-Methylphenol (o-Cresol)	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
2-Nitrophenol	< 5	-	-	-	-	-	-	< 5	-	-	-	-	< 5
Pentachlorophenol (PCP)	< 30	-	-	-	-	-	-	< 30	-	-	-	-	< 30
Phenol	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
2,4,5-Trichlorophenol	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
2,4,6-Trichlorophenol	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Plasticisers in SVOC Soil Samples by GC-MS													
Bis(2-ethylhexyl)phthalate	< 5	-	-	-	-	-	-	< 5	-	-	-	-	< 5
Butylbenzylphthalate	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Di(2-ethylhexyl)adipate	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Diethylphthalate	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Dimethylphthalate	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Di-n-butylphthalate	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Di-n-octylphthalate	< 1.0	-	-	-	-	-	-	< 1.0	-	-	-	-	< 1.0
Other Halogenated compounds in SVOC Soil Samples by GC-MS													
1,2-Dichlorobenzene	< 0.8	-	-	-	-	-	-	< 0.7	-	-	-	-	< 0.7
1,3-Dichlorobenzene	< 0.8	-	-	-	-	-	-	< 0.7	-	-	-	-	< 0.7
1,4-Dichlorobenzene	< 0.8	-	-	-	-	-	-	< 0.7	-	-	-	-	< 0.7
Hexachlorobutadiene	< 0.8	-	-	-	-	-	-	< 0.7	-	-	-	-	< 0.7
Hexachloroethane	< 0.8	-	-	-	-	-	-	< 0.7	-	-	-	-	< 0.7
1,2,4-Trichlorobenzene	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Other compounds in SVOC Soil Samples by GC-MS													
Benzyl alcohol	< 10	-	-	-	-	-	-	< 10	-	-	-	-	< 10

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
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	V14	V14	V14	V14	V14	V14	V15	V15	V15	V15	V15	V15	V16
Sample Type: Sediment	0.0-0.5m B	0.0-0.5m A	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-3.0m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	2.0-3.0m A	0-0.5m A
Carbazole	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Dibenzofuran	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Isophorone	< 0.5	-	-	-	-	-	-	< 0.5	-	-	-	-	< 0.5
Tributyl Tin Trace in Soil samples by GCMS													
Dibutyltin (as Sn)	< 0.005	-	-	< 0.005	-	-	-	< 0.005	-	< 0.005	-	-	< 0.005
Monobutyltin (as Sn)	< 0.007	-	-	< 0.007	-	-	-	< 0.007	-	< 0.007	-	-	< 0.007
Tributyltin (as Sn)	< 0.004	-	-	< 0.004	-	-	-	< 0.004	-	< 0.004	-	-	< 0.004
Triphenyltin (as Sn)	< 0.003	-	-	< 0.003	-	-	-	< 0.003	-	< 0.003	-	-	< 0.003
Total Petroleum Hydrocarbons in Soil													
C7 - C9	< 9	-	-	< 8	-	-	-	< 8	-	< 8	-	-	< 8
C10 - C14	< 20	-	-	< 20	-	-	-	< 20	-	< 20	-	-	< 20
C15 - C36	< 40	-	-	< 40	-	-	-	< 40	-	< 40	-	-	< 40
Total hydrocarbons (C7 - C36)	< 70	-	-	< 70	-	-	-	< 70	-	< 70	-	-	< 70

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V16	V16	V17	V17	V17	V17	V17	V17	V17	V18	V18	V18	V18
Sample Type: Sediment	0.5-1.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2m A	2-3m A	3-4m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B
Sample Name:	23/02/16	23/02/16	24/02/16	24/02/16	24/02/16	24/02/16	24/02/16	24/02/16	24/02/16	24/02/16	24/02/16	24/02/16	24/02/16
Lab Number:	1543364.3	1543364.5	1543396.1	1543396.2	1543396.4	1543396.5	1543396.7	1543396.1	1543396.13	1544100.9	1544100.1	1544100.12	1544100.13
Dry Matter (g/100g as rcvd)	85	-	-	89	-	85	-	-	-	-	88	-	84
Total Organic Carbon (g/100g dry wt)	0.4	-	< 0.13	-	< 0.13	-	< 0.13	< 0.13	< 0.13	< 0.13	-	< 0.05	-
Antifouling cobiocides in sediment samples by LCMSMS													
Diuron	< 0.010	-	-	< 0.010	-	< 0.010	-	-	-	-	< 0.010	-	< 0.010
Irgarol	< 0.010	-	-	< 0.010	-	< 0.010	-	-	-	-	< 0.010	-	< 0.010
Isoproturon	< 0.010	-	-	< 0.010	-	< 0.010	-	-	-	-	< 0.010	-	< 0.010
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg													
Total Recoverable Arsenic	< 4	2.4	2.3	-	1.9	-	2.4	5	3.3	1.9	-	2	-
Total Recoverable Cadmium	0.03	< 0.010	< 0.02	-	< 0.010	-	< 0.010	0.024	< 0.010	< 0.010	-	0.012	-
Total Recoverable Chromium	4.1	6.1	5.4	-	3.5	-	6.4	10.5	9.8	5.4	-	9.1	-
Total Recoverable Copper	1.1	0.4	0.5	-	0.3	-	0.4	0.6	0.7	0.4	-	0.3	-
Total Recoverable Lead	0.85	0.73	0.78	-	0.57	-	0.81	1.42	0.98	0.83	-	1.14	-
Total Recoverable Mercury	0.02	< 0.010	< 0.02	-	< 0.010	-	< 0.010	< 0.010	< 0.010	< 0.010	-	< 0.010	-
Total Recoverable Nickel	8.8	2.3	4.4	-	2.8	-	2.6	3.7	4.6	3.4	-	2.1	-
Total Recoverable Zinc	4.1	7.3	5.5	-	4.1	-	6.8	10.8	8.9	4.4	-	8.9	-
Polycyclic Aromatic Hydrocarbons Screening in Soil													
Acenaphthene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Acenaphthylene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Anthracene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Benzo[a]anthracene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Benzo[a]pyrene (BAP)	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Benzo[b]fluoranthene + Benzo[j]fluoranthene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Benzo[g,h,i]perylene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Benzo[k]fluoranthene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Chrysene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Dibenzo[a,h]anthracene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
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	V16	V16	V17	V17	V17	V17	V17	V17	V17	V18	V18	V18	V18
Sample Type: Sediment	0.5-1.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2m A	2-3m A	3-4m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B
Fluoranthene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Fluorene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Indeno(1,2,3-c,d)pyrene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Naphthalene	< 0.14	-	-	< 0.12	-	< 0.13	-	-	-	-	< 0.13	-	< 0.13
Phenanthrene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Pyrene	< 0.03	-	-	< 0.03	-	< 0.03	-	-	-	-	< 0.03	-	< 0.03
Haloethers in SVOC Soil Samples by GC-MS													
Bis(2-chloroethoxy) methane	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Bis(2-chloroethyl)ether	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Bis(2-chloroisopropyl)ether	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
4-Bromophenyl phenyl ether	-	-	-	< 0.4	-	-	-	-	-	-	< 0.4	-	-
4-Chlorophenyl phenyl ether	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Nitrogen containing compounds in SVOC Soil Samples by GC-MS													
2,4-Dinitrotoluene	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
2,6-Dinitrotoluene	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Nitrobenzene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
N-Nitrosodi-n-propylamine	-	-	-	< 0.7	-	-	-	-	-	-	< 0.7	-	-
N-Nitrosodiphenylamine + Diphenylamine	-	-	-	< 0.7	-	-	-	-	-	-	< 0.7	-	-
Organochlorine Pesticides in SVOC Soil Samples by GC-MS													
Aldrin	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
alpha-BHC	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
beta-BHC	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
delta-BHC	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
gamma-BHC (Lindane)	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
4,4'-DDD	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
4,4'-DDE	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
4,4'-DDT	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Dieldrin	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-

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	V16	V16	V17	V17	V17	V17	V17	V17	V17	V18	V18	V18	V18
Sample Type: Sediment	0.5-1.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2m A	2-3m A	3-4m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B
Endosulfan I	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Endosulfan II	-	-	-	< 2	-	-	-	-	-	-	< 2	-	-
Endosulfan sulphate	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Endrin	-	-	-	< 0.7	-	-	-	-	-	-	< 0.7	-	-
Endrin ketone	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Heptachlor	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Heptachlor epoxide	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Hexachlorobenzene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS													
Acenaphthene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Acenaphthylene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Anthracene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Benzo[a]anthracene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Benzo[a]pyrene (BAP)	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Benzo[g,h,i]perylene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Benzo[k]fluoranthene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
1&2-Chloronaphthalene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Chrysene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Dibenzo[a,h]anthracene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Fluoranthene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Fluorene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Indeno(1,2,3-c,d)pyrene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
2-Methylnaphthalene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Naphthalene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Phenanthrene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Pyrene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Phenols in SVOC Soil Samples by GC-MS													

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V16	V16	V17	V17	V17	V17	V17	V17	V17	V18	V18	V18	V18
Sample Type: Sediment	0.5-1.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2m A	2-3m A	3-4m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B
4-Chloro-3-methylphenol	-	-	-	< 5	-	-	-	-	-	-	< 5	-	-
2-Chlorophenol	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
2,4-Dichlorophenol	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
2,4-Dimethylphenol	-	-	-	< 3	-	-	-	-	-	-	< 3	-	-
3 & 4-Methylphenol (m- + p-cresol)	-	-	-	< 3	-	-	-	-	-	-	< 3	-	-
2-Methylphenol (o-Cresol)	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
2-Nitrophenol	-	-	-	< 5	-	-	-	-	-	-	< 5	-	-
Pentachlorophenol (PCP)	-	-	-	< 30	-	-	-	-	-	-	< 30	-	-
Phenol	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
2,4,5-Trichlorophenol	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
2,4,6-Trichlorophenol	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Plasticisers in SVOC Soil Samples by GC-MS													
Bis(2-ethylhexyl)phthalate	-	-	-	< 5	-	-	-	-	-	-	< 5	-	-
Butylbenzylphthalate	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Di(2-ethylhexyl)adipate	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Diethylphthalate	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Dimethylphthalate	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Di-n-butylphthalate	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Di-n-octylphthalate	-	-	-	< 1.0	-	-	-	-	-	-	< 1.0	-	-
Other Halogenated compounds in SVOC Soil Samples by GC-MS													
1,2-Dichlorobenzene	-	-	-	< 0.7	-	-	-	-	-	-	< 0.7	-	-
1,3-Dichlorobenzene	-	-	-	< 0.7	-	-	-	-	-	-	< 0.7	-	-
1,4-Dichlorobenzene	-	-	-	< 0.7	-	-	-	-	-	-	< 0.7	-	-
Hexachlorobutadiene	-	-	-	< 0.7	-	-	-	-	-	-	< 0.7	-	-
Hexachloroethane	-	-	-	< 0.7	-	-	-	-	-	-	< 0.7	-	-
1,2,4-Trichlorobenzene	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Other compounds in SVOC Soil Samples by GC-MS													
Benzyl alcohol	-	-	-	< 10	-	-	-	-	-	-	< 10	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V16	V16	V17	V17	V17	V17	V17	V17	V17	V18	V18	V18	V18
Sample Type: Sediment	0.5-1.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2m A	2-3m A	3-4m A	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B
Carbazole	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Dibenzofuran	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Isophorone	-	-	-	< 0.5	-	-	-	-	-	-	< 0.5	-	-
Tributyl Tin Trace in Soil samples by GCMS													
Dibutyltin (as Sn)	< 0.005	-	-	< 0.005	-	< 0.005	-	-	-	-	< 0.005	-	< 0.005
Monobutyltin (as Sn)	< 0.007	-	-	< 0.007	-	< 0.007	-	-	-	-	< 0.007	-	< 0.007
Tributyltin (as Sn)	< 0.004	-	-	< 0.004	-	< 0.004	-	-	-	-	< 0.004	-	< 0.004
Triphenyltin (as Sn)	< 0.003	-	-	< 0.003	-	< 0.003	-	-	-	-	< 0.003	-	< 0.003
Total Petroleum Hydrocarbons in Soil													
C7 - C9	< 8	-	-	< 8	-	< 8	-	-	-	-	< 8	-	< 8
C10 - C14	< 20	-	-	< 20	-	< 20	-	-	-	-	< 20	-	< 20
C15 - C36	< 40	-	-	< 40	-	< 40	-	-	-	-	< 40	-	< 40
Total hydrocarbons (C7 - C36)	< 70	-	-	< 70	-	< 70	-	-	-	-	< 70	-	< 70

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V18	V18	V19	V19	V19	V19	V19	V19A	V19A	V19A	V19A	V19A
Sample Type: Sediment	2.0-3.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1m A	0.5-1m B	1-1.5m A
Sample Name:	24/02/16	24/02/16	24/02/16	24/02/16	24/02/16	24/02/16	24/02/16	29/02/16	29/02/16	29/02/16	29/02/16	29/02/16
Lab Number:	1544100.16	1544100.19	1544100.22	1544100.23	1544100.25	1544100.26	1544100.28	1546000.1	1546000.2	1546000.4	1546000.5	1546000.7
Dry Matter (g/100g as rcvd)	-	-	-	86	-	82	-	82	-	82	-	-
Total Organic Carbon (g/100g dry wt)	0.17	< 0.05	< 0.13	-	0.06	-	< 0.13	-	< 0.05	-	< 0.05	< 0.05
Antifouling cobiocides in sediment samples by LCMSMS												
Diuron	-	-	-	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010	-	-
Irgarol	-	-	-	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010	-	-
Isoproturon	-	-	-	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010	-	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg												
Total Recoverable Arsenic	4	2.6	2	-	2	-	2.4	-	2.9	-	2.2	2.5
Total Recoverable Cadmium	0.038	0.011	< 0.010	-	0.027	-	0.037	-	< 0.010	-	< 0.010	0.015
Total Recoverable Chromium	14.7	8.3	5.5	-	12.2	-	34	-	50	-	10.6	37
Total Recoverable Copper	0.7	0.3	0.4	-	0.5	-	0.8	-	1.1	-	0.4	0.8
Total Recoverable Lead	1.66	1	0.68	-	1.45	-	1.05	-	1.19	-	0.87	0.9
Total Recoverable Mercury	< 0.010	< 0.010	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010	-	< 0.010	< 0.010
Total Recoverable Nickel	5	1.9	2.4	-	3.1	-	17.1	-	20	-	3.7	20
Total Recoverable Zinc	10.6	8.3	4.9	-	10.2	-	7.8	-	8.3	-	6.6	7.2
Polycyclic Aromatic Hydrocarbons Screening in Soil												
Acenaphthene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Acenaphthylene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Anthracene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Benzo[a]anthracene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Benzo[a]pyrene (BAP)	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Benzo[g,h,i]perylene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Benzo[k]fluoranthene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Chrysene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Dibenzo[a,h]anthracene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V18	V18	V19	V19	V19	V19	V19	V19A	V19A	V19A	V19A	V19A
Sample Type: Sediment	2.0-3.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1m A	0.5-1m B	1-1.5m A
Fluoranthene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Fluorene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Indeno(1,2,3-c,d)pyrene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Naphthalene	-	-	-	< 0.13	-	< 0.14	-	< 0.14	-	< 0.13	-	-
Phenanthrene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Pyrene	-	-	-	< 0.03	-	< 0.03	-	< 0.03	-	< 0.03	-	-
Haloethers in SVOC Soil Samples by GC-MS												
Bis(2-chloroethoxy) methane	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Bis(2-chloroethyl)ether	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Bis(2-chloroisopropyl)ether	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
4-Bromophenyl phenyl ether	-	-	-	< 0.4	-	-	-	< 0.4	-	-	-	-
4-Chlorophenyl phenyl ether	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Nitrogen containing compounds in SVOC Soil Samples by GC-MS												
2,4-Dinitrotoluene	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
2,6-Dinitrotoluene	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Nitrobenzene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
N-Nitrosodi-n-propylamine	-	-	-	< 0.7	-	-	-	< 0.7	-	-	-	-
N-Nitrosodiphenylamine + Diphenylamine	-	-	-	< 0.7	-	-	-	< 0.7	-	-	-	-
Organochlorine Pesticides in SVOC Soil Samples by GC-MS												
Aldrin	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
alpha-BHC	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
beta-BHC	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
delta-BHC	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
gamma-BHC (Lindane)	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
4,4'-DDD	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
4,4'-DDE	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
4,4'-DDT	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Dieldrin	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V18	V18	V19	V19	V19	V19	V19	V19A	V19A	V19A	V19A	V19A
Sample Type: Sediment	2.0-3.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1m A	0.5-1m B	1-1.5m A
Endosulfan I	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Endosulfan II	-	-	-	< 2	-	-	-	< 2	-	-	-	-
Endosulfan sulphate	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Endrin	-	-	-	< 0.7	-	-	-	< 0.7	-	-	-	-
Endrin ketone	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Heptachlor	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Heptachlor epoxide	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Hexachlorobenzene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS												
Acenaphthene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Acenaphthylene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Anthracene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Benzo[a]anthracene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Benzo[a]pyrene (BAP)	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Benzo[g,h,i]perylene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Benzo[k]fluoranthene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
1&2-Chloronaphthalene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Chrysene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Dibenzo[a,h]anthracene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Fluoranthene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Fluorene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
2-Methylnaphthalene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Naphthalene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Phenanthrene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Pyrene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Phenols in SVOC Soil Samples by GC-MS												

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V18	V18	V19	V19	V19	V19	V19	V19A	V19A	V19A	V19A	V19A
Sample Type: Sediment	2.0-3.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1m A	0.5-1m B	1-1.5m A
4-Chloro-3-methylphenol	-	-	-	< 5	-	-	-	< 5	-	-	-	-
2-Chlorophenol	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
2,4-Dichlorophenol	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
2,4-Dimethylphenol	-	-	-	< 3	-	-	-	< 3	-	-	-	-
3 & 4-Methylphenol (m- + p-cresol)	-	-	-	< 3	-	-	-	< 3	-	-	-	-
2-Methylphenol (o-Cresol)	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
2-Nitrophenol	-	-	-	< 5	-	-	-	< 5	-	-	-	-
Pentachlorophenol (PCP)	-	-	-	< 30	-	-	-	< 30	-	-	-	-
Phenol	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
2,4,5-Trichlorophenol	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
2,4,6-Trichlorophenol	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Plasticisers in SVOC Soil Samples by GC-MS												
Bis(2-ethylhexyl)phthalate	-	-	-	< 5	-	-	-	< 5	-	-	-	-
Butylbenzylphthalate	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Di(2-ethylhexyl)adipate	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Diethylphthalate	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Dimethylphthalate	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Di-n-butylphthalate	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Di-n-octylphthalate	-	-	-	< 1.0	-	-	-	< 1.0	-	-	-	-
Other Halogenated compounds in SVOC Soil Samples by GC-MS												
1,2-Dichlorobenzene	-	-	-	< 0.7	-	-	-	< 0.7	-	-	-	-
1,3-Dichlorobenzene	-	-	-	< 0.7	-	-	-	< 0.7	-	-	-	-
1,4-Dichlorobenzene	-	-	-	< 0.7	-	-	-	< 0.7	-	-	-	-
Hexachlorobutadiene	-	-	-	< 0.7	-	-	-	< 0.7	-	-	-	-
Hexachloroethane	-	-	-	< 0.7	-	-	-	< 0.7	-	-	-	-
1,2,4-Trichlorobenzene	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Other compounds in SVOC Soil Samples by GC-MS												
Benzyl alcohol	-	-	-	< 10	-	-	-	< 10	-	-	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V18	V18	V19	V19	V19	V19	V19	V19A	V19A	V19A	V19A	V19A
Sample Type: Sediment	2.0-3.0m A	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-2.0m A	0-0.5m A	0-0.5m B	0.5-1m A	0.5-1m B	1-1.5m A
Carbazole	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Dibenzofuran	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Isophorone	-	-	-	< 0.5	-	-	-	< 0.5	-	-	-	-
Tributyl Tin Trace in Soil samples by GCMS												
Dibutyltin (as Sn)	-	-	-	< 0.005	-	< 0.005	-	< 0.005	-	< 0.005	-	-
Monobutyltin (as Sn)	-	-	-	< 0.007	-	< 0.007	-	< 0.007	-	< 0.007	-	-
Tributyltin (as Sn)	-	-	-	< 0.004	-	< 0.004	-	< 0.004	-	< 0.004	-	-
Triphenyltin (as Sn)	-	-	-	< 0.003	-	< 0.003	-	< 0.003	-	< 0.003	-	-
Total Petroleum Hydrocarbons in Soil												
C7 - C9	-	-	-	< 8	-	< 9	-	< 9	-	< 8	-	-
C10 - C14	-	-	-	< 20	-	< 20	-	< 20	-	< 20	-	-
C15 - C36	-	-	-	< 40	-	< 40	-	< 40	-	< 40	-	-
Total hydrocarbons (C7 - C36)	-	-	-	< 70	-	< 70	-	< 70	-	< 70	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V20	V20	V20	V20	V20
Sample Type: Sediment	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-1.5m A
Sample Name:	24/02/16	24/02/16	24/02/16	24/02/16	24/02/16
Lab Number:	1544100.1	1544100.2	1544100.4	1544100.5	1544100.6
Dry Matter (g/100g as rcvd)	-	84	-	85	-
Total Organic Carbon (g/100g dry wt)	< 0.13	-	0.06	-	0.05
Antifouling cobiocides in sediment samples by LCMSMS					
Diuron	-	< 0.010	-	< 0.010	-
Irgarol	-	< 0.010	-	< 0.010	-
Isoproturon	-	< 0.010	-	< 0.010	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg					
Total Recoverable Arsenic	3	-	2.6	-	2.7
Total Recoverable Cadmium	0.083	-	0.02	-	0.017
Total Recoverable Chromium	210	-	8	-	8.9
Total Recoverable Copper	3.8	-	0.5	-	0.4
Total Recoverable Lead	1.35	-	0.96	-	1.07
Total Recoverable Mercury	< 0.010	-	< 0.010	-	< 0.010
Total Recoverable Nickel	123	-	1.9	-	2.2
Total Recoverable Zinc	8.9	-	7.6	-	8.1
Polycyclic Aromatic Hydrocarbons Screening in Soil					
Acenaphthene	-	< 0.03	-	< 0.03	-
Acenaphthylene	-	< 0.03	-	< 0.03	-
Anthracene	-	< 0.03	-	< 0.03	-
Benzo[a]anthracene	-	< 0.03	-	< 0.03	-
Benzo[a]pyrene (BAP)	-	< 0.03	-	< 0.03	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	-	< 0.03	-	< 0.03	-
Benzo[g,h,i]perylene	-	< 0.03	-	< 0.03	-
Benzo[k]fluoranthene	-	< 0.03	-	< 0.03	-
Chrysene	-	< 0.03	-	< 0.03	-
Dibenzo[a,h]anthracene	-	< 0.03	-	< 0.03	-

Results as mg/kg dry wt unless stated otherwise

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V20	V20	V20	V20	V20
Sample Type: Sediment	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-1.5m A
Fluoranthene	-	< 0.03	-	< 0.03	-
Fluorene	-	< 0.03	-	< 0.03	-
Indeno(1,2,3-c,d)pyrene	-	< 0.03	-	< 0.03	-
Naphthalene	-	< 0.13	-	< 0.13	-
Phenanthrene	-	< 0.03	-	< 0.03	-
Pyrene	-	< 0.03	-	< 0.03	-
Haloethers in SVOC Soil Samples by GC-MS					
Bis(2-chloroethoxy) methane	-	< 0.5	-	-	-
Bis(2-chloroethyl)ether	-	< 0.5	-	-	-
Bis(2-chloroisopropyl)ether	-	< 0.5	-	-	-
4-Bromophenyl phenyl ether	-	< 0.4	-	-	-
4-Chlorophenyl phenyl ether	-	< 0.5	-	-	-
Nitrogen containing compounds in SVOC Soil Samples by GC-MS					
2,4-Dinitrotoluene	-	< 1.0	-	-	-
2,6-Dinitrotoluene	-	< 1.0	-	-	-
Nitrobenzene	-	< 0.5	-	-	-
N-Nitrosodi-n-propylamine	-	< 0.7	-	-	-
N-Nitrosodiphenylamine + Diphenylamine	-	< 0.7	-	-	-
Organochlorine Pesticides in SVOC Soil Samples by GC-MS					
Aldrin	-	< 0.5	-	-	-
alpha-BHC	-	< 0.5	-	-	-
beta-BHC	-	< 0.5	-	-	-
delta-BHC	-	< 0.5	-	-	-
gamma-BHC (Lindane)	-	< 0.5	-	-	-
4,4'-DDD	-	< 0.5	-	-	-
4,4'-DDE	-	< 0.5	-	-	-
4,4'-DDT	-	< 1.0	-	-	-
Dieldrin	-	< 0.5	-	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V20	V20	V20	V20	V20
Sample Type: Sediment	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-1.5m A
Endosulfan I	-	< 1.0	-	-	-
Endosulfan II	-	< 2	-	-	-
Endosulfan sulphate	-	< 1.0	-	-	-
Endrin	-	< 0.7	-	-	-
Endrin ketone	-	< 1.0	-	-	-
Heptachlor	-	< 0.5	-	-	-
Heptachlor epoxide	-	< 0.5	-	-	-
Hexachlorobenzene	-	< 0.5	-	-	-
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS					
Acenaphthene	-	< 0.5	-	-	-
Acenaphthylene	-	< 0.5	-	-	-
Anthracene	-	< 0.5	-	-	-
Benzo[a]anthracene	-	< 0.5	-	-	-
Benzo[a]pyrene (BAP)	-	< 0.5	-	-	-
Benzo[b]fluoranthene + Benzo[j]fluoranthene	-	< 0.5	-	-	-
Benzo[g,h,i]perylene	-	< 0.5	-	-	-
Benzo[k]fluoranthene	-	< 0.5	-	-	-
1&2-Chloronaphthalene	-	< 0.5	-	-	-
Chrysene	-	< 0.5	-	-	-
Dibenzo[a,h]anthracene	-	< 0.5	-	-	-
Fluoranthene	-	< 0.5	-	-	-
Fluorene	-	< 0.5	-	-	-
Indeno(1,2,3-c,d)pyrene	-	< 0.5	-	-	-
2-Methylnaphthalene	-	< 0.5	-	-	-
Naphthalene	-	< 0.5	-	-	-
Phenanthrene	-	< 0.5	-	-	-
Pyrene	-	< 0.5	-	-	-
Phenols in SVOC Soil Samples by GC-MS					

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V20	V20	V20	V20	V20
Sample Type: Sediment	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-1.5m A
4-Chloro-3-methylphenol	-	< 5	-	-	-
2-Chlorophenol	-	< 1.0	-	-	-
2,4-Dichlorophenol	-	< 1.0	-	-	-
2,4-Dimethylphenol	-	< 3	-	-	-
3 & 4-Methylphenol (m- + p-cresol)	-	< 3	-	-	-
2-Methylphenol (o-Cresol)	-	< 1.0	-	-	-
2-Nitrophenol	-	< 5	-	-	-
Pentachlorophenol (PCP)	-	< 30	-	-	-
Phenol	-	< 1.0	-	-	-
2,4,5-Trichlorophenol	-	< 1.0	-	-	-
2,4,6-Trichlorophenol	-	< 1.0	-	-	-
Plasticisers in SVOC Soil Samples by GC-MS					
Bis(2-ethylhexyl)phthalate	-	< 5	-	-	-
Butylbenzylphthalate	-	< 1.0	-	-	-
Di(2-ethylhexyl)adipate	-	< 1.0	-	-	-
Diethylphthalate	-	< 1.0	-	-	-
Dimethylphthalate	-	< 1.0	-	-	-
Di-n-butylphthalate	-	< 1.0	-	-	-
Di-n-octylphthalate	-	< 1.0	-	-	-
Other Halogenated compounds in SVOC Soil Samples by GC-MS					
1,2-Dichlorobenzene	-	< 0.7	-	-	-
1,3-Dichlorobenzene	-	< 0.7	-	-	-
1,4-Dichlorobenzene	-	< 0.7	-	-	-
Hexachlorobutadiene	-	< 0.7	-	-	-
Hexachloroethane	-	< 0.7	-	-	-
1,2,4-Trichlorobenzene	-	< 0.5	-	-	-
Other compounds in SVOC Soil Samples by GC-MS					
Benzyl alcohol	-	< 10	-	-	-

APPENDIX C1: Summary Chemical database for sectioned vibracore samples
collected by Tonkin Taylor and analysed by R.J. Hill Laboratories

	V20	V20	V20	V20	V20
Sample Type: Sediment	0.0-0.5m A	0.0-0.5m B	0.5-1.0m A	0.5-1.0m B	1.0-1.5m A
Carbazole	-	< 0.5	-	-	-
Dibenzofuran	-	< 0.5	-	-	-
Isophorone	-	< 0.5	-	-	-
Tributyl Tin Trace in Soil samples by GCMS					
Dibutyltin (as Sn)	-	< 0.005	-	< 0.005	-
Monobutyltin (as Sn)	-	< 0.007	-	< 0.007	-
Tributyltin (as Sn)	-	< 0.004	-	< 0.004	-
Triphenyltin (as Sn)	-	< 0.003	-	< 0.003	-
Total Petroleum Hydrocarbons in Soil					
C7 - C9	-	< 8	-	< 8	-
C10 - C14	-	< 20	-	< 20	-
C15 - C36	-	< 40	-	< 40	-
Total hydrocarbons (C7 - C36)	-	< 70	-	< 70	-

APPENDIX C2

Hill Laboratories
BETTER TESTING BETTER RESULTS

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ANALYSIS REPORT

Client:	Tonkin & Taylor	**Lab No:**	1546000 SPv2
Contact:	A Pomfret	**Date Registered:**	02-Mar-2016
	C/- Tonkin & Taylor	**Date Reported:**	22-Apr-2016
	PO Box 5271	**Quote No:**	74906
	Auckland 1141	**Order No:**	98701
		Client Reference:	Contamination Sampling Marsden Point
		Submitted By:	J Yule

Amended Report

This report replaces an earlier report issued on the 10 Mar 2016 at 4:21 pm
Elutriation testing has been added at the request of the client.

Sample Type: Sediment

Sample Name:	V19A 0-0.5m A 29-Feb-2016 11:00 am	V19A 0-0.5m B 29-Feb-2016 11:00 am	V19A 0.5-1m A 29-Feb-2016 11:00 am	V19A 0.5-1m B 29-Feb-2016 11:00 am	V19A 1-1.5m A 29-Feb-2016 11:00 am
Lab Number:	1546000.1	1546000.2	1546000.4	1546000.5	1546000.7
Individual Tests					
Dry Matter g/100g as rcvd	82	-	82	-	-
Total Organic Carbon* g/100g dry wt	-	< 0.05	-	< 0.05	< 0.05
Antifouling cobiocides in sediment samples by LCMSMS					
Diuron* mg/kg dry wt	< 0.010	-	< 0.010	-	-
Irgarol* mg/kg dry wt	< 0.010	-	< 0.010	-	-
Isoproturon* mg/kg dry wt	< 0.010	-	< 0.010	-	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg					
Total Recoverable Arsenic mg/kg dry wt	-	2.9	-	2.2	2.5
Total Recoverable Cadmium mg/kg dry wt	-	< 0.010	-	< 0.010	0.015
Total Recoverable Chromium mg/kg dry wt	-	50	-	10.6	37
Total Recoverable Copper mg/kg dry wt	-	1.1	-	0.4	0.8
Total Recoverable Lead mg/kg dry wt	-	1.19	-	0.87	0.90
Total Recoverable Mercury mg/kg dry wt	-	< 0.010	-	< 0.010	< 0.010
Total Recoverable Nickel mg/kg dry wt	-	20	-	3.7	20
Total Recoverable Zinc mg/kg dry wt	-	8.3	-	6.6	7.2
Polycyclic Aromatic Hydrocarbons Screening in Soil					
Acenaphthene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Acenaphthylene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Anthracene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Benzo[a]anthracene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Benzo[a]pyrene (BAP) mg/kg dry wt	< 0.03	-	< 0.03	-	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Benzo[g,h,i]perylene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Benzo[k]fluoranthene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Chrysene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Dibenzo[a,h]anthracene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Fluoranthene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Fluorene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Indeno(1,2,3-c,d)pyrene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Naphthalene mg/kg dry wt	< 0.14	-	< 0.13	-	-
Phenanthrene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Pyrene mg/kg dry wt	< 0.03	-	< 0.03	-	-
Haloethers in SVOC Soil Samples by GC-MS					

ilac-MRA IANZ ACCREDITED LABORATORY

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Sediment						
Sample Name:		V19A 0-0.5m A 29-Feb-2016 11:00 am	V19A 0-0.5m B 29-Feb-2016 11:00 am	V19A 0.5-1m A 29-Feb-2016 11:00 am	V19A 0.5-1m B 29-Feb-2016 11:00 am	V19A 1-1.5m A 29-Feb-2016 11:00 am
Lab Number:		1546000.1	1546000.2	1546000.4	1546000.5	1546000.7
Haloethers in SVOC Soil Samples by GC-MS						
Bis(2-chloroethoxy) methane	mg/kg dry wt	< 0.5	-	-	-	-
Bis(2-chloroethyl)ether	mg/kg dry wt	< 0.5	-	-	-	-
Bis(2-chloroisopropyl)ether	mg/kg dry wt	< 0.5	-	-	-	-
4-Bromophenyl phenyl ether	mg/kg dry wt	< 0.4	-	-	-	-
4-Chlorophenyl phenyl ether	mg/kg dry wt	< 0.5	-	-	-	-
Nitrogen containing compounds in SVOC Soil Samples by GC-MS						
2,4-Dinitrotoluene	mg/kg dry wt	< 1.0	-	-	-	-
2,6-Dinitrotoluene	mg/kg dry wt	< 1.0	-	-	-	-
Nitrobenzene	mg/kg dry wt	< 0.5	-	-	-	-
N-Nitrosodi-n-propylamine	mg/kg dry wt	< 0.7	-	-	-	-
N-Nitrosodiphenylamine + Diphenylamine	mg/kg dry wt	< 0.7	-	-	-	-
Organochlorine Pesticides in SVOC Soil Samples by GC-MS						
Aldrin	mg/kg dry wt	< 0.5	-	-	-	-
alpha-BHC	mg/kg dry wt	< 0.5	-	-	-	-
beta-BHC	mg/kg dry wt	< 0.5	-	-	-	-
delta-BHC	mg/kg dry wt	< 0.5	-	-	-	-
gamma-BHC (Lindane)	mg/kg dry wt	< 0.5	-	-	-	-
4,4'-DDD	mg/kg dry wt	< 0.5	-	-	-	-
4,4'-DDE	mg/kg dry wt	< 0.5	-	-	-	-
4,4'-DDT	mg/kg dry wt	< 1.0	-	-	-	-
Dieldrin	mg/kg dry wt	< 0.5	-	-	-	-
Endosulfan I	mg/kg dry wt	< 1.0	-	-	-	-
Endosulfan II	mg/kg dry wt	< 2	-	-	-	-
Endosulfan sulphate	mg/kg dry wt	< 1.0	-	-	-	-
Endrin	mg/kg dry wt	< 0.7	-	-	-	-
Endrin ketone	mg/kg dry wt	< 1.0	-	-	-	-
Heptachlor	mg/kg dry wt	< 0.5	-	-	-	-
Heptachlor epoxide	mg/kg dry wt	< 0.5	-	-	-	-
Hexachlorobenzene	mg/kg dry wt	< 0.5	-	-	-	-
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS						
Acenaphthene	mg/kg dry wt	< 0.5	-	-	-	-
Acenaphthylene	mg/kg dry wt	< 0.5	-	-	-	-
Anthracene	mg/kg dry wt	< 0.5	-	-	-	-
Benzo[a]anthracene	mg/kg dry wt	< 0.5	-	-	-	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	< 0.5	-	-	-	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	< 0.5	-	-	-	-
Benzo[g,h,i]perylene	mg/kg dry wt	< 0.5	-	-	-	-
Benzo[k]fluoranthene	mg/kg dry wt	< 0.5	-	-	-	-
1&2-Chloronaphthalene	mg/kg dry wt	< 0.5	-	-	-	-
Chrysene	mg/kg dry wt	< 0.5	-	-	-	-
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.5	-	-	-	-
Fluoranthene	mg/kg dry wt	< 0.5	-	-	-	-
Fluorene	mg/kg dry wt	< 0.5	-	-	-	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	< 0.5	-	-	-	-
2-Methylnaphthalene	mg/kg dry wt	< 0.5	-	-	-	-
Naphthalene	mg/kg dry wt	< 0.5	-	-	-	-
Phenanthrene	mg/kg dry wt	< 0.5	-	-	-	-
Pyrene	mg/kg dry wt	< 0.5	-	-	-	-
Phenols in SVOC Soil Samples by GC-MS						
4-Chloro-3-methylphenol	mg/kg dry wt	< 5	-	-	-	-
2-Chlorophenol	mg/kg dry wt	< 1.0	-	-	-	-
2,4-Dichlorophenol	mg/kg dry wt	< 1.0	-	-	-	-

Sample Type: Sediment						
Sample Name:		V19A 0-0.5m A 29-Feb-2016 11:00 am	V19A 0-0.5m B 29-Feb-2016 11:00 am	V19A 0.5-1m A 29-Feb-2016 11:00 am	V19A 0.5-1m B 29-Feb-2016 11:00 am	V19A 1-1.5m A 29-Feb-2016 11:00 am
Lab Number:		1546000.1	1546000.2	1546000.4	1546000.5	1546000.7
Phenols in SVOC Soil Samples by GC-MS						
2,4-Dimethylphenol	mg/kg dry wt	< 3	-	-	-	-
3 & 4-Methylphenol (m- + p-cresol)	mg/kg dry wt	< 3	-	-	-	-
2-Methylphenol (o-Cresol)	mg/kg dry wt	< 1.0	-	-	-	-
2-Nitrophenol	mg/kg dry wt	< 5	-	-	-	-
Pentachlorophenol (PCP)	mg/kg dry wt	< 30	-	-	-	-
Phenol	mg/kg dry wt	< 1.0	-	-	-	-
2,4,5-Trichlorophenol	mg/kg dry wt	< 1.0	-	-	-	-
2,4,6-Trichlorophenol	mg/kg dry wt	< 1.0	-	-	-	-
Plasticisers in SVOC Soil Samples by GC-MS						
Bis(2-ethylhexyl)phthalate	mg/kg dry wt	< 5	-	-	-	-
Butylbenzylphthalate	mg/kg dry wt	< 1.0	-	-	-	-
Di(2-ethylhexyl)adipate	mg/kg dry wt	< 1.0	-	-	-	-
Diethylphthalate	mg/kg dry wt	< 1.0	-	-	-	-
Dimethylphthalate	mg/kg dry wt	< 1.0	-	-	-	-
Di-n-butylphthalate	mg/kg dry wt	< 1.0	-	-	-	-
Di-n-octylphthalate	mg/kg dry wt	< 1.0	-	-	-	-
Other Halogenated compounds in SVOC Soil Samples by GC-MS						
1,2-Dichlorobenzene	mg/kg dry wt	< 0.7	-	-	-	-
1,3-Dichlorobenzene	mg/kg dry wt	< 0.7	-	-	-	-
1,4-Dichlorobenzene	mg/kg dry wt	< 0.7	-	-	-	-
Hexachlorobutadiene	mg/kg dry wt	< 0.7	-	-	-	-
Hexachloroethane	mg/kg dry wt	< 0.7	-	-	-	-
1,2,4-Trichlorobenzene	mg/kg dry wt	< 0.5	-	-	-	-
Other compounds in SVOC Soil Samples by GC-MS						
Benzyl alcohol	mg/kg dry wt	< 10	-	-	-	-
Carbazole	mg/kg dry wt	< 0.5	-	-	-	-
Dibenzofuran	mg/kg dry wt	< 0.5	-	-	-	-
Isophorone	mg/kg dry wt	< 0.5	-	-	-	-
Tributyl Tin Trace in Soil samples by GCMS						
Dibutyltin (as Sn)	mg/kg dry wt	< 0.005	-	< 0.005	-	-
Monobutyltin (as Sn)	mg/kg dry wt	< 0.007	-	< 0.007	-	-
Tributyltin (as Sn)	mg/kg dry wt	< 0.004	-	< 0.004	-	-
Triphenyltin (as Sn)	mg/kg dry wt	< 0.003	-	< 0.003	-	-
Total Petroleum Hydrocarbons in Soil						
C7 - C9	mg/kg dry wt	< 9	-	< 8	-	-
C10 - C14	mg/kg dry wt	< 20	-	< 20	-	-
C15 - C36	mg/kg dry wt	< 40	-	< 40	-	-
Total hydrocarbons (C7 - C36)	mg/kg dry wt	< 70	-	< 70	-	-

Sample Type: Aqueous						
Sample Name:		V19A 0-0.5m A [Elutriation extract]				
Lab Number:		1546000.10				
Individual Tests						
Total Chromium*	g/m³	< 0.0011	-	-	-	-
Total Nickel*	g/m³	< 0.007	-	-	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Antifouling cobiocides in sediment samples by LCMSMS*		0.010 mg/kg dry wt	1, 4
Antifouling cobiocides suite in sediment by LCMSMS*	Ethyl acetate extraction, SPE cleanup, determination by LCMSMS.	-	1, 4
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-2, 4-5, 7
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	2, 5, 7
Elutriation testing*	Extn with (client supplied) water, eg seawater, Sed:Water 1:4 by vol, mix 30 min, settle 1 hr, filtration or centrifugation. US EPA 503/8-91/001, "Evaluation of Dredged Material for Ocean Disposal".	-	1
Polycyclic Aromatic Hydrocarbons Screening in Soil	Sonication extraction, Dilution or SPE cleanup (if required), GC-MS SIM analysis (modified US EPA 8270). Tested on as received sample. [KBIs:5786,2805,2695]	0.010 - 0.05 mg/kg dry wt	1, 4
Semivolatile Organic Compounds Screening in Soil by GC-MS	Sonication extraction, GPC cleanup (if required), GC-MS FS analysis. Tested on as received sample	0.3 - 30 mg/kg dry wt	1
Tributyl Tin Trace in Soil samples by GCMS	Solvent extraction, ethylation, SPE cleanup, GC-MS SIM analysis. Tested on dried sample	0.003 - 0.007 mg/kg dry wt	1, 4
Total Petroleum Hydrocarbons in Soil	Sonication extraction in DCM, Silica cleanup, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines. Tested on as received sample [KBIs:5786,2805,10734]	8 - 60 mg/kg dry wt	1, 4
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. US EPA 3550. (Free water removed before analysis).	0.10 g/100g as rcvd	1, 4
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	2, 5, 7
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	2, 5, 7

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	10
Total Chromium*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	10
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	10

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

APPENDIX C3

Hill Laboratories
BETTER TESTING BETTER RESULTS

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ANALYSIS REPORT

Client:	Tonkin & Taylor	**Lab No:**	1544100 SUPv2
Contact:	A Pomfret	**Date Registered:**	27-Feb-2016
	C/- Tonkin & Taylor	**Date Reported:**	22-Apr-2016
	PO Box 5271	**Quote No:**	74906
	Auckland 1141	**Order No:**	98701
		Client Reference:	Contamination sampling Marsden Point
		Submitted By:	J Yule

Amended Report

This report replaces an earlier report issued on the 10 Mar 2016 at 12:28 pm
Elutriation testing has been added at the request of the client.

Sample Type: Sediment

Sample Name:	V20 0.0-0.5m A 24-Feb-2016 11:00 am	V20 0.0-0.5m B 24-Feb-2016 11:00 am	V20 0.5-1.0m A 24-Feb-2016 11:00 am	V20 0.5-1.0m B 24-Feb-2016 11:00 am
Lab Number:	1544100.1	1544100.2	1544100.4	1544100.5
Individual Tests				
Dry Matter g/100g as rcvd	-	83.5 ± 5.0	-	84.6 ± 5.0
Total Organic Carbon* g/100g dry wt	< 0.13 ± 0.042	-	0.055 ± 0.041	-
Antifouling cobiocides in sediment samples by LCMSMS				
Diuron* mg/kg dry wt	-	< 0.010	-	< 0.010
Irgarol* mg/kg dry wt	-	< 0.010	-	< 0.010
Isoproturon* mg/kg dry wt	-	< 0.010	-	< 0.010
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg				
Total Recoverable Arsenic mg/kg dry wt	2.71 ± 0.31	-	2.58 ± 0.29	-
Total Recoverable Cadmium mg/kg dry wt	0.083 ± 0.012	-	0.0202 ± 0.0065	-
Total Recoverable Chromium mg/kg dry wt	213 ± 26	-	8.04 ± 0.98	-
Total Recoverable Copper mg/kg dry wt	3.83 ± 0.56	-	0.46 ± 0.15	-
Total Recoverable Lead mg/kg dry wt	1.35 ± 0.17	-	0.96 ± 0.12	-
Total Recoverable Mercury mg/kg dry wt	< 0.010 ± 0.0067	-	< 0.010 ± 0.0067	-
Total Recoverable Nickel mg/kg dry wt	123 ± 13	-	1.86 ± 0.23	-
Total Recoverable Zinc mg/kg dry wt	8.9 ± 1.5	-	7.6 ± 1.3	-
Polycyclic Aromatic Hydrocarbons Screening in Soil				
Acenaphthene mg/kg dry wt	-	< 0.03 ± 0.0094	-	< 0.03 ± 0.0093
Acenaphthylene mg/kg dry wt	-	< 0.03 ± 0.0070	-	< 0.03 ± 0.0070
Anthracene mg/kg dry wt	-	< 0.03 ± 0.0097	-	< 0.03 ± 0.0096
Benzo[a]anthracene mg/kg dry wt	-	< 0.03 ± 0.0090	-	< 0.03 ± 0.0089
Benzo[a]pyrene (BAP) mg/kg dry wt	-	< 0.03 ± 0.0069	-	< 0.03 ± 0.0069
Benzo[b]fluoranthene + Benzo[j] fluoranthene mg/kg dry wt	-	< 0.03 ± 0.0082	-	< 0.03 ± 0.0082
Benzo[g,h,i]perylene mg/kg dry wt	-	< 0.03 ± 0.0078	-	< 0.03 ± 0.0078
Benzo[k]fluoranthene mg/kg dry wt	-	< 0.03 ± 0.0073	-	< 0.03 ± 0.0073
Chrysene mg/kg dry wt	-	< 0.03 ± 0.0075	-	< 0.03 ± 0.0075
Dibenzo[a,h]anthracene mg/kg dry wt	-	< 0.03 ± 0.0073	-	< 0.03 ± 0.0073
Fluoranthene mg/kg dry wt	-	< 0.03 ± 0.0071	-	< 0.03 ± 0.0071
Fluorene mg/kg dry wt	-	< 0.03 ± 0.0073	-	< 0.03 ± 0.0072
Indeno(1,2,3-c,d)pyrene mg/kg dry wt	-	< 0.03 ± 0.0070	-	< 0.03 ± 0.0070
Naphthalene mg/kg dry wt	-	< 0.13 ± 0.044	-	< 0.13 ± 0.044
Phenanthrene mg/kg dry wt	-	< 0.03 ± 0.0075	-	< 0.03 ± 0.0074
Pyrene mg/kg dry wt	-	< 0.03 ± 0.0073	-	< 0.03 ± 0.0073
Haloethers in SVOC Soil Samples by GC-MS				
Bis(2-chloroethoxy) methane mg/kg dry wt	-	< 0.5 ± 0.34	-	-

ilac-MRA IANZ ACCREDITED LABORATORY

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Sediment					
Sample Name:		V20 0.0-0.5m A 24-Feb-2016 11:00 am	V20 0.0-0.5m B 24-Feb-2016 11:00 am	V20 0.5-1.0m A 24-Feb-2016 11:00 am	V20 0.5-1.0m B 24-Feb-2016 11:00 am
Lab Number:		1544100.1	1544100.2	1544100.4	1544100.5
Haloethers in SVOC Soil Samples by GC-MS					
Bis(2-chloroethyl)ether	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Bis(2-chloroisopropyl)ether	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
4-Bromophenyl phenyl ether	mg/kg dry wt	-	< 0.4 ± 0.21	-	-
4-Chlorophenyl phenyl ether	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Nitrogen containing compounds in SVOC Soil Samples by GC-MS					
2,4-Dinitrotoluene	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
2,6-Dinitrotoluene	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
Nitrobenzene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
N-Nitrosodi-n-propylamine	mg/kg dry wt	-	< 0.7 ± 0.35	-	-
N-Nitrosodiphenylamine + Diphenylamine	mg/kg dry wt	-	< 0.7 ± 0.43	-	-
Organochlorine Pesticides in SVOC Soil Samples by GC-MS					
Aldrin	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
alpha-BHC	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
beta-BHC	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
delta-BHC	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
gamma-BHC (Lindane)	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
4,4'-DDD	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
4,4'-DDE	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
4,4'-DDT	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
Dieldrin	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Endosulfan I	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
Endosulfan II	mg/kg dry wt	-	< 2 ± 1.4	-	-
Endosulfan sulphate	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
Endrin	mg/kg dry wt	-	< 0.7 ± 0.40	-	-
Endrin ketone	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
Heptachlor	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Heptachlor epoxide	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Hexachlorobenzene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS					
Acenaphthene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Acenaphthylene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Anthracene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Benzo[a]anthracene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Benzo[g,h,i]perylene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Benzo[k]fluoranthene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
1&2-Chloronaphthalene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Chrysene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Dibenzo[a,h]anthracene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Fluoranthene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Fluorene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
2-Methylnaphthalene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Naphthalene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Phenanthrene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Pyrene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Phenols in SVOC Soil Samples by GC-MS					
4-Chloro-3-methylphenol	mg/kg dry wt	-	< 5 ± 3.4	-	-
2-Chlorophenol	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
2,4-Dichlorophenol	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
2,4-Dimethylphenol	mg/kg dry wt	-	< 3 ± 1.2	-	-

Sample Type: Sediment					
Sample Name:		V20 0.0-0.5m A 24-Feb-2016 11:00 am	V20 0.0-0.5m B 24-Feb-2016 11:00 am	V20 0.5-1.0m A 24-Feb-2016 11:00 am	V20 0.5-1.0m B 24-Feb-2016 11:00 am
Lab Number:		1544100.1	1544100.2	1544100.4	1544100.5
Phenols in SVOC Soil Samples by GC-MS					
3 & 4-Methylphenol (m- + p-cresol)	mg/kg dry wt	-	< 3 ± 1.2	-	-
2-Methylphenol (o-Cresol)	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
2-Nitrophenol	mg/kg dry wt	-	< 5 ± 3.4	-	-
Pentachlorophenol (PCP)	mg/kg dry wt	-	< 30 ± 68	-	-
Phenol	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
2,4,5-Trichlorophenol	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
2,4,6-Trichlorophenol	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
Plasticisers in SVOC Soil Samples by GC-MS					
Bis(2-ethylhexyl)phthalate	mg/kg dry wt	-	< 5 ± 3.4	-	-
Butylbenzylphthalate	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
Di(2-ethylhexyl)adipate	mg/kg dry wt	-	< 1.0 ± 5.1	-	-
Diethylphthalate	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
Dimethylphthalate	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
Di-n-butylphthalate	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
Di-n-octylphthalate	mg/kg dry wt	-	< 1.0 ± 0.67	-	-
Other Halogenated compounds in SVOC Soil Samples by GC-MS					
1,2-Dichlorobenzene	mg/kg dry wt	-	< 0.7 ± 0.35	-	-
1,3-Dichlorobenzene	mg/kg dry wt	-	< 0.7 ± 0.35	-	-
1,4-Dichlorobenzene	mg/kg dry wt	-	< 0.7 ± 0.35	-	-
Hexachlorobutadiene	mg/kg dry wt	-	< 0.7 ± 0.35	-	-
Hexachloroethane	mg/kg dry wt	-	< 0.7 ± 0.36	-	-
1,2,4-Trichlorobenzene	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Other compounds in SVOC Soil Samples by GC-MS					
Benzyl alcohol	mg/kg dry wt	-	< 10 ± 6.7	-	-
Carbazole	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Dibenzofuran	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Isophorone	mg/kg dry wt	-	< 0.5 ± 0.34	-	-
Tributyl Tin Trace in Soil samples by GCMS					
Dibutyltin (as Sn)	mg/kg dry wt	-	< 0.005 ± 0.0056	-	< 0.005 ± 0.0056
Monobutyltin (as Sn)	mg/kg dry wt	-	< 0.007 ± 0.0075	-	< 0.007 ± 0.0075
Tributyltin (as Sn)	mg/kg dry wt	-	< 0.004 ± 0.0044	-	< 0.004 ± 0.0044
Triphenyltin (as Sn)	mg/kg dry wt	-	< 0.003 ± 0.0021	-	< 0.003 ± 0.0021
Total Petroleum Hydrocarbons in Soil					
C7 - C9	mg/kg dry wt	-	< 8 ± 5.4	-	< 8 ± 5.4
C10 - C14	mg/kg dry wt	-	< 20 ± 7.6	-	< 20 ± 7.6
C15 - C36	mg/kg dry wt	-	< 40 ± 9.3	-	< 40 ± 9.3
Total hydrocarbons (C7 - C36)	mg/kg dry wt	-	< 70 ± 14	-	< 70 ± 14

Sample Name:		V201.0-1.5m A 24-Feb-2016 11:00 am	V18 0.0-0.5m A 24-Feb-2016 1:00 pm	V18 0.0-0.5m B 24-Feb-2016 1:00 pm	V18 0.5-1.0m A 24-Feb-2016 1:00 pm
Lab Number:		1544100.6	1544100.9	1544100.10	1544100.12
Individual Tests					
Dry Matter	g/100g as rcvd	-	-	88.1 ± 5.0	-
Total Organic Carbon*	g/100g dry wt	0.052 ± 0.041	< 0.13 ± 0.042	-	< 0.05 ± 0.041
Antifouling cobiocides in sediment samples by LCMSMS					
Diuron*	mg/kg dry wt	-	-	< 0.010	-
Irgarol*	mg/kg dry wt	-	-	< 0.010	-
Isoproturon*	mg/kg dry wt	-	-	< 0.010	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg					
Total Recoverable Arsenic	mg/kg dry wt	2.68 ± 0.30	1.92 ± 0.24	-	2.21 ± 0.26
Total Recoverable Cadmium	mg/kg dry wt	0.0174 ± 0.0064	< 0.010 ± 0.0062	-	0.0121 ± 0.0062
Total Recoverable Chromium	mg/kg dry wt	8.9 ± 1.1	5.44 ± 0.67	-	9.1 ± 1.1
Total Recoverable Copper	mg/kg dry wt	0.45 ± 0.15	0.41 ± 0.15	-	0.35 ± 0.14
Total Recoverable Lead	mg/kg dry wt	1.07 ± 0.14	0.83 ± 0.11	-	1.14 ± 0.14

Sample Type: Sediment					
Sample Name:		V201.0-1.5m A 24-Feb-2016 11:00 am	V18 0.0-0.5m A 24-Feb-2016 1:00 pm	V18 0.0-0.5m B 24-Feb-2016 1:00 pm	V18 0.5-1.0m A 24-Feb-2016 1:00 pm
Lab Number:		1544100.6	1544100.9	1544100.10	1544100.12
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg					
Total Recoverable Mercury	mg/kg dry wt	< 0.010 ± 0.0067	< 0.010 ± 0.0067	-	< 0.010 ± 0.0067
Total Recoverable Nickel	mg/kg dry wt	2.16 ± 0.26	3.39 ± 0.37	-	2.10 ± 0.25
Total Recoverable Zinc	mg/kg dry wt	8.1 ± 1.4	4.38 ± 0.75	-	8.9 ± 1.5
Polycyclic Aromatic Hydrocarbons Screening in Soil					
Acenaphthene	mg/kg dry wt	-	-	< 0.03 ± 0.0092	-
Acenaphthylene	mg/kg dry wt	-	-	< 0.03 ± 0.0070	-
Anthracene	mg/kg dry wt	-	-	< 0.03 ± 0.0095	-
Benzo[a]anthracene	mg/kg dry wt	-	-	< 0.03 ± 0.0089	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	-	-	< 0.03 ± 0.0069	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	-	-	< 0.03 ± 0.0081	-
Benzo[g,h,i]perylene	mg/kg dry wt	-	-	< 0.03 ± 0.0077	-
Benzo[k]fluoranthene	mg/kg dry wt	-	-	< 0.03 ± 0.0073	-
Chrysene	mg/kg dry wt	-	-	< 0.03 ± 0.0075	-
Dibenzo[a,h]anthracene	mg/kg dry wt	-	-	< 0.03 ± 0.0073	-
Fluoranthene	mg/kg dry wt	-	-	< 0.03 ± 0.0071	-
Fluorene	mg/kg dry wt	-	-	< 0.03 ± 0.0072	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	-	-	< 0.03 ± 0.0070	-
Naphthalene	mg/kg dry wt	-	-	< 0.13 ± 0.043	-
Phenanthrene	mg/kg dry wt	-	-	< 0.03 ± 0.0074	-
Pyrene	mg/kg dry wt	-	-	< 0.03 ± 0.0073	-
Haloethers in SVOC Soil Samples by GC-MS					
Bis(2-chloroethoxy) methane	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Bis(2-chloroethyl)ether	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Bis(2-chloroisopropyl)ether	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
4-Bromophenyl phenyl ether	mg/kg dry wt	-	-	< 0.4 ± 0.21	-
4-Chlorophenyl phenyl ether	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Nitrogen containing compounds in SVOC Soil Samples by GC-MS					
2,4-Dinitrotoluene	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
2,6-Dinitrotoluene	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
Nitrobenzene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
N-Nitrosodi-n-propylamine	mg/kg dry wt	-	-	< 0.7 ± 0.35	-
N-Nitrosodiphenylamine + Diphenylamine	mg/kg dry wt	-	-	< 0.7 ± 0.40	-
Organochlorine Pesticides in SVOC Soil Samples by GC-MS					
Aldrin	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
alpha-BHC	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
beta-BHC	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
delta-BHC	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
gamma-BHC (Lindane)	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
4,4'-DDD	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
4,4'-DDE	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
4,4'-DDT	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
Dieldrin	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Endosulfan I	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
Endosulfan II	mg/kg dry wt	-	-	< 2 ± 1.4	-
Endosulfan sulphate	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
Endrin	mg/kg dry wt	-	-	< 0.7 ± 0.38	-
Endrin ketone	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
Heptachlor	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Heptachlor epoxide	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Hexachlorobenzene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS					
Acenaphthene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Acenaphthylene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-

Sample Type: Sediment					
Sample Name:		V201.0-1.5m A 24-Feb-2016 11:00 am	V18 0.0-0.5m A 24-Feb-2016 1:00 pm	V18 0.0-0.5m B 24-Feb-2016 1:00 pm	V18 0.5-1.0m A 24-Feb-2016 1:00 pm
Lab Number:		1544100.6	1544100.9	1544100.10	1544100.12
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS					
Anthracene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Benzo[a]anthracene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Benzo[g,h,i]perylene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Benzo[k]fluoranthene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
1&2-Chloronaphthalene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Chrysene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Dibenzo[a,h]anthracene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Fluoranthene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Fluorene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
2-Methylnaphthalene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Naphthalene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Phenanthrene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Pyrene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Phenols in SVOC Soil Samples by GC-MS					
4-Chloro-3-methylphenol	mg/kg dry wt	-	-	< 5 ± 3.4	-
2-Chlorophenol	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
2,4-Dichlorophenol	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
2,4-Dimethylphenol	mg/kg dry wt	-	-	< 3 ± 1.2	-
3 & 4-Methylphenol (m- + p-cresol)	mg/kg dry wt	-	-	< 3 ± 1.2	-
2-Methylphenol (o-Cresol)	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
2-Nitrophenol	mg/kg dry wt	-	-	< 5 ± 3.4	-
Pentachlorophenol (PCP)	mg/kg dry wt	-	-	< 30 ± 68	-
Phenol	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
2,4,5-Trichlorophenol	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
2,4,6-Trichlorophenol	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
Plasticisers in SVOC Soil Samples by GC-MS					
Bis(2-ethylhexyl)phthalate	mg/kg dry wt	-	-	< 5 ± 3.4	-
Butylbenzylphthalate	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
Di(2-ethylhexyl)adipate	mg/kg dry wt	-	-	< 1.0 ± 5.1	-
Diethylphthalate	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
Dimethylphthalate	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
Di-n-butylphthalate	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
Di-n-octylphthalate	mg/kg dry wt	-	-	< 1.0 ± 0.67	-
Other Halogenated compounds in SVOC Soil Samples by GC-MS					
1,2-Dichlorobenzene	mg/kg dry wt	-	-	< 0.7 ± 0.35	-
1,3-Dichlorobenzene	mg/kg dry wt	-	-	< 0.7 ± 0.35	-
1,4-Dichlorobenzene	mg/kg dry wt	-	-	< 0.7 ± 0.35	-
Hexachlorobutadiene	mg/kg dry wt	-	-	< 0.7 ± 0.35	-
Hexachloroethane	mg/kg dry wt	-	-	< 0.7 ± 0.36	-
1,2,4-Trichlorobenzene	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Other compounds in SVOC Soil Samples by GC-MS					
Benzyl alcohol	mg/kg dry wt	-	-	< 10 ± 6.7	-
Carbazole	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Dibenzofuran	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Isophorone	mg/kg dry wt	-	-	< 0.5 ± 0.34	-
Tributyl Tin Trace in Soil samples by GCMS					
Dibutyltin (as Sn)	mg/kg dry wt	-	-	< 0.005 ± 0.0056	-
Monobutyltin (as Sn)	mg/kg dry wt	-	-	< 0.007 ± 0.0075	-
Tributyltin (as Sn)	mg/kg dry wt	-	-	< 0.004 ± 0.0044	-
Triphenyltin (as Sn)	mg/kg dry wt	-	-	< 0.003 ± 0.0021	-

Sample Type: Sediment					
Sample Name:		V201.0-1.5m A 24-Feb-2016 11:00 am	V18 0.0-0.5m A 24-Feb-2016 1:00 pm	V18 0.0-0.5m B 24-Feb-2016 1:00 pm	V18 0.5-1.0m A 24-Feb-2016 1:00 pm
Lab Number:		1544100.6	1544100.9	1544100.10	1544100.12
Total Petroleum Hydrocarbons in Soil					
C7 - C9	mg/kg dry wt	-	-	< 8 ± 5.4	-
C10 - C14	mg/kg dry wt	-	-	< 20 ± 7.6	-
C15 - C36	mg/kg dry wt	-	-	< 40 ± 9.3	-
Total hydrocarbons (C7 - C36)	mg/kg dry wt	-	-	< 70 ± 14	-

Sample Name:		V18 0.5-1.0m B 24-Feb-2016 1:00 pm	V18 2.0-3.0m A 24-Feb-2016 1:00 pm	V18 1.0-2.0m A 24-Feb-2016 1:00 pm	V19 0-0.5m A 24-Feb-2016 12:00 pm
Lab Number:		1544100.13	1544100.16	1544100.19	1544100.22
Individual Tests					
Dry Matter	g/100g as rcvd	84.0 ± 5.0	-	-	-
Total Organic Carbon*	g/100g dry wt	-	0.166 ± 0.043	< 0.05 ± 0.041	< 0.13 ± 0.042
Antifouling cobiocides in sediment samples by LCMSMS					
Diuron*	mg/kg dry wt	< 0.010	-	-	-
Irgarol*	mg/kg dry wt	< 0.010	-	-	-
Isoproturon*	mg/kg dry wt	< 0.010	-	-	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg					
Total Recoverable Arsenic	mg/kg dry wt	-	4.18 ± 0.44	2.60 ± 0.30	2.49 ± 0.29
Total Recoverable Cadmium	mg/kg dry wt	-	0.0380 ± 0.0076	0.0105 ± 0.0062	< 0.010 ± 0.0062
Total Recoverable Chromium	mg/kg dry wt	-	14.7 ± 1.8	8.3 ± 1.1	5.54 ± 0.68
Total Recoverable Copper	mg/kg dry wt	-	0.68 ± 0.17	0.35 ± 0.14	0.39 ± 0.15
Total Recoverable Lead	mg/kg dry wt	-	1.66 ± 0.21	1.00 ± 0.13	0.685 ± 0.087
Total Recoverable Mercury	mg/kg dry wt	-	< 0.010 ± 0.0067	< 0.010 ± 0.0067	< 0.010 ± 0.0067
Total Recoverable Nickel	mg/kg dry wt	-	4.98 ± 0.52	1.92 ± 0.24	2.38 ± 0.28
Total Recoverable Zinc	mg/kg dry wt	-	10.6 ± 1.8	8.3 ± 1.4	4.90 ± 0.83
Polycyclic Aromatic Hydrocarbons Screening in Soil					
Acenaphthene	mg/kg dry wt	< 0.03 ± 0.0093	-	-	-
Acenaphthylene	mg/kg dry wt	< 0.03 ± 0.0070	-	-	-
Anthracene	mg/kg dry wt	< 0.03 ± 0.0096	-	-	-
Benzo[a]anthracene	mg/kg dry wt	< 0.03 ± 0.0090	-	-	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	< 0.03 ± 0.0069	-	-	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	< 0.03 ± 0.0082	-	-	-
Benzo[g,h,i]perylene	mg/kg dry wt	< 0.03 ± 0.0078	-	-	-
Benzo[k]fluoranthene	mg/kg dry wt	< 0.03 ± 0.0073	-	-	-
Chrysene	mg/kg dry wt	< 0.03 ± 0.0075	-	-	-
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.03 ± 0.0073	-	-	-
Fluoranthene	mg/kg dry wt	< 0.03 ± 0.0071	-	-	-
Fluorene	mg/kg dry wt	< 0.03 ± 0.0072	-	-	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	< 0.03 ± 0.0070	-	-	-
Naphthalene	mg/kg dry wt	< 0.13 ± 0.044	-	-	-
Phenanthrene	mg/kg dry wt	< 0.03 ± 0.0074	-	-	-
Pyrene	mg/kg dry wt	< 0.03 ± 0.0073	-	-	-
Tributyl Tin Trace in Soil samples by GCMS					
Dibutyltin (as Sn)	mg/kg dry wt	< 0.005 ± 0.0056	-	-	-
Monobutyltin (as Sn)	mg/kg dry wt	< 0.007 ± 0.0075	-	-	-
Tributyltin (as Sn)	mg/kg dry wt	< 0.004 ± 0.0044	-	-	-
Triphenyltin (as Sn)	mg/kg dry wt	< 0.003 ± 0.0021	-	-	-
Total Petroleum Hydrocarbons in Soil					
C7 - C9	mg/kg dry wt	< 8 ± 5.4	-	-	-
C10 - C14	mg/kg dry wt	< 20 ± 7.6	-	-	-
C15 - C36	mg/kg dry wt	< 40 ± 9.3	-	-	-
Total hydrocarbons (C7 - C36)	mg/kg dry wt	< 70 ± 14	-	-	-

Sample Type: Sediment					
Sample Name:		V19 0-0.5m B 24-Feb-2016 12:00 pm	V19 0.5-1.0m A 24-Feb-2016 12:00 pm	V19 0.5-1.0m B 24-Feb-2016 12:00 pm	V19 1.0-2.0m A 24-Feb-2016 12:00 pm
Lab Number:		1544100.23	1544100.25	1544100.26	1544100.28
Individual Tests					
Dry Matter	g/100g as rcvd	86.3 ± 5.0	-	81.9 ± 5.0	-
Total Organic Carbon*	g/100g dry wt	-	0.059 ± 0.041	-	< 0.13 ± 0.042
Antifouling cobiocides in sediment samples by LCMSMS					
Diuron*	mg/kg dry wt	< 0.010	-	< 0.010	-
Irgarol*	mg/kg dry wt	< 0.010	-	< 0.010	-
Isoproturon*	mg/kg dry wt	< 0.010	-	< 0.010	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg					
Total Recoverable Arsenic	mg/kg dry wt	-	2.44 ± 0.28	-	2.37 ± 0.28
Total Recoverable Cadmium	mg/kg dry wt	-	0.0271 ± 0.0069	-	0.0368 ± 0.0075
Total Recoverable Chromium	mg/kg dry wt	-	12.2 ± 1.5	-	34.1 ± 4.1
Total Recoverable Copper	mg/kg dry wt	-	0.49 ± 0.15	-	0.80 ± 0.18
Total Recoverable Lead	mg/kg dry wt	-	1.45 ± 0.18	-	1.05 ± 0.13
Total Recoverable Mercury	mg/kg dry wt	-	< 0.010 ± 0.0067	-	< 0.010 ± 0.0067
Total Recoverable Nickel	mg/kg dry wt	-	3.07 ± 0.34	-	17.1 ± 1.8
Total Recoverable Zinc	mg/kg dry wt	-	10.2 ± 1.7	-	7.8 ± 1.3
Polycyclic Aromatic Hydrocarbons Screening in Soil					
Acenaphthene	mg/kg dry wt	< 0.03 ± 0.0095	-	< 0.03 ± 0.0098	-
Acenaphthylene	mg/kg dry wt	< 0.03 ± 0.0070	-	< 0.03 ± 0.0071	-
Anthracene	mg/kg dry wt	< 0.03 ± 0.0098	-	< 0.03 ± 0.011	-
Benzo[a]anthracene	mg/kg dry wt	< 0.03 ± 0.0091	-	< 0.03 ± 0.0094	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	< 0.03 ± 0.0069	-	< 0.03 ± 0.0070	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	< 0.03 ± 0.0083	-	< 0.03 ± 0.0084	-
Benzo[g,h,i]perylene	mg/kg dry wt	< 0.03 ± 0.0078	-	< 0.03 ± 0.0080	-
Benzo[k]fluoranthene	mg/kg dry wt	< 0.03 ± 0.0073	-	< 0.03 ± 0.0074	-
Chrysene	mg/kg dry wt	< 0.03 ± 0.0076	-	< 0.03 ± 0.0077	-
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.03 ± 0.0074	-	< 0.03 ± 0.0074	-
Fluoranthene	mg/kg dry wt	< 0.03 ± 0.0071	-	< 0.03 ± 0.0072	-
Fluorene	mg/kg dry wt	< 0.03 ± 0.0073	-	< 0.03 ± 0.0073	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	< 0.03 ± 0.0071	-	< 0.03 ± 0.0071	-
Naphthalene	mg/kg dry wt	< 0.13 ± 0.044	-	< 0.14 ± 0.046	-
Phenanthrene	mg/kg dry wt	< 0.03 ± 0.0075	-	< 0.03 ± 0.0076	-
Pyrene	mg/kg dry wt	< 0.03 ± 0.0074	-	< 0.03 ± 0.0074	-
Haloethers in SVOC Soil Samples by GC-MS					
Bis(2-chloroethoxy) methane	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Bis(2-chloroethyl)ether	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Bis(2-chloroisopropyl)ether	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
4-Bromophenyl phenyl ether	mg/kg dry wt	< 0.4 ± 0.21	-	-	-
4-Chlorophenyl phenyl ether	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Nitrogen containing compounds in SVOC Soil Samples by GC-MS					
2,4-Dinitrotoluene	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
2,6-Dinitrotoluene	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
Nitrobenzene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
N-Nitrosodi-n-propylamine	mg/kg dry wt	< 0.7 ± 0.35	-	-	-
N-Nitrosodiphenylamine + Diphenylamine	mg/kg dry wt	< 0.7 ± 0.41	-	-	-
Organochlorine Pesticides in SVOC Soil Samples by GC-MS					
Aldrin	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
alpha-BHC	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
beta-BHC	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
delta-BHC	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
gamma-BHC (Lindane)	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
4,4'-DDD	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
4,4'-DDE	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
4,4'-DDT	mg/kg dry wt	< 1.0 ± 0.67	-	-	-

Sample Type: Sediment					
Sample Name:		V19 0-0.5m B 24-Feb-2016 12:00 pm	V19 0.5-1.0m A 24-Feb-2016 12:00 pm	V19 0.5-1.0m B 24-Feb-2016 12:00 pm	V19 1.0-2.0m A 24-Feb-2016 12:00 pm
Lab Number:		1544100.23	1544100.25	1544100.26	1544100.28
Organochlorine Pesticides in SVOC Soil Samples by GC-MS					
Dieldrin	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Endosulfan I	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
Endosulfan II	mg/kg dry wt	< 2 ± 1.4	-	-	-
Endosulfan sulphate	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
Endrin	mg/kg dry wt	< 0.7 ± 0.39	-	-	-
Endrin ketone	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
Heptachlor	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Heptachlor epoxide	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Hexachlorobenzene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Polycyclic Aromatic Hydrocarbons in SVOC Soil Samples by GC-MS					
Acenaphthene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Acenaphthylene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Anthracene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Benzo[a]anthracene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Benzo[g,h,i]perylene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Benzo[k]fluoranthene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
1&2-Chloronaphthalene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Chrysene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Fluoranthene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Fluorene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
2-Methylnaphthalene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Naphthalene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Phenanthrene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Pyrene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Phenols in SVOC Soil Samples by GC-MS					
4-Chloro-3-methylphenol	mg/kg dry wt	< 5 ± 3.4	-	-	-
2-Chlorophenol	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
2,4-Dichlorophenol	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
2,4-Dimethylphenol	mg/kg dry wt	< 3 ± 1.2	-	-	-
3 & 4-Methylphenol (m- + p-cresol)	mg/kg dry wt	< 3 ± 1.2	-	-	-
2-Methylphenol (o-Cresol)	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
2-Nitrophenol	mg/kg dry wt	< 5 ± 3.4	-	-	-
Pentachlorophenol (PCP)	mg/kg dry wt	< 30 ± 68	-	-	-
Phenol	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
2,4,5-Trichlorophenol	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
2,4,6-Trichlorophenol	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
Plasticisers in SVOC Soil Samples by GC-MS					
Bis(2-ethylhexyl)phthalate	mg/kg dry wt	< 5 ± 3.4	-	-	-
Butylbenzylphthalate	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
Di(2-ethylhexyl)adipate	mg/kg dry wt	< 1.0 ± 5.1	-	-	-
Diethylphthalate	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
Dimethylphthalate	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
Di-n-butylphthalate	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
Di-n-octylphthalate	mg/kg dry wt	< 1.0 ± 0.67	-	-	-
Other Halogenated compounds in SVOC Soil Samples by GC-MS					
1,2-Dichlorobenzene	mg/kg dry wt	< 0.7 ± 0.35	-	-	-
1,3-Dichlorobenzene	mg/kg dry wt	< 0.7 ± 0.35	-	-	-
1,4-Dichlorobenzene	mg/kg dry wt	< 0.7 ± 0.35	-	-	-
Hexachlorobutadiene	mg/kg dry wt	< 0.7 ± 0.35	-	-	-

Sample Type: Sediment					
Sample Name:		V19 0-0.5m B 24-Feb-2016 12:00 pm	V19 0.5-1.0m A 24-Feb-2016 12:00 pm	V19 0.5-1.0m B 24-Feb-2016 12:00 pm	V19 1.0-2.0m A 24-Feb-2016 12:00 pm
Lab Number:		1544100.23	1544100.25	1544100.26	1544100.28
Other Halogenated compounds in SVOC Soil Samples by GC-MS					
Hexachloroethane	mg/kg dry wt	< 0.7 ± 0.36	-	-	-
1,2,4-Trichlorobenzene	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Other compounds in SVOC Soil Samples by GC-MS					
Benzyl alcohol	mg/kg dry wt	< 10 ± 6.7	-	-	-
Carbazole	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Dibenzofuran	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Isophorone	mg/kg dry wt	< 0.5 ± 0.34	-	-	-
Tributyl Tin Trace in Soil samples by GCMS					
Dibutyltin (as Sn)	mg/kg dry wt	< 0.005 ± 0.0056	-	< 0.005 ± 0.0056	-
Monobutyltin (as Sn)	mg/kg dry wt	< 0.007 ± 0.0075	-	< 0.007 ± 0.0075	-
Tributyltin (as Sn)	mg/kg dry wt	< 0.004 ± 0.0044	-	< 0.004 ± 0.0044	-
Triphenyltin (as Sn)	mg/kg dry wt	< 0.003 ± 0.0021	-	< 0.003 ± 0.0021	-
Total Petroleum Hydrocarbons in Soil					
C7 - C9	mg/kg dry wt	< 8 ± 5.4	-	< 9 ± 5.4	-
C10 - C14	mg/kg dry wt	< 20 ± 7.6	-	< 20 ± 7.6	-
C15 - C36	mg/kg dry wt	< 40 ± 9.3	-	< 40 ± 9.3	-
Total hydrocarbons (C7 - C36)	mg/kg dry wt	< 70 ± 14	-	< 70 ± 14	-

Sample Type: Aqueous					
Sample Name:		V20 0.0-0.5m A [Elutriation extract]			
Lab Number:		1544100.31			
Individual Tests					
Total Chromium*	g/m³	< 0.0011 ± 0.00074	-	-	-
Total Nickel*	g/m³	0.014	-	-	-

The reported uncertainty is an expanded uncertainty with a level of confidence of approximately 95 percent (i.e. two standard deviations, calculated using a coverage factor of 2). Reported uncertainties are calculated from the performance of typical matrices, and do not include variation due to sampling.

For further information on uncertainty of measurement at Hill Laboratories, refer to the technical note on our website: www.hill-laboratories.com/files/Intro_To_UOM.pdf, or contact the laboratory.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Antifouling cobiocides in sediment samples by LCMSMS*		0.010 mg/kg dry wt	2, 5, 10, 13, 23, 26
Antifouling cobiocides suite in sediment by LCMSMS*	Ethyl acetate extraction, SPE cleanup, determination by LCMSMS.	-	2, 5, 10, 13, 23, 26
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-2, 4-6, 9-10, 12-13, 16, 19, 22-23, 25-26, 28
TPH Oil Industry Profile + PAHscreen	Sonication in DCM extraction, SPE cleanup, GC-FID & GC-MS analysis. Tested on as received sample. US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:5786,2805,10734;2695]	0.010 - 60 mg/kg dry wt	2, 5, 10, 13, 23, 26
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1, 4, 6, 9, 12, 16, 19, 22, 25, 28
Elutriation testing*	Extn with (client supplied) water, eg seawater, Sed:Water 1:4 by vol, mix 30 min, settle 1 hr, filtration or centrifugation. US EPA 503/8-91/001, "Evaluation of Dredged Material for Ocean Disposal".	-	1
Semivolatile Organic Compounds Screening in Soil by GC-MS	Sonication extraction, GPC cleanup (if required), GC-MS FS analysis. Tested on as received sample	0.3 - 30 mg/kg dry wt	2, 10, 23

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Tributyl Tin Trace in Soil samples by GCMS	Solvent extraction, ethylation, SPE cleanup, GC-MS SIM analysis. Tested on dried sample	0.003 - 0.007 mg/kg dry wt	2, 5, 10, 13, 23, 26
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. US EPA 3550. (Free water removed before analysis).	0.10 g/100g as rcvd	2, 5, 10, 13, 23, 26
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1, 4, 6, 9, 12, 16, 19, 22, 25, 28
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1, 4, 6, 9, 12, 16, 19, 22, 25, 28

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	31
Total Chromium*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	31
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	31

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

Annexure Two: Technical Reports

l) **Recreation and Tourism Effects Assessment. Rob Greenaway and Associates. Rob Greenaway. Dated August 2017**

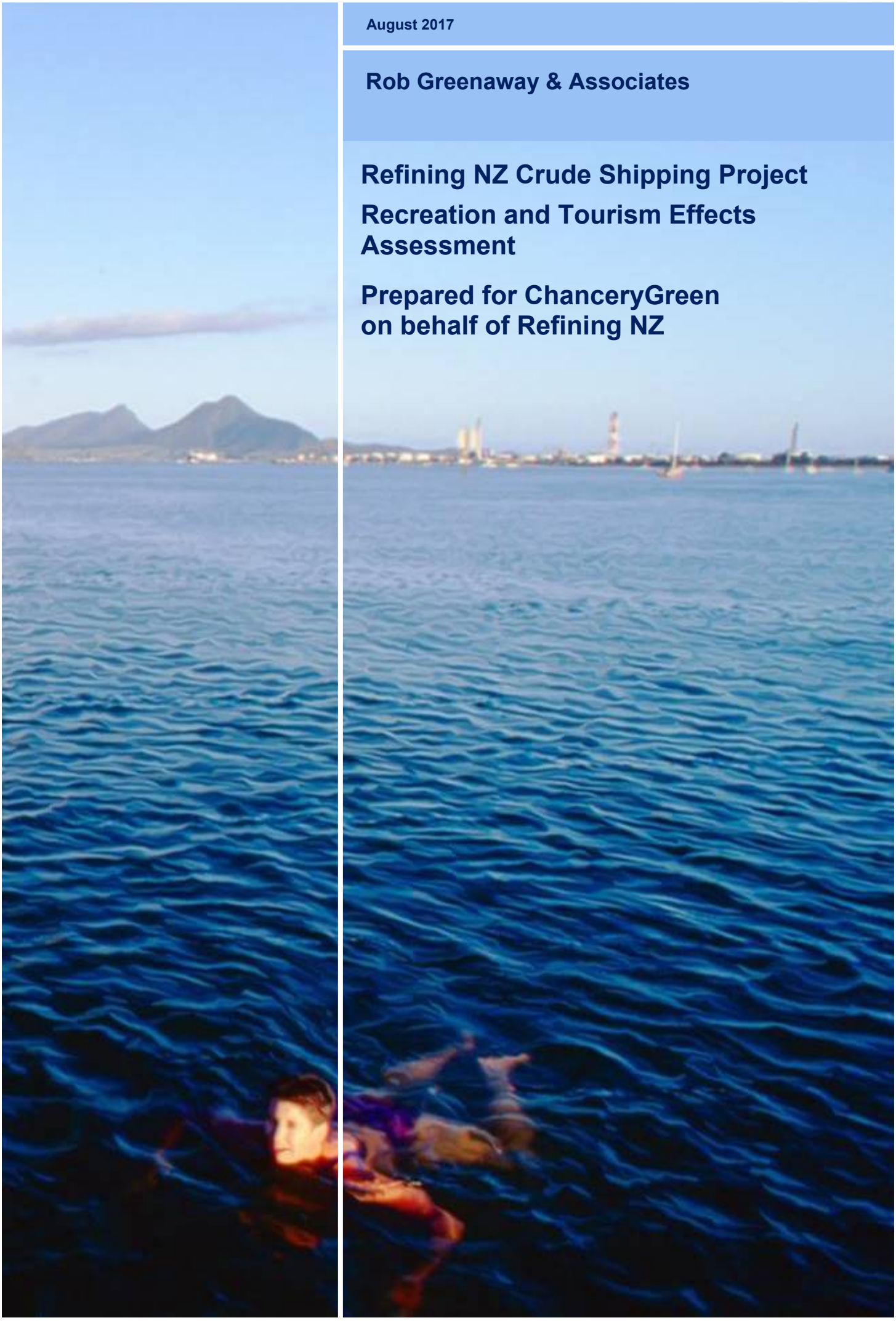
August 2017

Rob Greenaway & Associates

Refining NZ Crude Shipping Project

Recreation and Tourism Effects Assessment

Prepared for ChanceryGreen on behalf of Refining NZ



Refining NZ Crude Shipping Project

Recreation and Tourism Effects Assessment

Prepared for ChanceryGreen on behalf of Refining NZ

by Rob Greenaway & Associates

www.greenaway.co.nz

August 2017

Version status:

Final – 11 August 2017

Contents

1 Summary 5

1.1 Method 6
1.2 Recreation activity summaries 6
1.3 Potential adverse effects 14
1.4 Summary of effects 14
1.5 Conclusion 16

2 National and regional marine recreation participation 17

3 Regional recreation planning and policy 19

3.1 Department of Conservation 19
3.2 Northland Regional Council 23
3.3 Whangarei District Council 28
3.4 Northland Harbour Board 28

4 Activity reviews 30

4.1 Swimming and beach use 30
4.2 Fishing 34
4.3 Shellfishing 37
4.4 Diving 41
4.5 Boating 43
4.6 Surfing 46
4.7 Tourism and commercial marine recreation 49
4.8 Hunting 51
4.9 Terrestrial recreation and access 51

5 Assessment of effects 53

5.1 Potential adverse effects 53
5.2 Technical review findings 54
5.2.1 Turbidity 54
5.2.2 Waves 55
5.2.3 Tides 56
5.2.4 Beaches 56
5.2.5 Marine ecology 57
5.2.6 Contaminants 58
5.2.7 Dredge activity 58
5.3 Navaids 60
5.4 Cumulative effects 61

6 Conclusion 62

7 References 63

Appendix 1: Project activity maps 65

Appendix 2: Northland Regional Council Regional Coastal Plan maps 66

Appendix 3: Spot X fishing guide recommendations 68

List of Figures

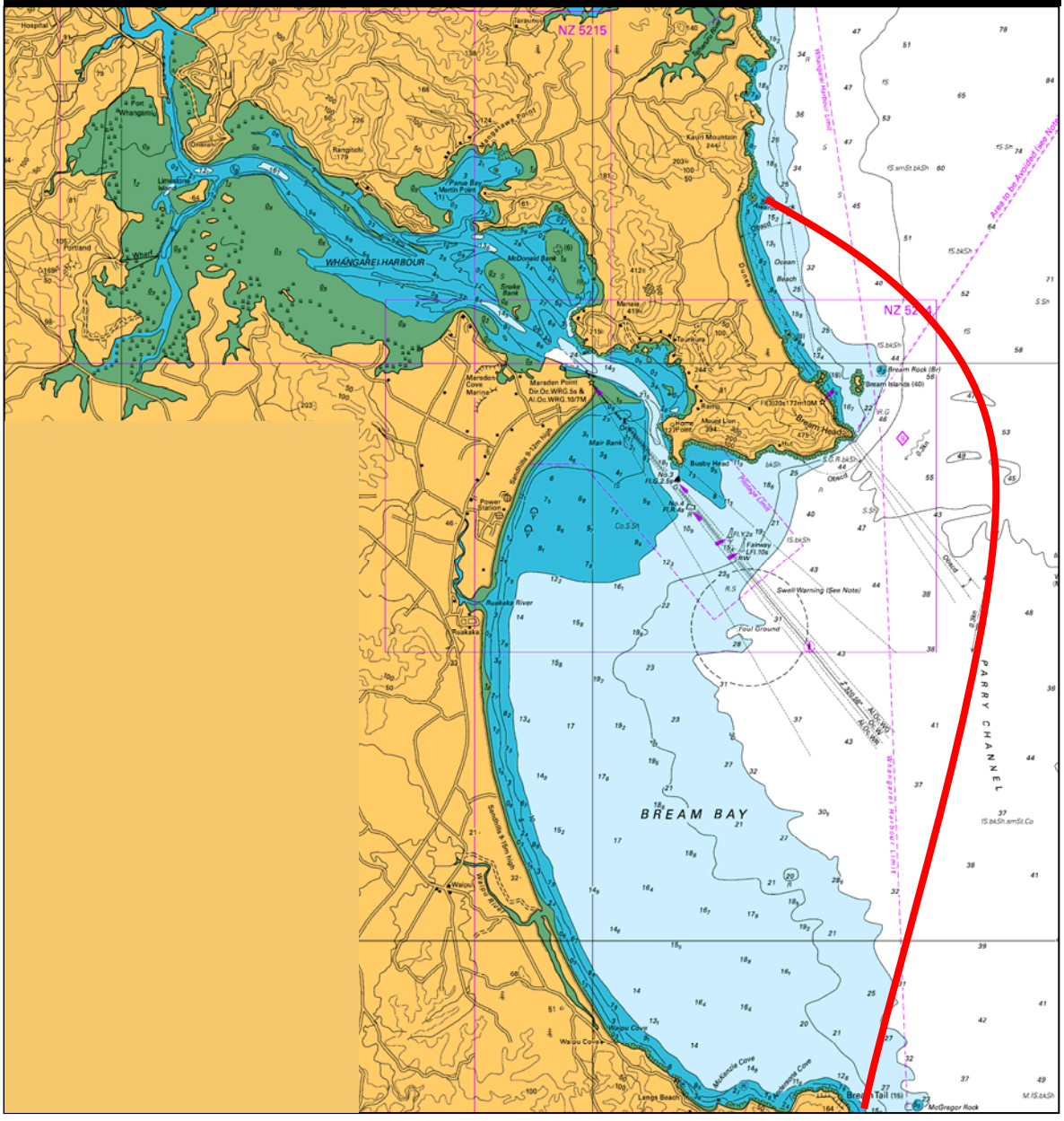
Figure 1: Study area: inshore from the red line spanning Awarua Rock to Bream Tail 5
Figure 2: Swimming / beach activity – main areas 7
Figure 3: Fishing activity - main areas 8
Figure 4: Shell fishing main areas – shore based (not scallops) 9
Figure 5: Diving and snorkelling main sites – craysfish, scallops, spear fishing, scenic 10
Figure 6: Boating, including sailing – main sites 11
Figure 7: Summary recreation activity – high use areas 12
Figure 8: Summary recreation activity – moderate use areas 13
Figure 9: National sport and recreation activities with the highest participation levels (SPARC 2009b) . 17
Figure 10: Public Conservation areas in the study area. DOC CMS 2014 19
Figure 11: Bream Head / Te Whara Scenic Reserve and Peach Cove location 21
Figure 12: Excerpt from CMS Appendix 8 - Marine habitats 22
Figure 13: Coastal water quality classification zones, Whāngārei Harbour – NRC 2012 25
Figure 14: 'Common uses of the Harbour' – NRC 2012 26
Figure 15: Proposed Marine Park boundary in blue – from Hampson et al 2013 27
Figure 16: Recreation activities in Whangarei Harbour (NHB 1989) 29
Figure 17: NRC monitored marine bathing sites in and around Whangarei Harbour 2013/14 30
Figure 18: Surf Lifesaving NZ recommended beaches 31
Figure 19: Beaches showing number of carparking spaces 1997 (Allen et al 2009) 32
Figure 20: Recreation fishing effort Matauri Bay to Whangamata. MPI NABIS data 34
Figure 21: Recreational fishing effort in the study area. MPI NABIS data 35
Figure 22: Surfcasting guide recommendation, Draper & Airey (2012) 36
Figure 23: Recreational line fishing locations and fishing clubs from Allen et al 2009 37
Figure 24: NRC water quality monitoring sites 2016/17, Whangarei Harbour 38
Figure 25: Recreational shellfishing locations from Allen et al 2009 39
Figure 26: Sites assessed for suitability of future shellfish reseeding in Cummings and Hatton (2003) .. 39
Figure 27: Diving recommendations near Bream Head, Enderby & Enderby (2007) 41
Figure 28: Diving recommendations near Bream Tail, Enderby & Enderby (2007) 42
Figure 29: Anchorages, boat clubs and boat launching around Whangarei Harbour 43
Figure 30: Draft Regional Plan regionally significant moorings 44
Figure 31: Windsurf sites 45
Figure 32: Kitesurf sites (Ruakaka Kite Sports) 45
Figure 33: Whangarei area surf breaks (Morse & Brunskill 2004) 46
Figure 34: Surf break details (Morse & Brunskill 2004) 47
Figure 35: Surf break details (Morse & Brunskill 2004) 48
Figure 36: Regionally significant surf breaks – Draft Regional Plan for Northland 49
Figure 37: Crown Land (yellow) around Whangarei Harbour. Source: WAMS 51
Figure 38: Public access around Whangarei Harbour and Bream Bay excluding legal roads 52
Figure 39: Commercial Vessel Route, Whangarei Harbour – cyan. NRC data 59

1 Summary

This report reviews the potential effects of Refining New Zealand Ltd's (RNZ) Crude Shipping Project ('the Project') on recreation and tourism values. This involves dredging the Whangarei Harbour entrance to allow the transit of deep-draught large crude carrier vessels (Suezmax vessels). RNZ is applying for resource consents to:

- partially realign the access channel to provide safe navigational access for fully loaded Suezmax ships,
- modify the placement of navigational aids along the new channel alignment,
- carry out capital and maintenance dredging to achieve and maintain a minimum depth to support 16.6m ship draught in the access channel, and
- dispose of dredged materials. Most of this material (up to 97.5%) will be placed more than 7km off Busby Head in approximately 45m of water depth (directly south east of the foul ground shown Figure 1). The remainder will be deposited south of the ebb tide

Figure 1: Study area: inshore from the red line spanning Awarua Rock to Bream Tail



shoal which borders Mair Bank in water depths of between 7 and 15m to supplement the coastal sand supply.

The location of these activities are illustrated in the figures in Appendix 1 of this report.

The study area is defined by the recreation settings potentially affected by the proposal and includes the inshore area from Awarua Rock to Bream Head as shown in Figure 1.

1.1 Method

This report is based on:

- A preliminary literature review completed in 2015 to identify regional marine recreation values and direct research required to identify the potential effects of the Project on these values,
- Community consultation carried out by RNZ through 2015 and 2016 (a full summary of consultation undertaken in connection with the project is provided separately),
- Team meetings between independent experts contracted by RNZ to undertake research activities for the Project and author parallel technical reports,
- An updated literature review in 2017,
- Reference to relevant technical reports commissioned by RNZ, and in particular those for marine ecology and coastal processes, and discussions with the authors of those reports,
- The release of a consultation draft of this report in early 2017, and revisions based on feedback from the consultation process, including attendance at public information days in April 2017.

1.2 Recreation activity summaries

The data indicate that the study area, and especially Whangarei Harbour, the Harbour entrance, and the marine and coastal marine settings between Marsden Point and Bream Head, are intensely-used recreation settings, and are popular for a wide range of different activity groups.

No data reviewed indicate the scale of significance of the setting for recreation and tourism (that is, state whether it is nationally, regionally or locally significant). The scale and variety of activities suggests the setting is of at least regional significance.

The following figures show summary data based on the literature reviewed in this report, and consultation findings from public open days held by Refining New Zealand – and attended by the author of this document – in March 2015 and April 2017 – and further feedback received by RNZ directly or via its website feedback form. The final two figures in this summary section (Figure 7, Figure 8) use the base data to identify moderate and high recreation activity areas.

Figure 2: Swimming / beach activity – main areas

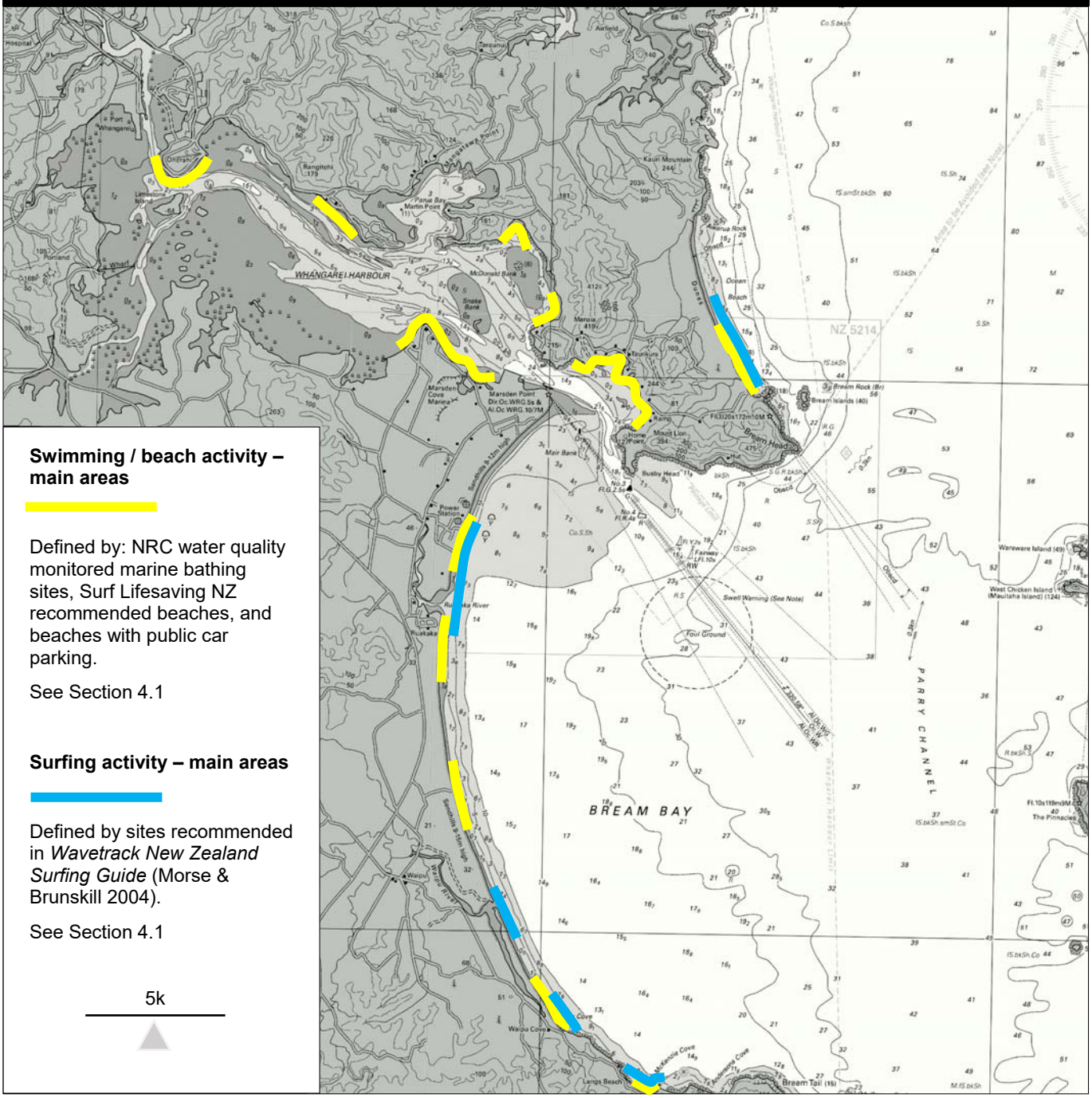


Figure 3: Fishing activity - main areas

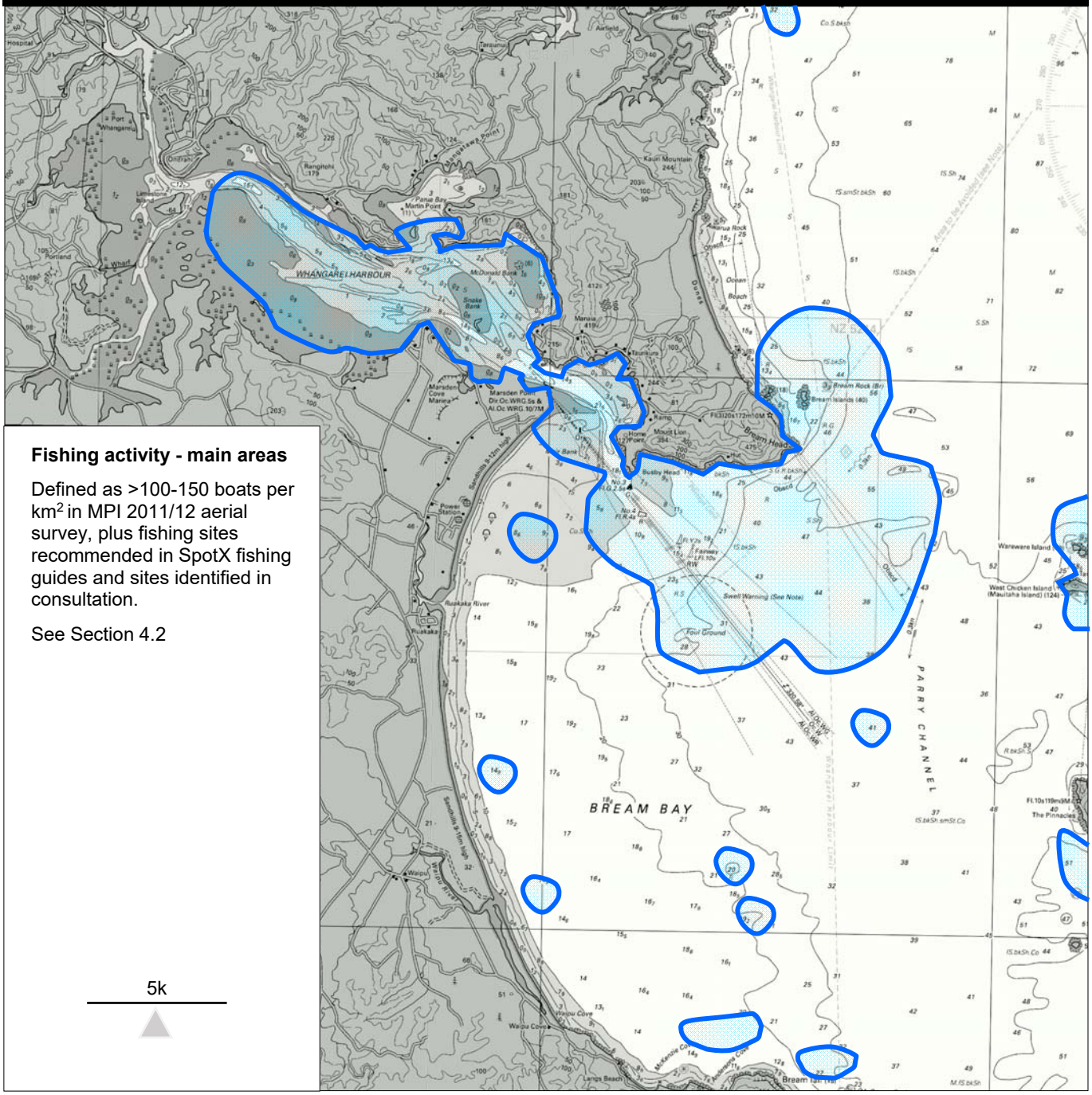


Figure 4: Shell fishing main areas – shore based (not scallops)

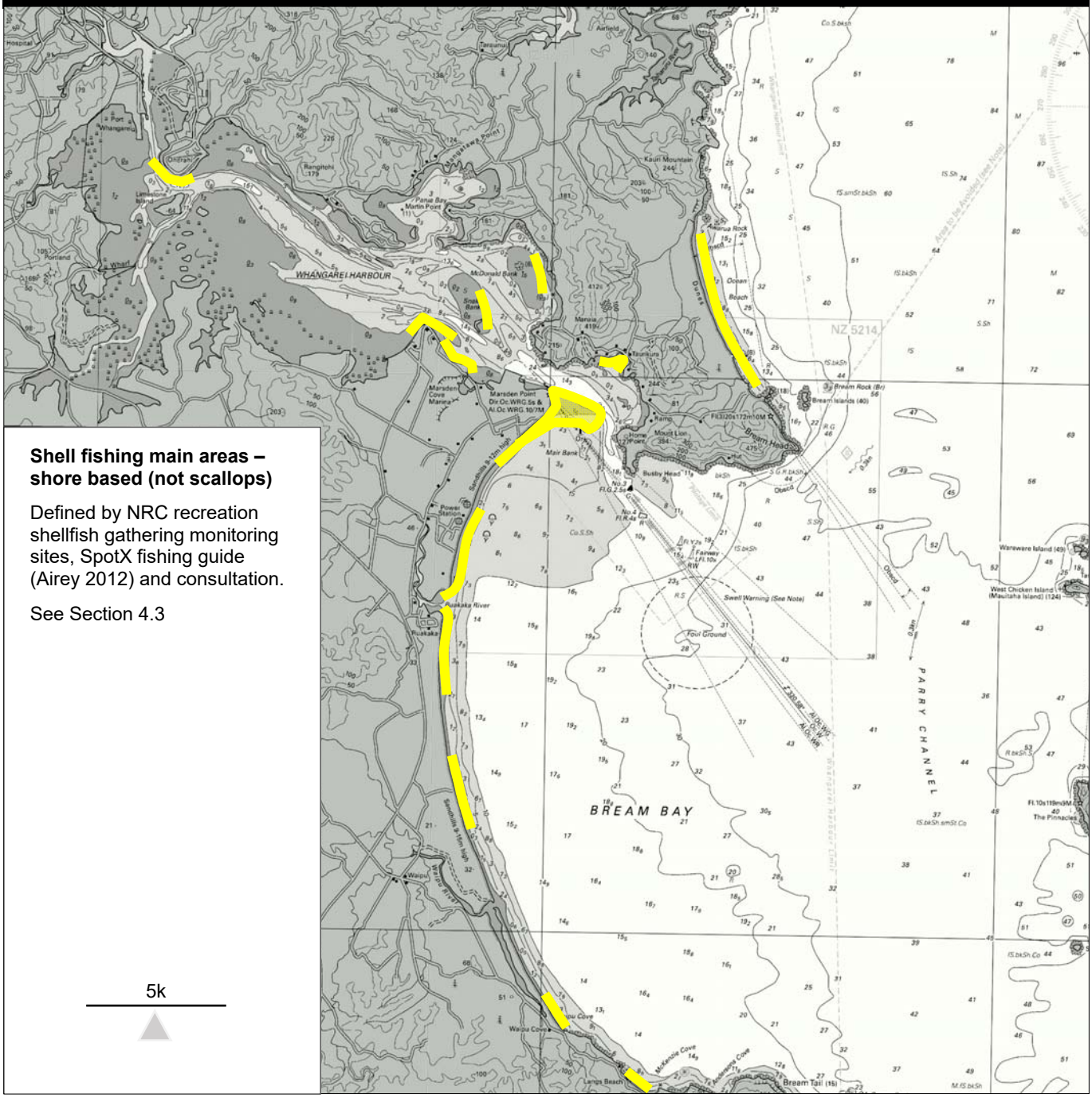


Figure 5: Diving and snorkelling main sites – craysfish, scallops, spear fishing, scenic

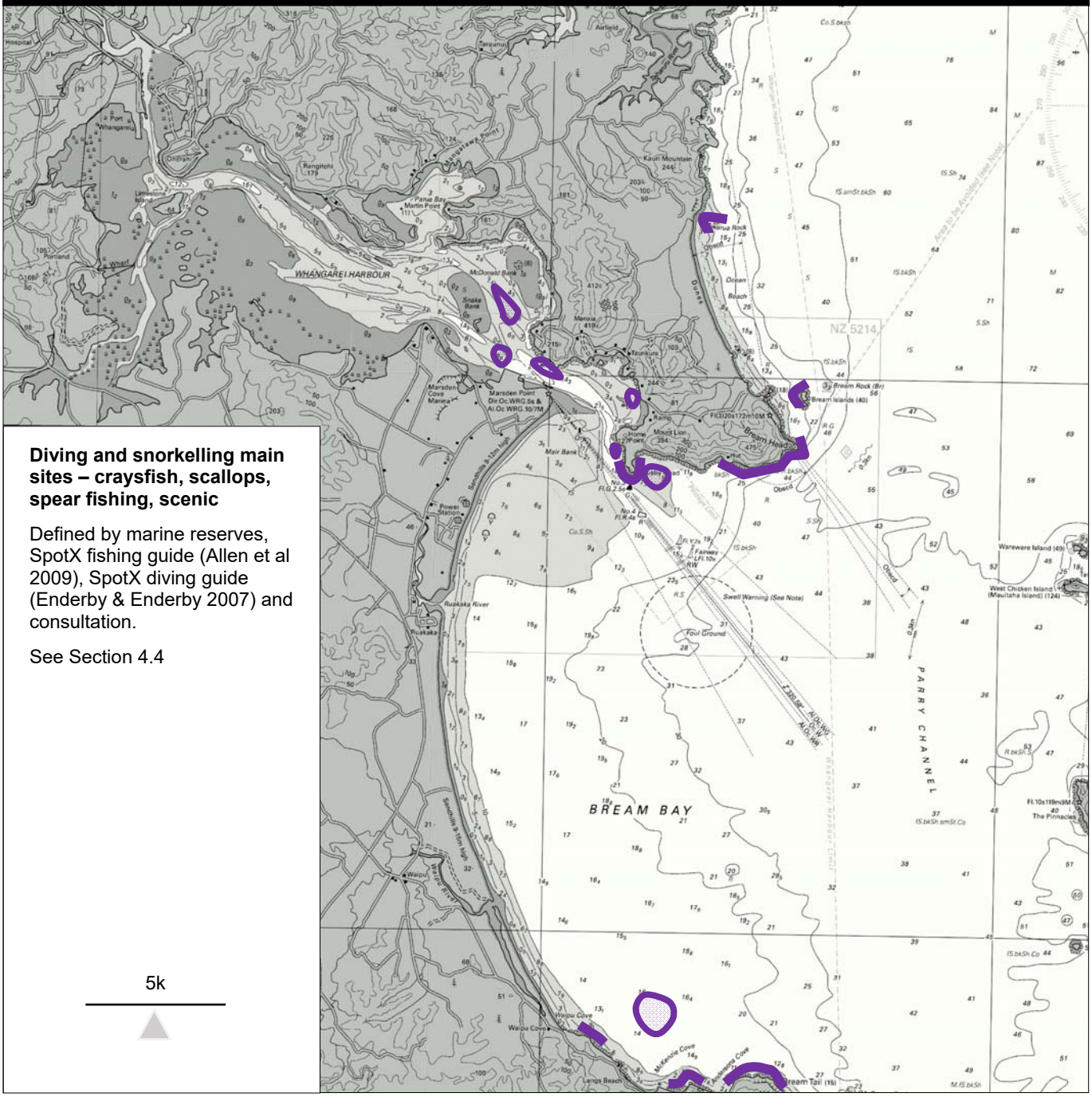


Figure 6: Boating, including sailing – main sites

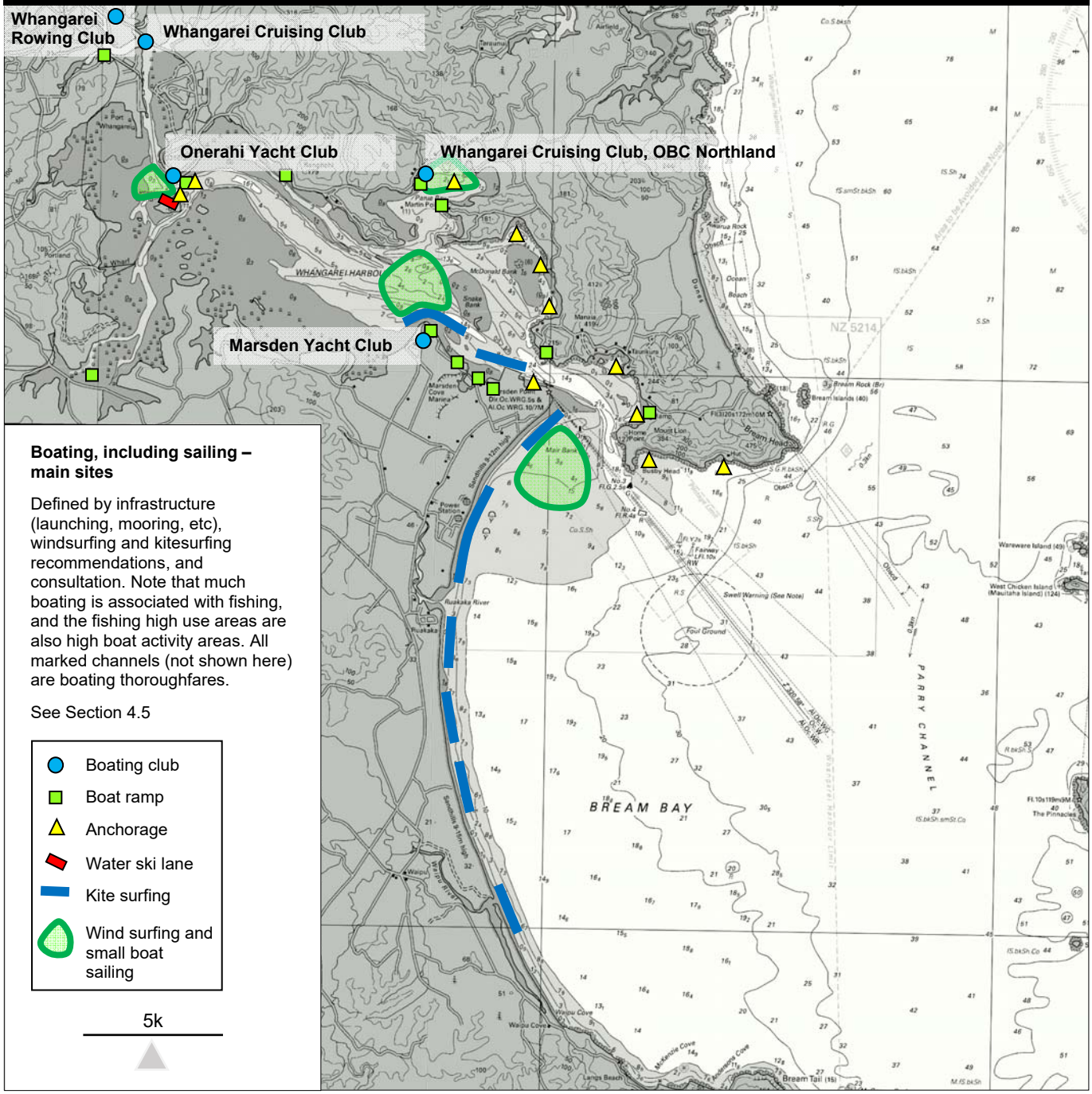


Figure 7: Summary recreation activity – high use areas

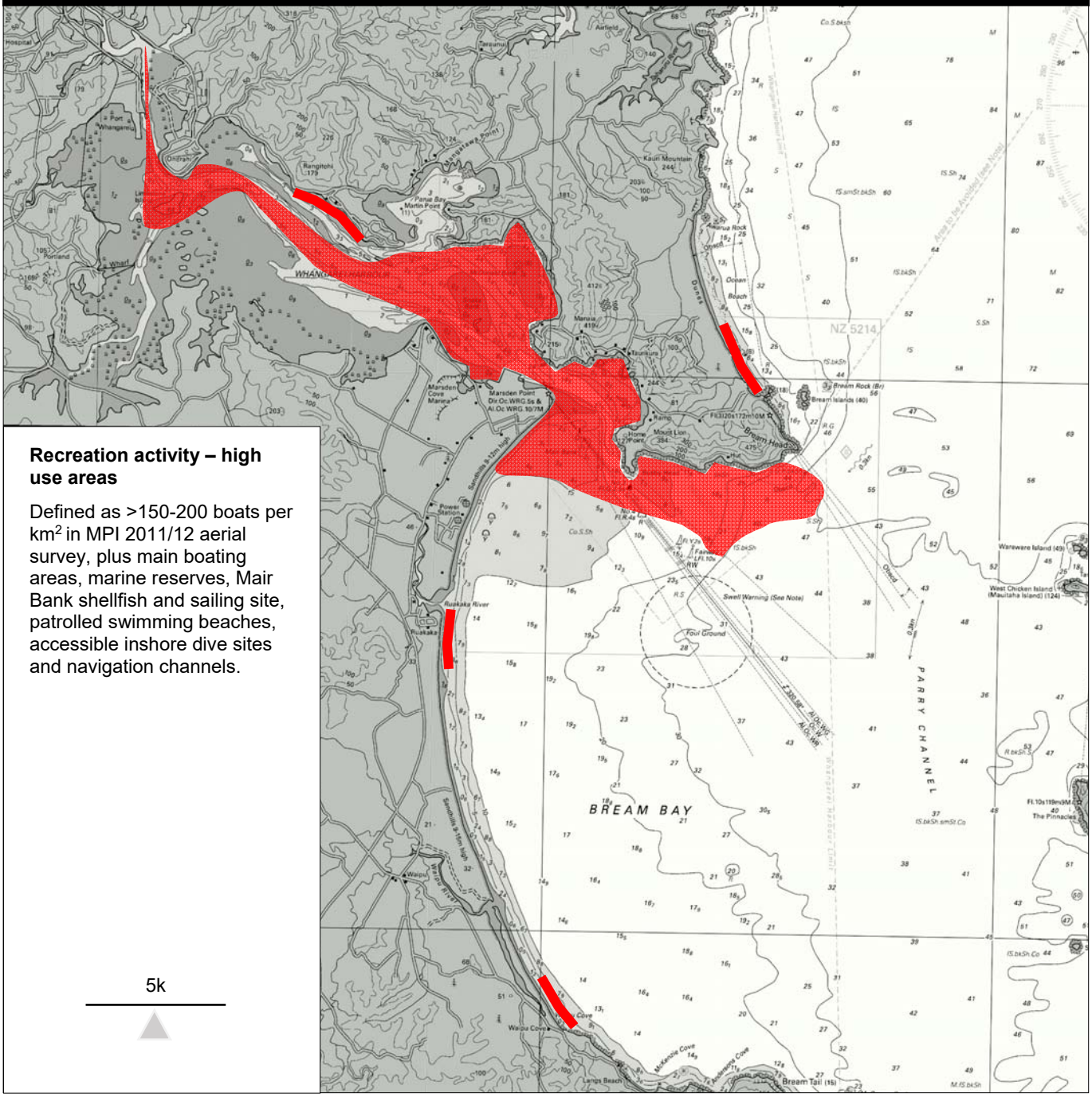
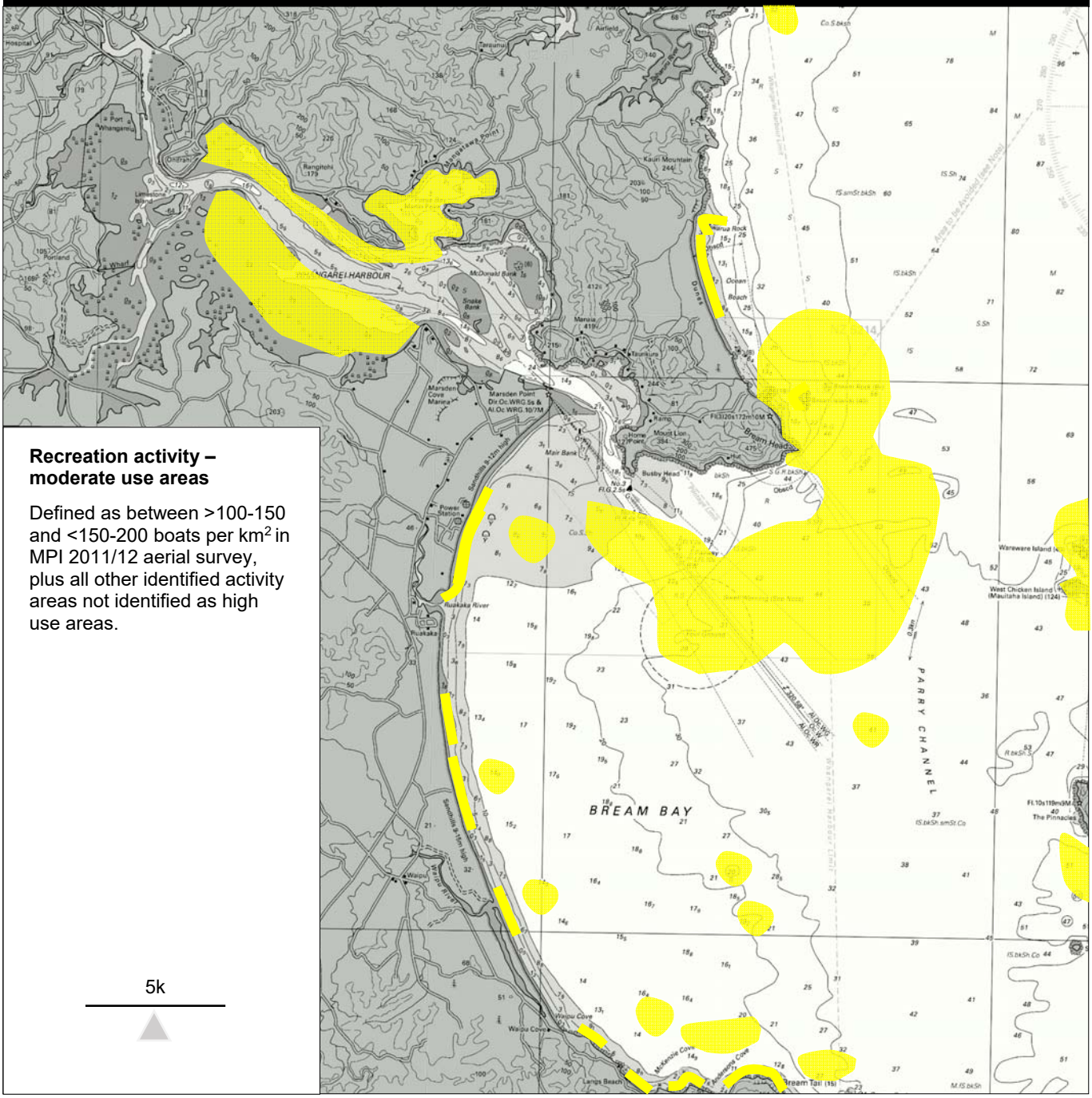


Figure 8: Summary recreation activity – moderate use areas



1.3 Potential adverse effects

The following potential effects of the proposal are of interest to recreation.

Construction and maintenance

- Turbidity effects on recreation settings (particularly swimming and diving areas) and visual amenity at and near the Harbour entrance,
- Mobilisation of contaminants and potential effects on shellfish and other seafood, and for water-contact recreation,
- Effects on marine ecology and the quality, abundance and catchability of marine species, in and around the entrance and at and near the spoil dumping site offshore during the dredging period/s, and
- Occupation of marine settings by dredges working or in transit and the creation of hazards for, especially, boaters.

Operation

- Changes to tides, currents and wave patterns resulting from altered bathymetry,
- Changes to beach and foreshore profiles resulting from changes to wave patterns, including remobilisation of dumped material,
- Effects on wave energy as a result of the passage of larger vessels,
- Effects associated with the location and operation of aids to navigation, such as navigation buoys and markers (*Navaids*).

Effects on birds, from noise, and navigation risk are separately assessed, but, in a recreation context, those effects are considered to be not relevant, nil or too low to be reviewed further. Similarly, the increased harbour depth or alignment is not considered to offer any advantage to recreational boaters due to their shallow draught.

1.4 Summary of effects

Turbidity

The dispersal of sediment from the dredging activity is likely to be strongly confined to the dredge channel and has a low chance of dispersal to any contact recreation setting. However, real-time monitoring is planned to ensure there are no effects on important marine ecosystems near the dredge channel. There is likely to be very little if any adverse effect on recreational dive and swimming sites, including on the marine life that attracts most divers.

Waves

Preferred wave heights for surfing range between 1 and 3m. Changes which might be noted by surfers only accrue during storm events with wave heights around 5m and only at the northern end of the Marsden Point surf break at Mair Bank. This is unlikely to affect surfing amenity.

Increases in wave energy could have adverse effects on diving an swimming, but effects (as small as they are modelled to be) only occur when there is little natural amenity for recreation due to natural wave action (that is, there needs to be waves in action for there to be an effect on them, and the smaller the wave, the less effect).

Tides

An acceleration in tidal strength could pose a hazard for boaters in the harbour channel. However, by deepening the channel, tidal speed generally decreases, albeit by a very small

amount. There are therefore no adverse effects resulting from changes in tidal speed. There is the potential for a minor change in timing of high and low tides, which will not affect recreation participation (timing of tides change every day).

Beaches

The potential for changes to beach profiles is confined to Mair Bank, which, for recreation values, is predominantly a shellfish gathering setting. Mitigation options are proposed and a monitoring programme would be implemented. Any changes of relevance to recreation are confined and managed.

Marine ecology

Coffey (2017) indicates that the scale of effect on benthic biomass (food sources for recreationally taken fish) are expected to be 'minor to moderate', short-term, and to progressively ameliorate within 6 to 12 months in the dredged channel and inshore/ebb tide shoal disposal area, and within 12 to 24 months in the offshore disposal area, although at the latter an 'ecologically constructive benthic community' (one able to provide feeding grounds for fish) is expected to re-establish within 12 months (meaning all affected areas will be supporting recreational fish species within 6 to 12 months). This is likely to similarly result in some local displacement of fishing activity from the dredge and disposal footprints during the recovery period. However, due to the scale of the local fishing resource, the mobility of finfish, the lack of effect on biota beyond the activity footprints, the progressive recovery of the benthos and the temporary nature of the effect, the net outcome for recreational fishing from capital dredging is likely to be adverse but also minor. Maintenance dredging will have a lower scale of effect during each event, but due to its frequency (2 to 5 yearly) its net effect will also be adverse but minor. There is likely to be some temporary increase in local finfish activity as the dredging activity exposes food sources, but this is not considered to be a mitigating effect.

Contaminants

Coffey (2017) states that the material to be dredged is not contaminated with any toxins and also has very low levels of organic matter (which, if present, could lead to a drop in dissolved oxygen levels due to spikes in algal growth). This means there are no water quality issues associated with the activity.

Dredge activity

Any recreation skipper operating in or near the harbour entrance would expect to encounter large ships and to comply with harbour navigation rules. While the presence of a dredge is an additional navigational issue, it should not limit recreation participation by large and small recreational vessels. Eighty-percent of dredge activity will be in the outer channel beyond Home Point, outside recreational diving, snorkelling and swimming areas, and where there is ample navigation space. However, it is recommended that RNZ place on its website information about dredge activities (location and duration of activity) and advise the regional harbourmaster who can then make judgements about the importance of additional maritime notifications – including whether it warrants a Notice to Mariners (via LINZ). Required maritime practice means the dredge will be appropriately lit at night and will obey all marine navigation rules. The net effect on recreation participation is likely to be minor or less.

Navaids

Navaids are required structures for safe navigation. They are used by both recreational and commercial craft and need to be in the right locations. The recommendations for their placement as part of the Project are made by Royal Haskoning DHV (2016) for the purposes of navigation safety. This is a necessary response to the Project. However, if it was required due to natural changes in channel alignment, it would not be considered an adverse effect on

recreation participation. Local boaters will rapidly adjust to very obvious changes in beacon location, which should be considered a pre-requisite skill for operating watercraft in a navigation channel. The proposed navaid developments are not considered to be adverse effects on recreation, and any safety improvement in navigation is likely to have a positive effect. They will require a Notice to Mariners and updates to marine charts via LINZ.

Cumulative effects

For recreation, the effects of the proposal are sufficiently slight to make it unlikely for cumulative adverse effects to arise. There are no locally consented activities identified which have not been implemented which would increase the potential for adverse effects from the proposal. There has been no identified mechanism by which the proposed activity would affect pipi beds on Mair Bank, and the relocation of sand to the ebb tide shoal will support the maintenance of habitat.

1.5 Conclusion

Whangarei Harbour, its margins and the surrounding coast are intensely used marine recreation resources, with a variety of different recreation values and almost no corner that is not used for some leisure activity. The dredging activity is proposed to be undertaken within an area used extensively and intensively for fishing and boating (although fishing and anchoring directly in the navigation channel is not prudent). Nearby settings support diving, snorkelling, swimming, surfing, kite surfing, shellfishing, beach activities, and more boating and fishing.

The main potential effects of concern for recreation relate to changes in the abundance and location of fin and shellfish, changes to water clarity and quality, changes to wave patterns and effects on shoreline processes. Navigating near an operating dredge is also of interest, but a normal part of boating near an existing commercial port.

Potential effects on water clarity and quality are minor or less for recreation values, with a real-time monitoring programme proposed to avoid any sedimentation affecting important benthic communities outside the dredge and disposal footprints. This is the result of the quality of the dredge material and the pattern of currents which confine sediment plumes to within the navigation channel.

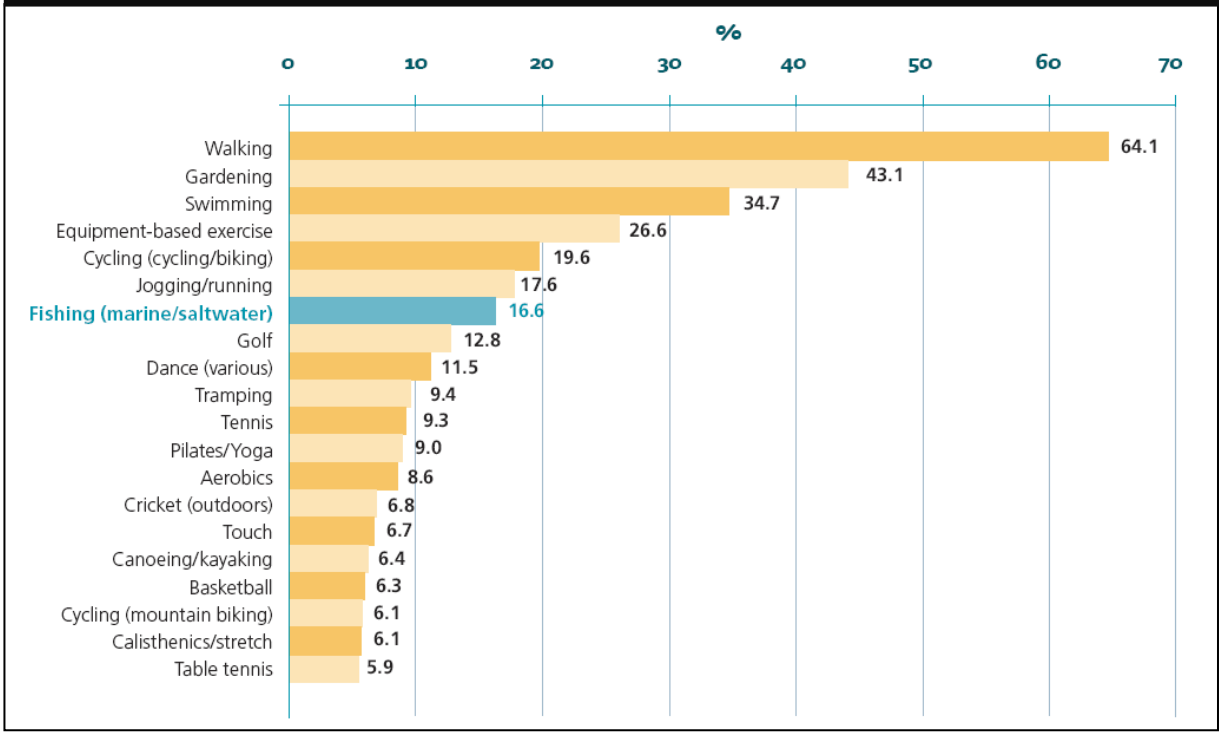
Changes to wave heights are small and variable depending on swell direction, and are unlikely to be discernible by surfers and other beach users. Changes to beach profiles are consequently unaffected by the capital dredge programme, and a sand augmentation and monitoring programme is proposed for the Mair Bank area to mitigate potential long term effects from maintenance dredging and to potentially contribute to reducing the effects of existing coastal change processes.

The main effect of interest to recreation is likely to be a temporary displacement of some fishing activity from near the dredged channel and the disposal site as they recover from bed disturbance. This effect is predicted to last for 6 to 12 months for capital dredging (the recovery time for ‘constructive benthic communities’ in all affected sites). Due to: the scale of the local fishing resource, the mobility of finfish, the lack of effect on biota beyond the activity footprints, the progressive recovery of the benthos, and the temporary nature of the effect, the net outcome for recreational fishing from capital dredging is likely to be adverse but also minor and represented by fishers choosing an alternative fishing site nearby. Maintenance dredging will have a lower scale of effect during each event, but will occur repeatedly and over time, and thus also have an adverse effect which is likely to be minor. The use of berley to attract fish is normal practice when boat-fishing, and Brian Coffey (author of Coffey (2017), pers comm) notes that using this method in a disturbed area will remain effective in attracting finfish.

2 National and regional marine recreation participation

SPARC (now Sport NZ) (2009a and 2009b) reported via the Active NZ survey that fishing, both freshwater and marine, was the seventh most important 'active leisure' pursuit in New Zealand with, in 2007/08, 19.5% of the national population participating, and 16.6% fishing in marine settings (approximately 540,000 people). This makes fishing more popular as a participation activity than, for example, golf, tramping, cricket, tennis and rugby (Figure 9). Almost 30% of men fished in 2007/08, and 9.7% of women. Sport NZ (2015) indicates that participation in fishing grew between 2007/08 and 2013/14 for both men and women (from 18.8% to 19.5% of the population, and 27.5% for Maori), and it was one of the main activities where additional participation was desired.

Figure 9: National sport and recreation activities with the highest participation levels (SPARC 2009b)



The level of participation in fishing (marine and freshwater) in the Northland Region is far higher than the national average with 40.2% of the region's population fishing (59.8% of men and 26.2% of women) in 2007/08 and 37.8% in 2013/14, making it the second-most popular active recreation or sport pursuit in the region after walking (and excluding gardening, which was not reported in 2013/14). Regionally, it was the most popular activity for men and the fifth-most popular activity for women (SPARC 2009c, Sport NZ 2015a). Other research completed for Sport NZ indicates that in Northland almost all those reporting fishing as an activity are marine fishers, while a small percent are also fresh-water anglers (Sport NZ 2013).

At the national level, 3.8% of the population reported going diving in 2007/8 and 3.4% in 2013/14; and 2.4% went sailing or yachting in 2007/08 and 2.1% in 2013/14 (SPARC 2009d & Sport NZ 2015b). The Active New Zealand survey only considered physically active, non-motorised pursuits and so did not review motor boating participation. In contrast, 13.5% of adults in Northland went scuba diving in 2007/08 and 7.6% in 2013/14 (SPARC 2009c and Sport NZ 2015a), and participation in yachting was also relatively high at 3.5% (Sport NZ 2015a). The Northland Regional Council reported one permanent boat mooring for every 45 permanent Northland residents, as well as five marinas in 2002 (NRC 2002).

Kalafatelis & Magill (2013) completed a national survey of recreational boating activity for Maritime NZ with 1500 respondents. The results do not appear to have been filtered for marine activity only. This indicated, at the national level, that:

- 24% of New Zealanders aged over 18 own or use a vessel for recreation boating purposes (57% male and 43% female):
    - 15% own or use a canoe or kayak,
    - 9% own or use a power boat under 6m,
    - 9% own or use a dinghy,
    - 5% own or use a power boat over 6m,
    - 3% own or use a sail boat under 6m,
    - 2% own or use a sail boat over 6m,
    - 2% own or use a jet ski.
- During periods when boaties are 'most active', such as over summer, 24% of users of power boats under 6m go out at least weekly, and another 25% go out once every couple of weeks. Similar levels of activity are evident for other vessels, and power boats under 6m are the most frequently used.
- The average number of years of boating experience was 12.9 years, with those owning or using kayaks and canoes the least experienced.

Kalafatelis & Magill (2013) reported the number of respondents based in Northland, but as the figure is quite low (n=24) there is limited reliability in the data from this sub-group.

Vance (2014) used the data gathered by Kalafatelis & Magill (2013) and older information to review trends in boat ownership. Eight Colmar Brunton surveys completed between 2002 and 2011 gave a range of 16% to 19% of households owning at least one boat in New Zealand; or 641,000 people and 727,000 vessels. Kalafatelis & Magill (2013) gave an estimate of 900,000 vessels. Vance (2014) estimates that between 30% and 50% of boat users go out at least every couple of weeks; and that levels of ownership have been reasonably consistent since at least 2006, but with possible increases in the ownership of trailer power boats and canoes and kayaks. However, the use of different survey methods means these trends are not certain.

3 Regional recreation planning and policy

This section reviews references to the management of recreation values in the study area from planning literature published by, or about, the Department of Conservation (DOC), the Northland Regional Council (NRC), the Whangarei District Council (WDC) and the disestablished Northland Harbour Board (NHB).

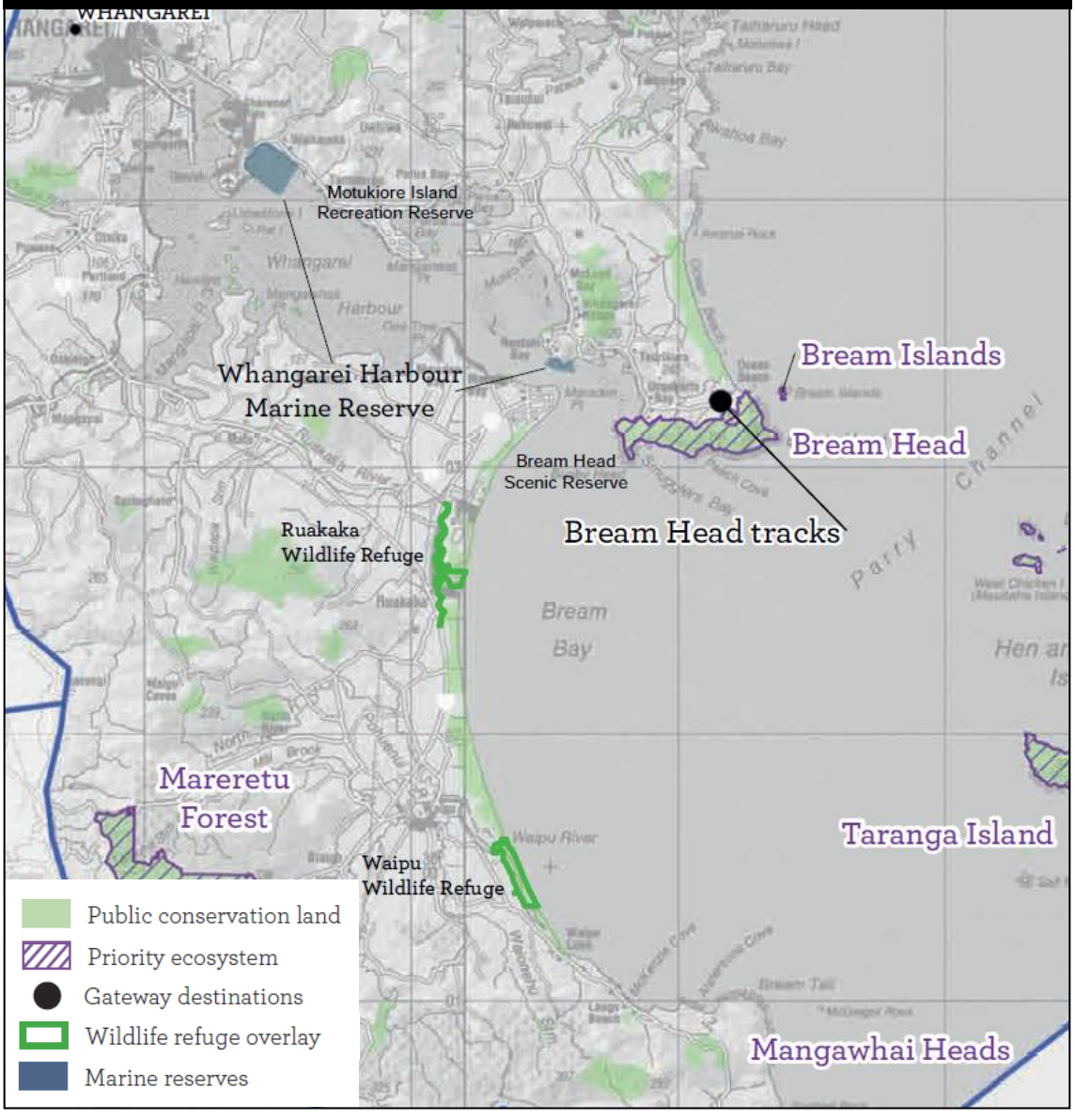
3.1 Department of Conservation

The Department of Conservation's Conservation Management Strategy (CMS) for Northland 2014-2024 (DOC 2014a) locates the study area in the 'Whangaruru–Mangawhai Coast Place'. The public conservation areas within this place and the study area are shown in Figure 10. The Bream Head tracks are identified as a 'gateway destination' (one of eight in the Northland Conservancy).[1]

The CMS describes the recreation setting as (p89):

> *Whangarei Harbour has some significant harbour features and estuarine habitats,*

Figure 10: Public Conservation areas in the study area. DOC CMS 2014



[1] 'Gateways' are places that the Department will promote as suitable for people's first adventures in the outdoors, or repeat adventures of a gentle nature. (DOC 2104a, p10)

ranging from upper harbour mud and sand flats to deep channels, islands, extensive shellfish sand banks and deep holes near the harbour entrance. Whangarei Harbour Marine Reserve comprises two sites — Waikaraka and around Motukaroro (Passage) Island at Reotahi.

The establishment of a marine recreational park between Cape Brett, Poor Knights Islands Marine Reserve and Bream Head has been proposed as a means of making the most of the spectacular coastline to provide multiple sustainable economic benefits for Northland. The intention of a marine recreational park is to align Māori values of long term sustainability and kaitiakitanga with enhanced conservation outcomes and recreation opportunities.

Visitor use is moderate to high in this Place, especially in summer when camping and boating are very popular, along with the active use of the many sandy beaches for fishing, swimming and surfing. Snorkelling and scuba diving are also popular along the coast, particularly at the Poor Knights Islands Marine Reserve. There are four camping grounds administered by the Department, all of which are heavily used over the height of the summer months, especially since many private camps have been converted into coastal subdivisions. Tracks and walkways through many of the reserves supplement those provided by the local authority. The Te Araroa Trail follows close to the coast for its entire length through this Place. The attractions and activities are primarily used by locals, but domestic and international tourism is increasing…..

Whangarei, the major urban area and administrative centre for the Northland region, is the location for principal sites of industrial processing. It includes the only oil refinery in New Zealand, a large forestry port, cement and fertiliser works, transport systems, and other planned or existing activities adjacent to Whangarei Harbour such as at Marsden Point and lower Port Road. All of these have the potential to cause adverse impacts on natural and historic values if not closely monitored. Three pipelines carrying gas and petroleum products from the Marsden Point Oil Refinery pass through land administered by the Department, and require ongoing inspection and maintenance. The Marsden Point Oil Refinery, deep water export port and new manufacturing plants lie immediately adjacent to recreation areas, kiwi and shorebird habitat, sites important for biodiversity, historical and archaeological sites, and marine reserves. Extensive flat land and improved transport links with Auckland are creating opportunities for economic growth that are increasing pressure on natural values and the types of visitor experience.

The following outcomes for the Whangaruru–Mangawhai Coast Place are sought (p90):

The Whangaruru–Mangawhai Coast Place is a diverse and highly used coastline centred on Whangarei, where the population and industrial and economic activity in Northland are concentrated. The Department works collaboratively with tangata whenua, other agencies, business interests and the community to achieve a net conservation benefit wherever possible….

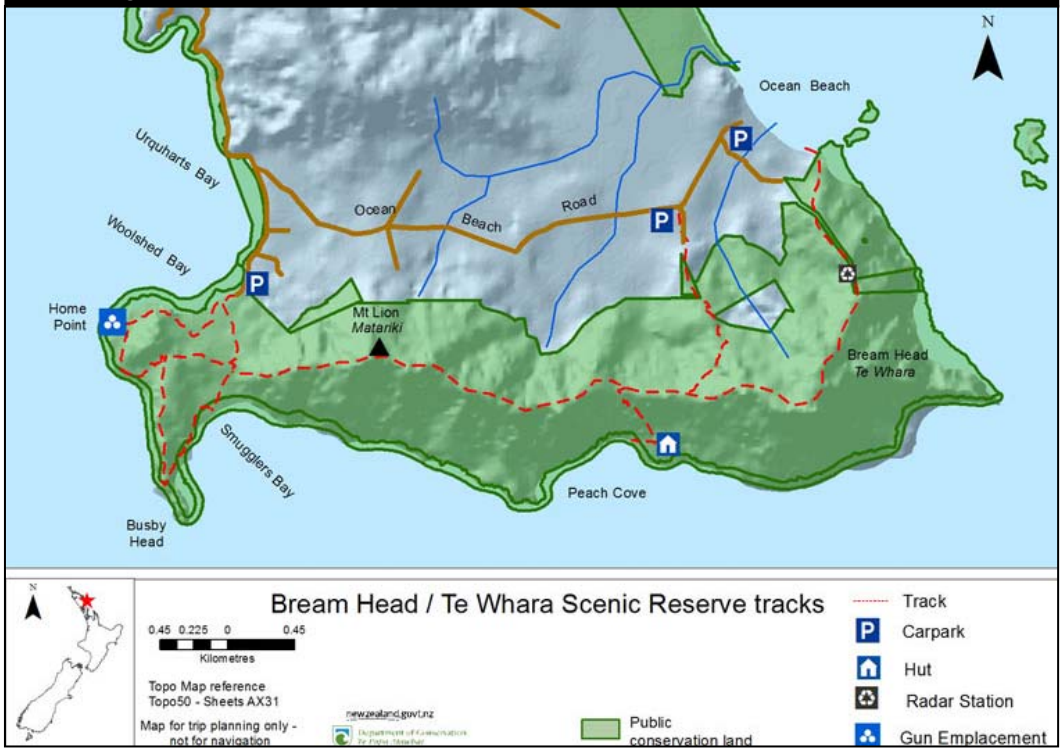
Whangarei Heads

The Bream Head and Manaia Ridge Scenic Reserves are ecological gems where visitors get a real feel for what the nearby offshore islands are like without accessing them….

Bream Head Scenic Reserve is a Gateway Destination where visitors also enjoy coastal vistas, coastal defence historic features and pā sites from a network of

generally easy-grade walking tracks. The secluded Peach Cove Hut [Figure 11][2] *enables a special experience of coastal biodiversity. Opportunities for visitors to participate in education, research and restoration programmes are provided by a community trust, community groups and concessionaires. In these reserves, as well as at Bream Islands Scenic Reserve and Ocean Beach, the community and tangata whenua are working together with the Department to restore and manage natural, cultural, recreational and historic values.*

Figure 11: Bream Head / Te Whara Scenic Reserve and Peach Cove location



Bream Bay and Mangawhai

The Te Araroa Trail and another popular walkway pass near/through it, providing spectacular views of the islands of the Hauraki Gulf, Bream Bay and Bream Head….

Public access to the beaches is via access points managed in collaboration with Whangarei District Council and Northland Regional Council to protect the foredunes. New recreation opportunities have been developed to enable increasing numbers of visitors to enjoy basic-facility campgrounds, walking and cycle trails, bird-watching hides, and guided tours. There is a collaborative approach between the Department, tangata whenua, local authorities and communities to ensure that recreational, residential and industrial expansion does not compromise and, wherever possible, enhances the natural, cultural and already established recreational values of the area. The long, unbroken stretch of white sandy beach at Bream Bay and Mangawhai, and the vista across the water to the islands and Bream Head are valued, enjoyed and appreciated by all.

Marine Protected Areas

The ecosystems at the internationally ranked diving destination at the Poor Knights Islands Marine Reserve and the Whangarei Harbour Marine Reserve have recovered,

[2] http://www.doc.govt.nz/parks-and-recreation/tracks-and-walks/northland/whangarei-area/bream-head-peach-cove-track/#map retrieved 13 Nov 2014

and both sites are enjoyed by many who strongly defend their values. The marine reserves sustain diverse populations of native plants and animals. Their conservation values are recognised and valued for their contribution to the biodiversity of the wider marine environment. Visitors leave the reserves with an enhanced understanding and appreciation of the value of no-take reserves and long-term protection of the marine environment. Public enjoyment and scientific research are encouraged in marine reserves.

Human activities in marine reserves and on adjoining public conservation lands are not detrimental to scientific study or conservation values, and do not detract from the visitor experience. The Department continues to advocate for the appropriate use of land within marine reserve catchments to reduce land-based effects on marine reserves. Biosecurity measures are established where practicable and maintained to prevent the establishment of viable populations of new marine pests within marine reserves.

….Further areas on the Whangarei coastline have been identified for marine conservation initiatives and everyone enjoys a restored food-basket as a result. In conjunction with regional and district councils, tangata whenua, the community and tourism organisations, a marine recreational park is investigated to protect, enhance and increase sustainable coastal and marine tourism and recreation opportunities.

Figure 12: Excerpt from CMS Appendix 8 - Marine habitats

Ecosystem	Habitat type	Significant values	Pressures/threats	Protected areas
Whangarei Harbour	Saltmarsh Mānawa/mangroves Karepō/seagrass Intertidal sand and mudflats Estuarine beach Estuarine sand Estuarine reef High-current shallow sand High-current shallow reef	Diverse benthic invertebrate and fish assemblages. Diverse high-current assemblages at Motukaroro. Productive customary, commercial (fin and shell fish) and recreational fisheries. Important coastal and wading bird habitat. Kera wēra/killer whale foraging habitat.	Significant historic and ongoing anthropogenic impacts resulting in environmental degradation, including loss of shellfish beds and extensive karepō/seagrass meadows (and their associated fishery and biodiversity values). Overfishing. Chronic disturbance and underwater noise pollution.	Whangarei Harbour Marine Reserve—Motukaroro, Waikaraka.
Bream Bay / outer Hauraki Gulf	Saltmarsh Mānawa/mangroves Intertidal sand and mudflats Estuarine sand Moderate beach Moderate rocky shore Moderate shallow sand Moderate shallow reef Deep sand Deep mud Deep reef	Waipu, Ruakaka and Mangawhai Government Purpose Wildlife Refuge Reserve estuaries contain important coastal and wading bird habitat. Relatively pristine inshore benthic invertebrate assemblages. Productive reef systems, particularly around islands, supporting diverse invertebrate and reef fish fauna. Algal forests are an important source of nutrients to surrounding soft sediments. High natural character values.	Habitat loss due to coastal development. Sand mining. Overfishing. Disturbance to nesting shorebirds by domestic animals, people and vehicles. Removal of epifauna and habitat homogenisation by mobile fishing gear. Invasive marine species. Toxic algal blooms.	

The DOC CMS refers in the preceding quote to the investigation of a 'marine recreational park' in the Whangaruru–Mangawhai Coast Place. A scoping report has been prepared on this concept for the Northland Regional Council and is discussed in section 3.2 below.

Whangarei Harbour and Bream Bay are identified as marine habitats with recreation values (fisheries, high natural character and marine and avian wildlife), as well as adverse effects from overfishing and fishing gear (Appendix 8, p198) (Figure 12).

The recreation values of the Whangarei Harbour Marine Reserve (see Figure 10) are described in a DOC pamphlet, with the following introduction and activity description (DOC 2014b):

> *The reserve was established in October 2006 and is located on the east coast of Northland. The reserve is the result of over 16 years of hard work, supported by marine experts and initiated by Kamo High School students of Whangarei. Whangarei Harbour Marine Reserve comprises two sites: an intertidal mudflat/mangrove environment at Waikaraka, which is approximately 8km from Whangarei town; and a mix of sandy beach, rocky reef and small high-current outcrops at Motukaroro/Passage Island, approximately 30km from Whangarei. It protects a combined area of 253.7 hectares of shore and sea providing a safe haven where the region's marine life can flourish.*
>
> *Visitors to the marine reserve are welcome and activities like boating, snorkelling, scuba diving, picnicking and canoeing are encouraged. We hope you enjoy your visit.*

3.2 Northland Regional Council

The *Operative Regional Policy Statement for Northland* (RPS) (NRC, May 2016) states (p91):

> *Northland's unique coastal environment has a range of landscape, seascape and recreational qualities that make it a popular place for development. Most of our existing settlements are located in the coastal environment and this is also where most development in Northland is occurring. The coastal environment is of huge economic importance to the region (for example, tourism and aquaculture) and our coast is an attribute that sets us apart from other regions. Northland has one of the longest coastlines of any region in the country.*

The RPS does not quantify or describe regional coastal recreation values in any detail. Objective 3.2 (d) and (c) of the RPS are to:

> *Improve the overall quality of Northland's fresh and coastal water with a particular focus on: …*
>
> *(c) Reducing sedimentation rates in the region's estuaries and harbours;*
>
> *(d) Improving microbiological water quality at popular contact recreation sites, recreational and cultural shellfish gathering sites, and commercial shellfish growing areas to minimise risk to human health.*

Policy 4.4.1 (2) (b) refers to "maintaining and protecting significant ecological areas and habitats" that of are importance to recreation:

> *(2) In the coastal environment, avoid significant adverse effects and avoid, remedy, or mitigate other adverse effects of subdivision, use and development on:…*
>
> *(b) Habitats of indigenous species that are important for recreational, commercial, traditional or cultural purposes;*

Part 9 of the RPS states the 'environmental results anticipated' and, with reference to Objective 3.2 (as above), expects:

4.2. Regional-wide water quality management…

5. Compliance rates for contact recreation at popular swimming sites are maintained or improved with respect to the relevant guidelines.

The RPS does not define or refer to specific guidelines – these are stated in the *Northland Regional Council Regional Coastal Plan* (RCP). Appendix 2 includes the RCP maps for Whangarei Harbour and Bream Bay. These show the dominant management zones as Marine 1 (Protection) and Marine 2 (Conservation) Management Areas. Mooring Zones are shown in Urquharts Bay, Taurikura Bay, McLeod Bay, Parau Bay and west and east of One Tree Point. A ski lane is shown on the north-west corner of Limestone Island. Port Facilities Management Areas are also indicated.

The RCP describes regional coastal recreation values (p111):

Northland's warm climate, multitude of harbours and sandy beaches, often dramatic coastal scenery and high coastal water quality make its coast attractive for outdoor recreational pursuits. The diversity of recreational opportunities provided within Northland's coastal marine area is a major reason for its popularity both with Northlanders and visitors to the region and as a result, additional demands are placed on the coastal environment.

The region's coastline is extensively used for swimming, boating and fishing. It also contains numerous areas which are suitable for a wide range of other activities such as scuba diving, snorkelling, water skiing, surfing, windsurfing, sailing, jet-skiing, canoeing, sunbathing, horse riding, picnicking and tramping. In terms of the Resource Management Act, the coast has very high amenity value.

Recreational activity occurs mainly in Marine 1 and Marine 2 Management Areas and, to a lesser extent, in Marine 4 (Moorings) Management Areas.

Management of recreation around Northland's coast is generally only necessary where there are large numbers of recreational users and/or there are competing demands for the use of coastal space. In Northland, such situations generally occur over the summer period when large numbers of people "head for the coast" for their holidays.

The recreation section (16) of the RCP focuses on avoiding adverse effects caused by recreation and adopts a 'permissive approach' (Policy 16.4) to recreational activities in the Marine 1 and 2 Management Areas, and applies rules to limit adverse effects on environmental and amenity values and public health and safety.

Section 22 of the RCP considers capital and maintenance dredging and, although it does not refer to potential adverse effects on recreation, it considers effects on ecological values and the potential release of contaminants, and siltation.

Section 13 of the RCP reviews water quality and identifies as an issue (13.2 (2)):

The importance of water quality to safe contact recreation, shellfish gathering and other significant uses of Northland's coastal marine area, and the consequent need to provide an effective management framework for maintaining and enhancing water quality for the benefit of future generations.

With a subsequent policy (13.4 (1)):

1. To classify the waters within Northland's coastal marine area as a means of clearly identifying the water quality management aims for individual areas of coastal water, and in a manner which recognises:

(a) the high standard of existing water quality of the majority of Northland's coastal waters;

(b) existing detailed information on the quality of the waters of the Whangarei Harbour and the Bay of Islands;

(c) the importance of water quality to safe contact recreation and the quality of naturally occurring and commercially-grown edible shellfish resources;….

Water quality classifications referred to in the RCP are as stated in the NRC *Whāngārei Harbour Water Quality Plan 1990* (NRC 1990), most recently illustrated in the NRC *Whāngārei Harbour Water Quality Improvement Strategy* (NRC 2012). This relies on classes for contact recreation and general water quality including shellfish, with defined mixing zones where the relevant water quality standards may be exceeded (Figure 13, provided by NRC based on data shown in a low resolution image in NRC (2012)).

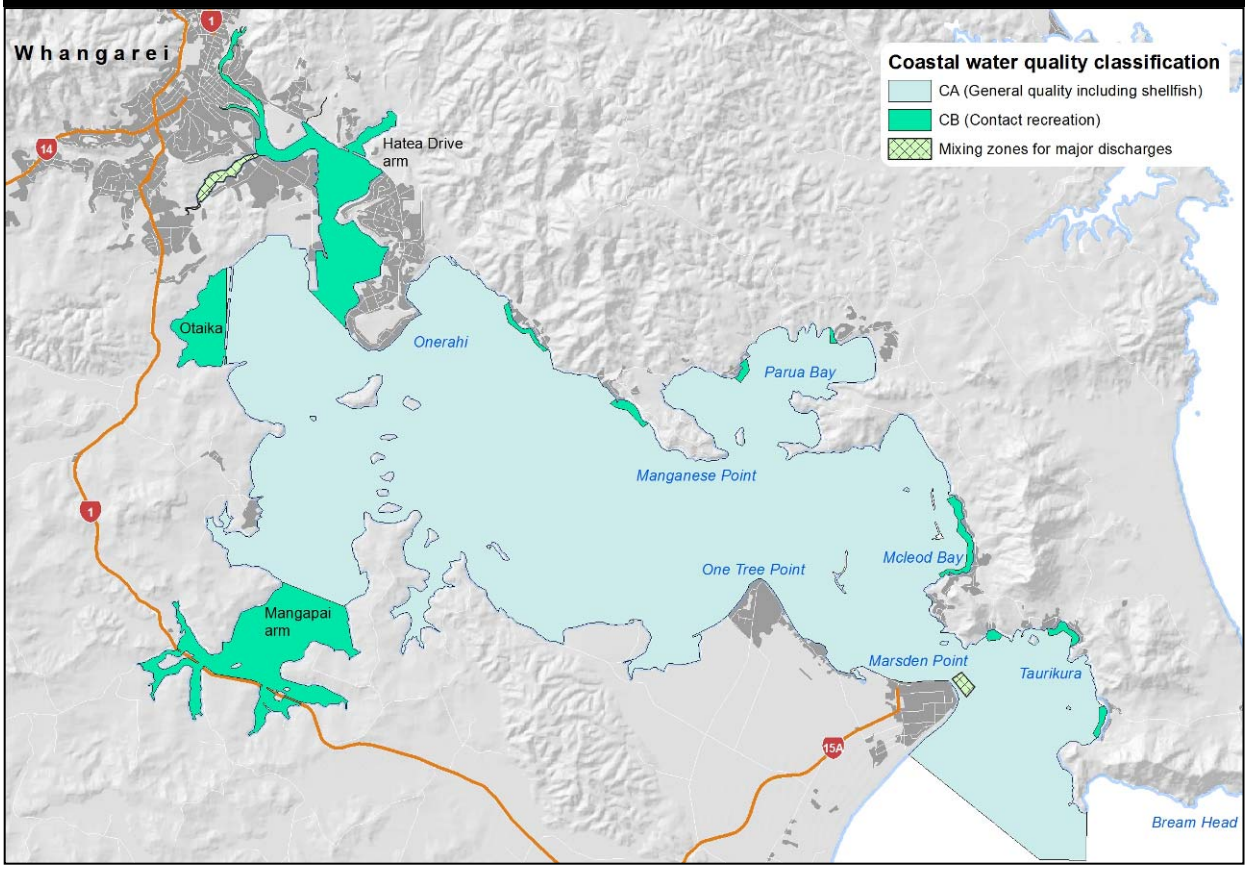
The Contact Recreation standard (CB) provides for "contact recreation and shellfish collection but not for marine ecosystems" (NRC 2012, p31). The *Water Quality Improvement Strategy* notes (NRC 2012, p31):

It is also important to note that as a result of a consent process under the Resource Management Act, a direct discharge to the harbour does not necessarily have to meet the relevant classifications and standards after reasonable mixing. However, it would be unlikely in today's environment that consent would be granted for discharges that would result in large departures from the water quality classifications and standards.

The standards are defined in Appendix 4 of the RCP, and are considered in sections 5.2.1 and 5.2.6 of this report.

The Water Quality Improvement Strategy briefly describes the recreation values of the Harbour (NRC 2012, p25):

Figure 13: Coastal water quality classification zones, Whāngārei Harbour – NRC 2012



The harbour is a place of great bounty and enjoyment. Water-based recreation in the harbour includes fishing, seafood gathering, sailing, waka ama, windsurfing, kayaking, rowing, stand-up paddle boarding, snorkelling, diving, and swimming.

Most of these activities are undertaken in the middle and lower harbour. Muddy intertidal flats, water quality issues (including poor water clarity), and limited public access (due to urban and industrial development) discourage primary contact recreation in the upper harbour. However, secondary contact uses such as waka ama (outrigger canoes), rowing, kayaking, and stand-up paddle boarding are common….

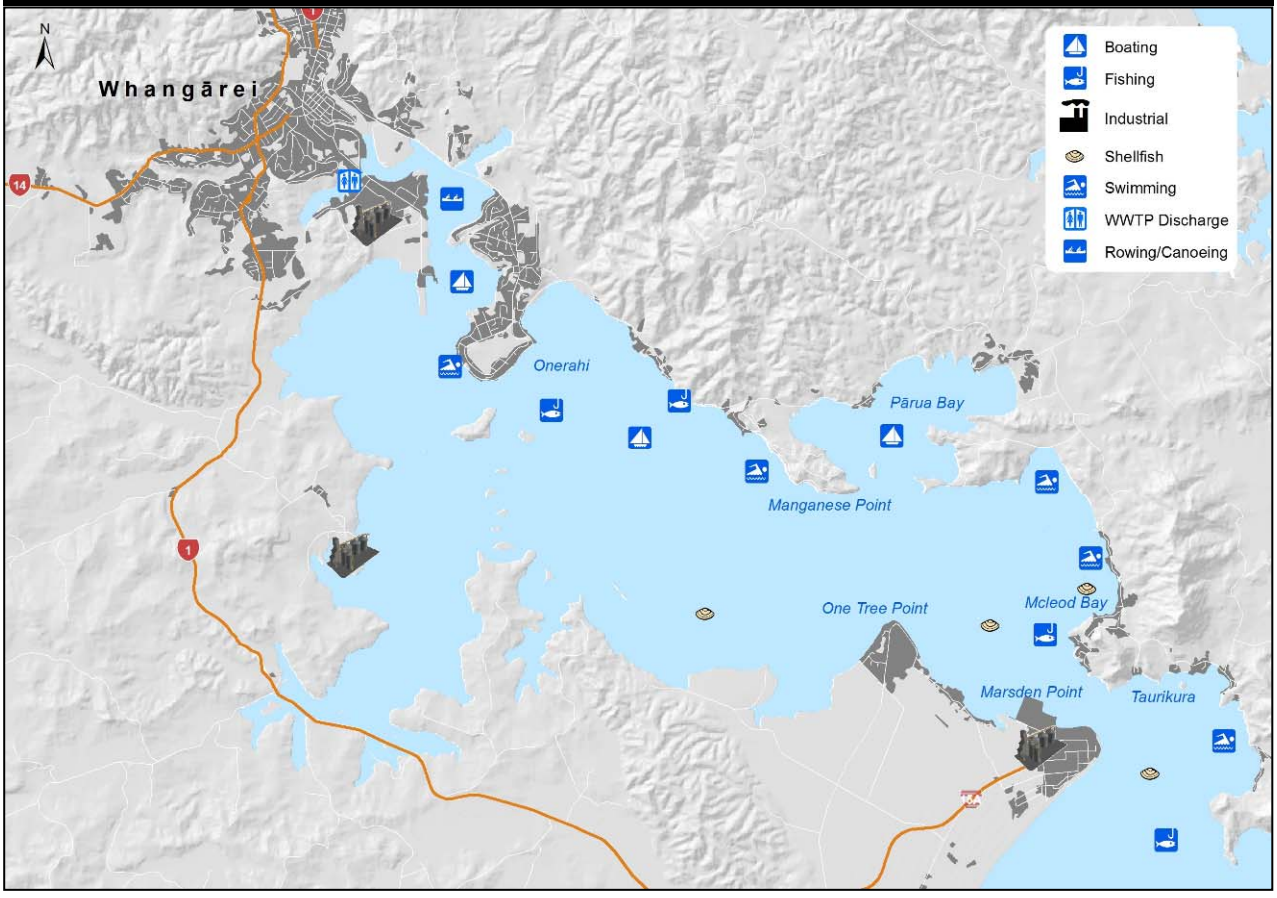
The harbour is a popular destination for domestic and overseas sailors, and is often the home of a number of international users. There are approximately 350 moorings and 430 marine berths in the harbour. Most of these are found in the Hātea River arm of the upper harbour and in the lower harbour at One Tree Point and Marsden Cove. There are also a small number of private jetties used for permanent mooring, most of which are in the Waiarohia Canal (the lower estuarine reach of the Waiarohia Stream)….

A graphic summary of 'common uses' of the Harbour is also provided (Figure 14).

The *Draft Regional Plan for Northland* (August 2016) identifies several relevant recreation settings which are described in section 4 of this report.

At the 18 March 2014 NRC Council meeting, a proposal to establish a 'national marine park' in Northland was considered. The idea was to implement a set of restrictions on commercial take, reductions in recreation catch limits, and to establish some 'no take' marine reserves, over approximately 1800km^2 extending from Cape Brett to the Whangarei Heads, and including the Poor Knights Islands (Figure 15). A 'scoping and review' report for the proposal had been prepared for NRC in 2013 (Hampson *et al* 2013 – the 'ME Report') and a review of

Figure 14: 'Common uses of the Harbour' – NRC 2012

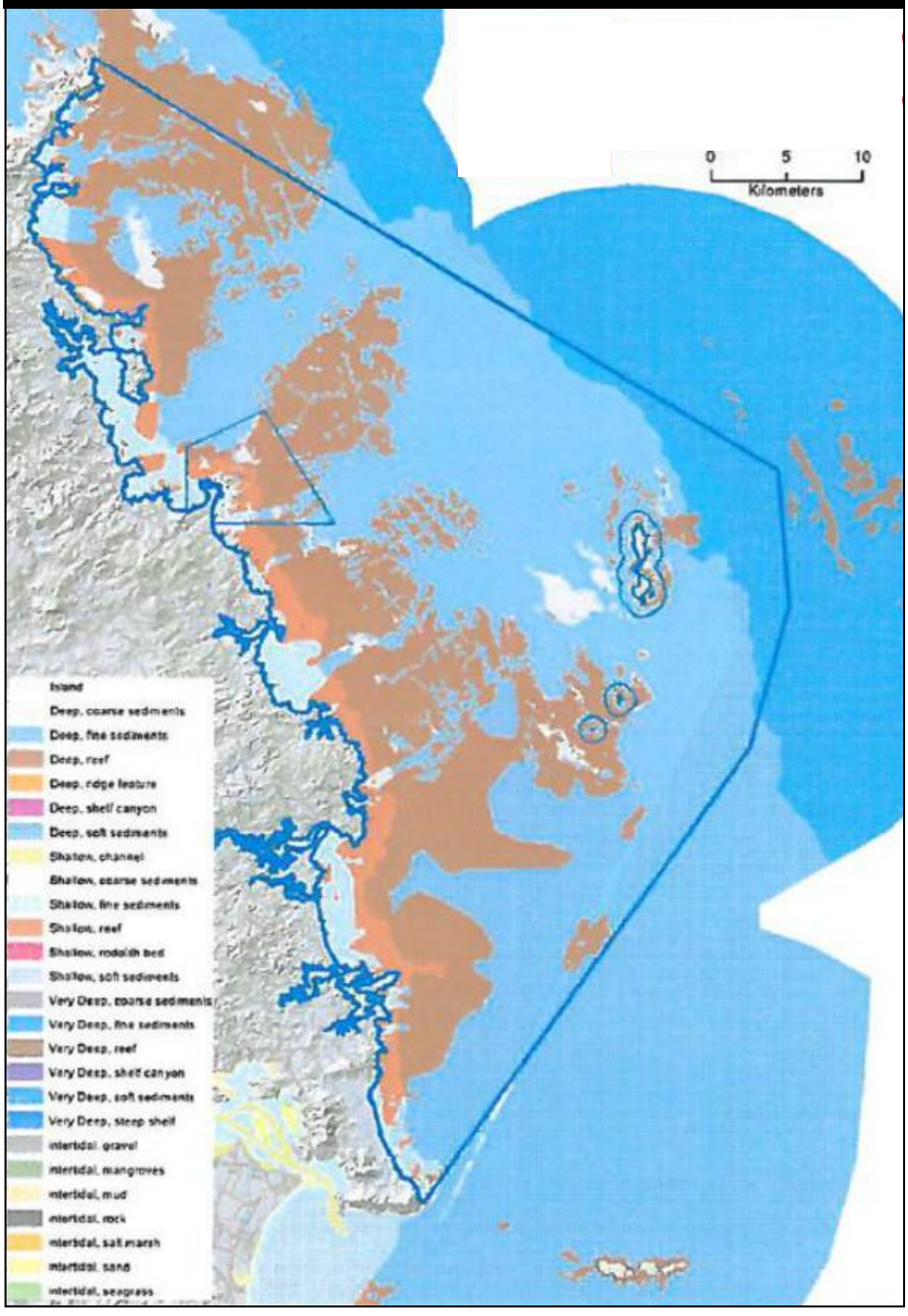


that report and a recommendation to not proceed with the idea was presented at the Council meeting (Murfitt 2014). Minutes of the meeting are not available online. The report concluded:

> *Council will be aware that there are other community groups in the region looking to progress marine park/reserve proposals (Bay of Islands and Whangaroa for example), which individually may have more chance of success than the larger marine park concept (i.e. these proposals might have a higher chance of success on ecological grounds which is the primary driver behind the Marine Reserves Act). It is considered that we do not have enough evidence that this marine park proposal is better than others in the region to justify exclusively pursuing this one over others. In addition the development of a network of smaller marine protected areas under the Marine Reserves Act could encompass the community aspirations of these other groups.*

The ME report did not quantify or assess recreation activity in the proposed marine park area.

Figure 15: Proposed Marine Park boundary in blue – from Hampson *et al* 2013



3.3 Whangarei District Council

The WDC released an Open Space Strategy in 2001 (WDC 2001). This described the recreation values of the Whangarei Harbour and its shoreline as a "a popular destination for aquatic activities, including swimming and fishing, sailing and boating, water skiing and kayaking" (p34). Identified 'threats and issues' for recreation and other values included (p34):

- *Abandoned islands, such as Matakohe/Limestone Island, have been left in a degraded state.*
- *Derelict structures litter the foreshore. Of particular concern are the jetties that are unsafe for the public to use.*
- *Boat access facilities to the harbour need upgrading and assessing.*
- *Runoff, erosion and siltation threaten the water quality of the harbour.*
- *The community is promoting a vision for marine reserves in the Whangarei Harbour.*
- *There are illegal structures, including boat sheds and baches, on coastal reserve land.*

Strengths and opportunities for the Harbour and shoreline included (p35):

- *Support community efforts to assist in protecting cultural sites and in restoring wildlife habitat, public access and understanding on Matakohe/Limestone Island.*
- *Acquire other islands in the harbour as the opportunity arises subject to funding.*
- *Assess coastal structures in the harbour and implement a removal or maintenance programme, as appropriate.*
- *Assess the boat access facilities to ensure they meet the needs of the community.*
- *Continue to plant the riparian margins to assist with stormwater filtration, bank stability and siltation. Where possible control the land-based activities that contribute to a reduction in water quality.*
- *Support the establishment of marine reserves in the Whangarei Harbour.*

Development priorities for recreation in coastal and marine settings identified in the Open Space Strategy focused primarily on improving coastal access, including in Bream Bay and throughout the Whangarei Harbour.

The Whangarei District Plan 2007 has no information on marine recreation and focuses on the terrestrial environment.

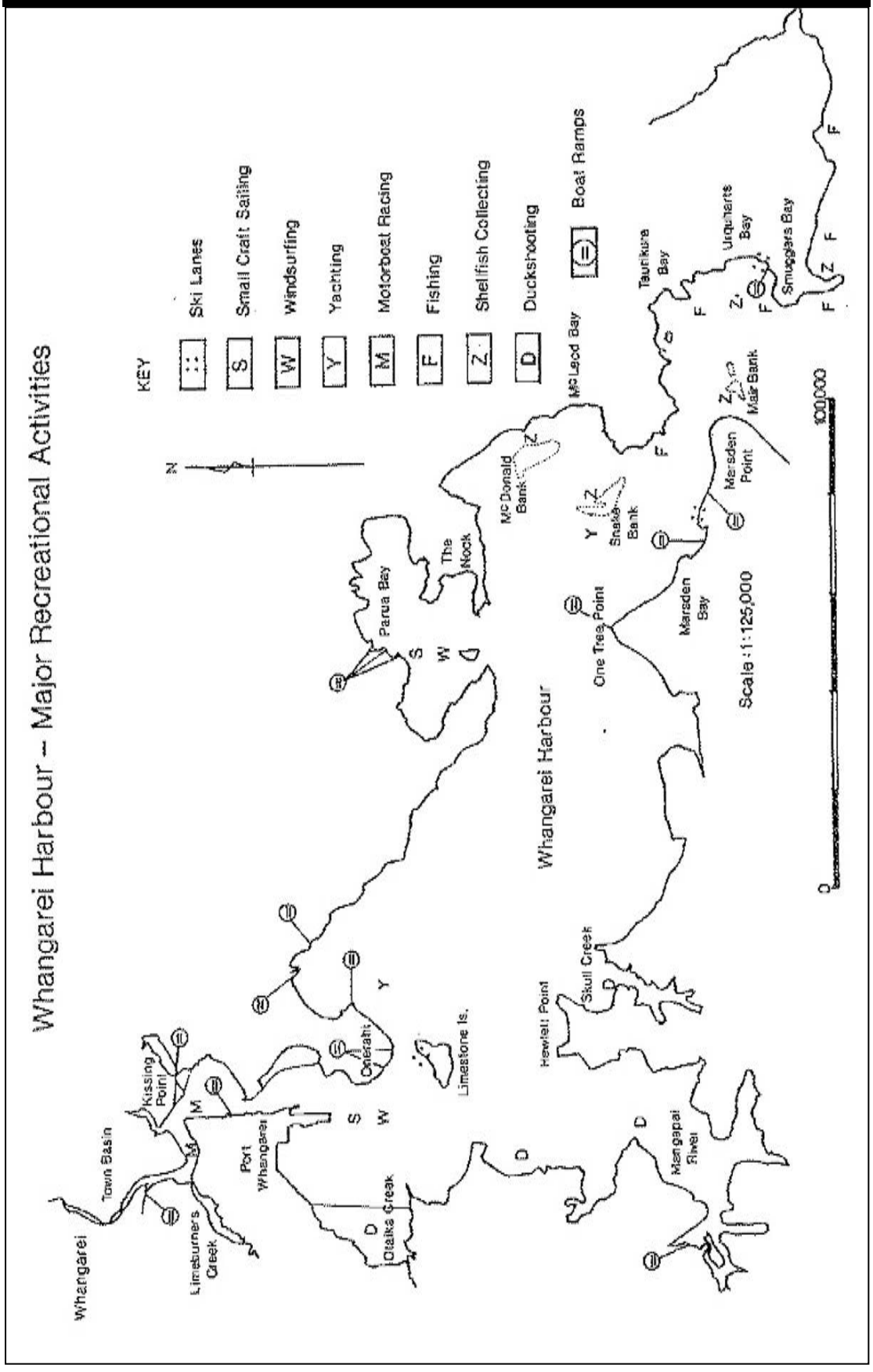
Other recreation information provided by the WDC is discussed in the activity-specific sections of this report (in section 4) .

3.4 Northland Harbour Board

The role of the Northland Harbour Board (NHB) is now carried about by the NRC. In the late 1980s the NHB completed a review of the uses and values of the Whangarei Harbour, and included a summary of recreation values relying on a telephone survey of "all the recreational user groups and clubs known to use the harbour and the harbour shore line." (NHB 1989, p113).

References to this document are made in section 4 of this report about specific activities that were identified in the late 1980s, and are updated where necessary. Figure 16 shows the main findings of NHB (1989) for the location of recreational activities in the Harbour. This report will provide some basis for trend analysis and discussions with stakeholders.

Figure 16: Recreation activities in Whangarei Harbour (NHB 1989)

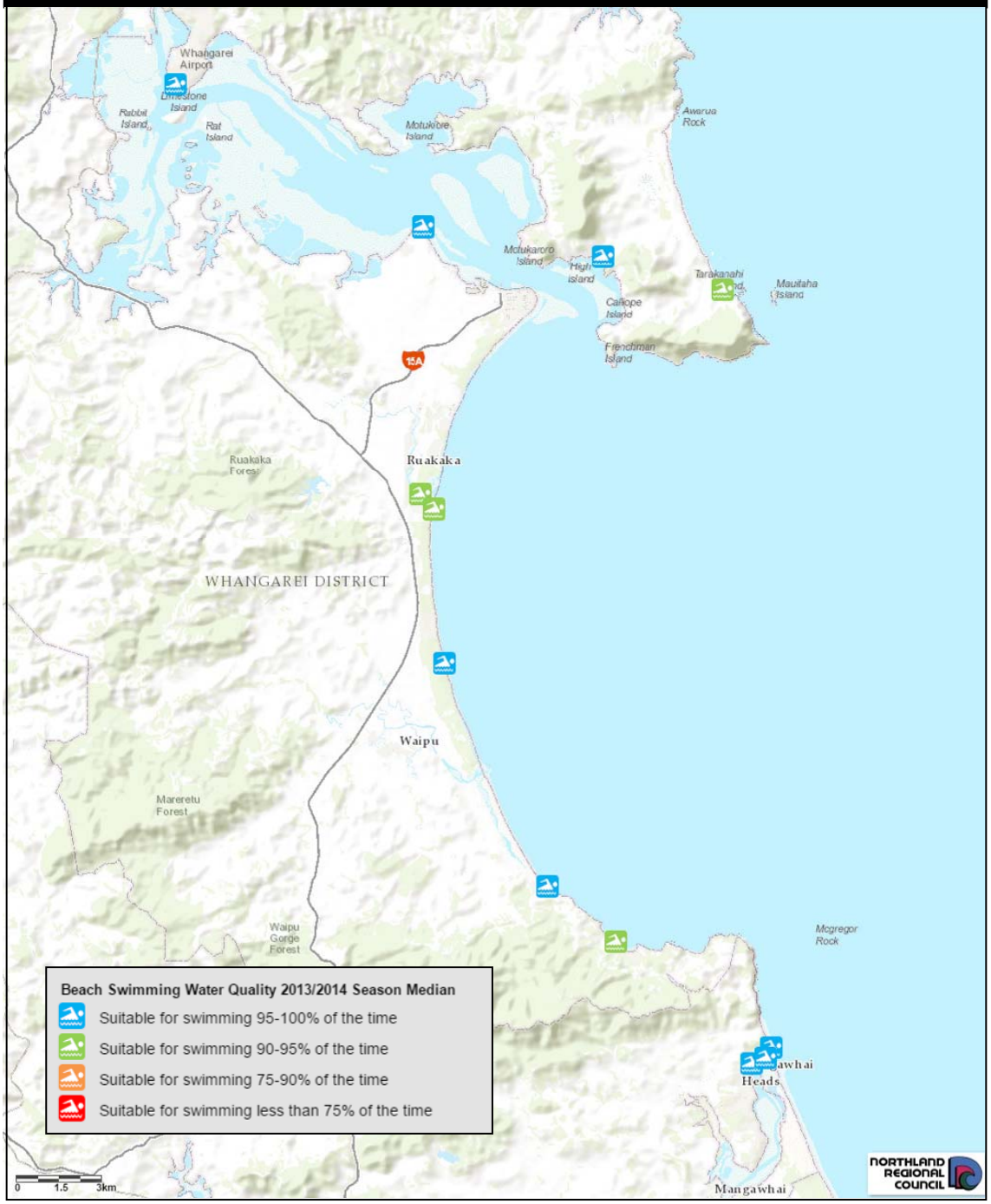


4 Activity reviews

4.1 Swimming and beach use

The NRC monitors water quality at nine popular swimming sites within the study area (Figure 17) – of 47 coastal sites throughout the region.[3] Data for the 2013/14 summer season showed bathing water quality to be generally good or very good. Results for the 2015/16 season were the same. Monitored swimming sites in the study area are shown in Figure 17 and listed below. Figure 17 shows data for the 2013/14 season. Results from the 2015/16 season onwards are presented on the LAWA national database[4].

Figure 17: NRC monitored marine bathing sites in and around Whangarei Harbour 2013/14



[3] http://www.nrc.govt.nz/Living-in-Northland/At-the-beach/Swimming-water-quality/Swimming-water-quality-results/ retrieved November 2014

[4] https://www.lawa.org.nz/explore-data/northland-region/swimming/ retrieved January 2017

- Ocean Beach
- Taurikura Beach
- Onerahi Playground
- One Tree Point
- Ruakaka Beach and River
- Uretiti Beach
- Waipu Cove
- Lang's Beach (mid)

Other swimming sites identified by the NRC are shown in Figure 14 on page 26.

The Whangarei District Council states:

> *Whangarei has a reputation as the city with 100 beaches, and offers a range of picturesque and safe places to swim, from the grand scale ocean beaches to small sandy bays along both edges of the harbour. …*
>
> *Surfing beaches at Ocean Beach and Waipu are patrolled by Surf Life Saving NZ at weekends during the summer months, generally from the end of October until early April and throughout the week during the summer school holiday in December and January.* [5]

Surf Lifesaving NZ identifies popular swimming beaches nationally on its 'Find a Beach' website, as well as beach activities popular at each site (Figure 18 for the four identified beaches in the study area).[6] All but Langs Beach is patrolled. Recommended beach activities at each are:

Ocean Beach

- Canoeing/kayaking
- Dog walking
- Scuba diving
- Snorkelling
- Wind/kite surfing

Ruakaka Beach

- Canoeing/kayaking
- Dog walking
- Horse riding
- Wind/kite surfing
- Wind-powered vehicles

Waipu Cove

- Dog walking
- Horse riding
- Snorkelling

Figure 18: Surf Lifesaving NZ recommended beaches



[5] http://www.wdc.govt.nz/FacilitiesandRecreation/Beaches-and-Coastal-Facilities/Pages/Default.aspx
[6] http://www.findabeach.co.nz/

- Wind-powered vehicles

Langs Beach

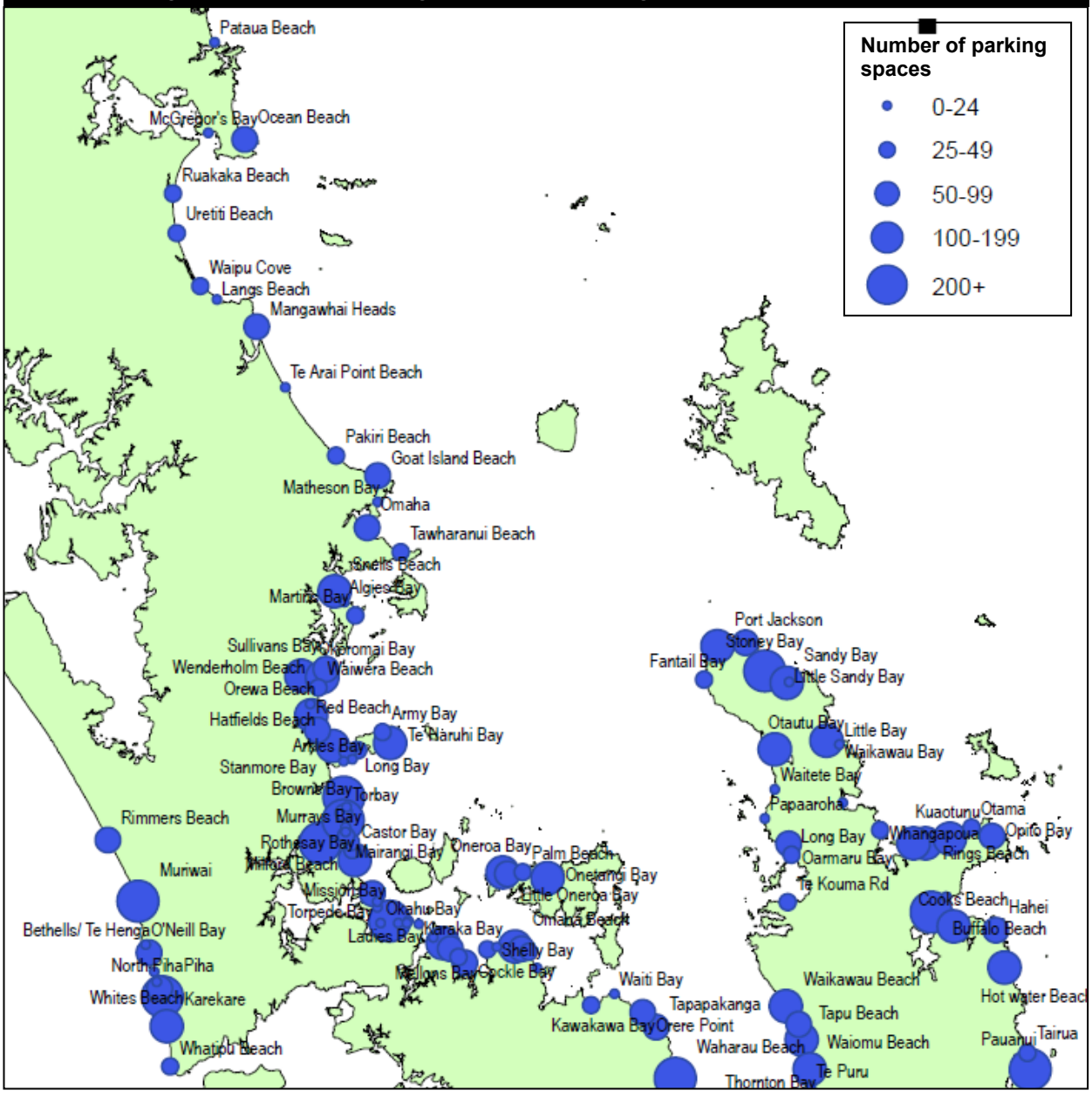
- Dog walking
- Horse riding
- Motorbikes/4WD's
- Scuba diving

Surf clubs are located Ruakaka, Waipu Cove and Ocean Beach (Whangarei Heads).[7]

The Northland Harbour Board (1989) noted (p114):

> *Swimming is not at present a widely popular pastime within the Whangarei Harbour. With the exception of the Marsden Point to One Tree Point area, the southern harbour shores contain large areas of tidal flats and mangroves. In*

Figure 19: Beaches showing number of carparking spaces 1997 (Allen et al 2009)



[7] http://www.nrc.govt.nz/Living-in-Northland/At-the-beach/Surf-clubs-and-safe-swimming/#surf

> *contrast, the northern shores consist mainly of rocky shorelines and stony beaches in the vicinity of .Whangarei Heads and Bream Head, with tidal mudflats in McLeod Bay, Parua Bay and from Tamaterau to Onerahi. Due to the lower water quality in the upper harbour, the harbour above Onerahi and the Hatea River is currently not considered to be suitable for swimming. It is anticipated that future water quality in the upper harbour will improve, consistent with the Northland Regional Council' s Water Quality Management Statement, and that swimming will be safe in the upper harbour by 1989.*

Biosecurity New Zealand released a review of coastal social values in 2009 (Allen *et al* 2009). This indicated that, at the national level, there is only a very coarse understanding of the distribution of marine recreation. The study considered beach recreation, surfing, diving, boating and seafood gathering. However, in the main, only proxy information was used to identify where these activities occur – such as the presence of a surf living saving club to identify swimming locations or a yacht club for sailing. This resulted in broad descriptions of activity patterns which are better described using more specific data sources (such as those discussed elsewhere in this report). Figure 19 shows proxy data for swimming site popularity around Coromandel, Auckland and some of Northland – the number of parking spaces provided at beach access areas – reported in Allen *et al* (2009) based on a 1997 Surf Lifesaving NZ count. Coromandel beaches – even in quite remote areas near Cape Colville – had higher provision than the beaches in the study area.

4.2 Fishing

The National Aquatic Biodiversity Information System (NABIS) provided by the Ministry for Primary Industry provides results from aerial surveys of recreational fishing effort undertaken over 2011 and 2012 (Figure 20).[8] Boats recorded include those scuba diving and so show 'fishing' effort within, for example, the marine reserve around The Poor Knight Islands. The data show the Whangarei Harbour area to be a relatively heavily fished setting, with similar vessel densities to the Bay of Islands and the inner Hauraki Gulf – although the latter has several areas with two to three times the density of vessels.

Figure 21 shows the vessel density data for the study area, with a peak of 100 to 150 vessels per km^2 immediately south of Peach Cove and a heavy concentration of activity in the main part of Whangarei Harbour and around Bream Head.

Consultation indicated that the channel boundary just outside Motukaroro Marine Reserve is a particularly good site for jigging for kingfish. Crab fishing was also identified as an activity in many harbour bays. Other preferred fishing sites identified by individuals were Three Mile Reef (approximately 5km due south of Peach Cove), and navigation buoy 9.

The Spot X national surfcasting (Draper & Airey 2012) and boat fishing (Airey 2012) guides identify many fishing opportunities in and around the study area. Relevant figures from Airey (2012) are shown in Appendix 3. These indicate diverse fishing opportunities within the study

Figure 20: Recreation fishing effort Matauri Bay to Whangamata. MPI NABIS data

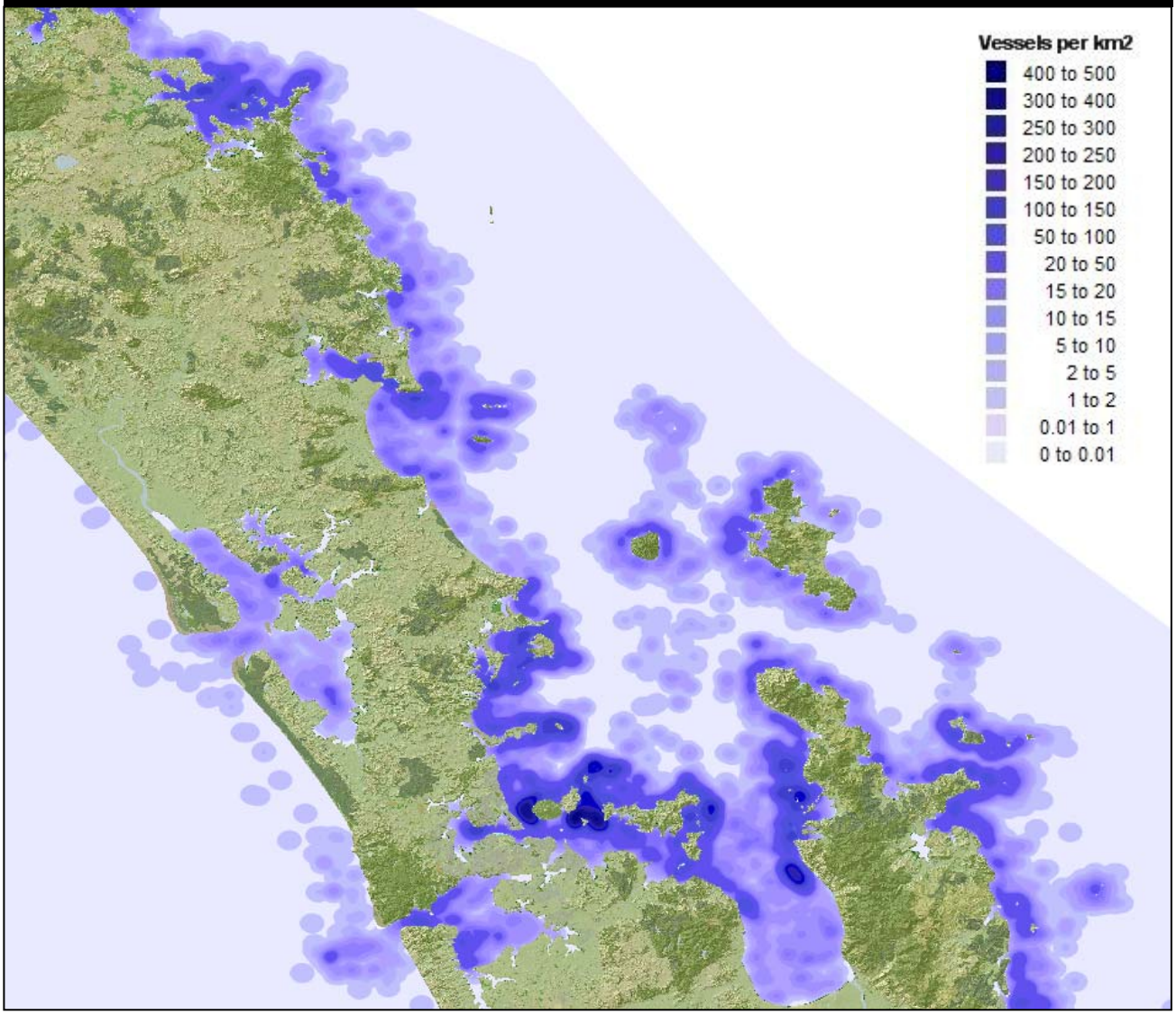
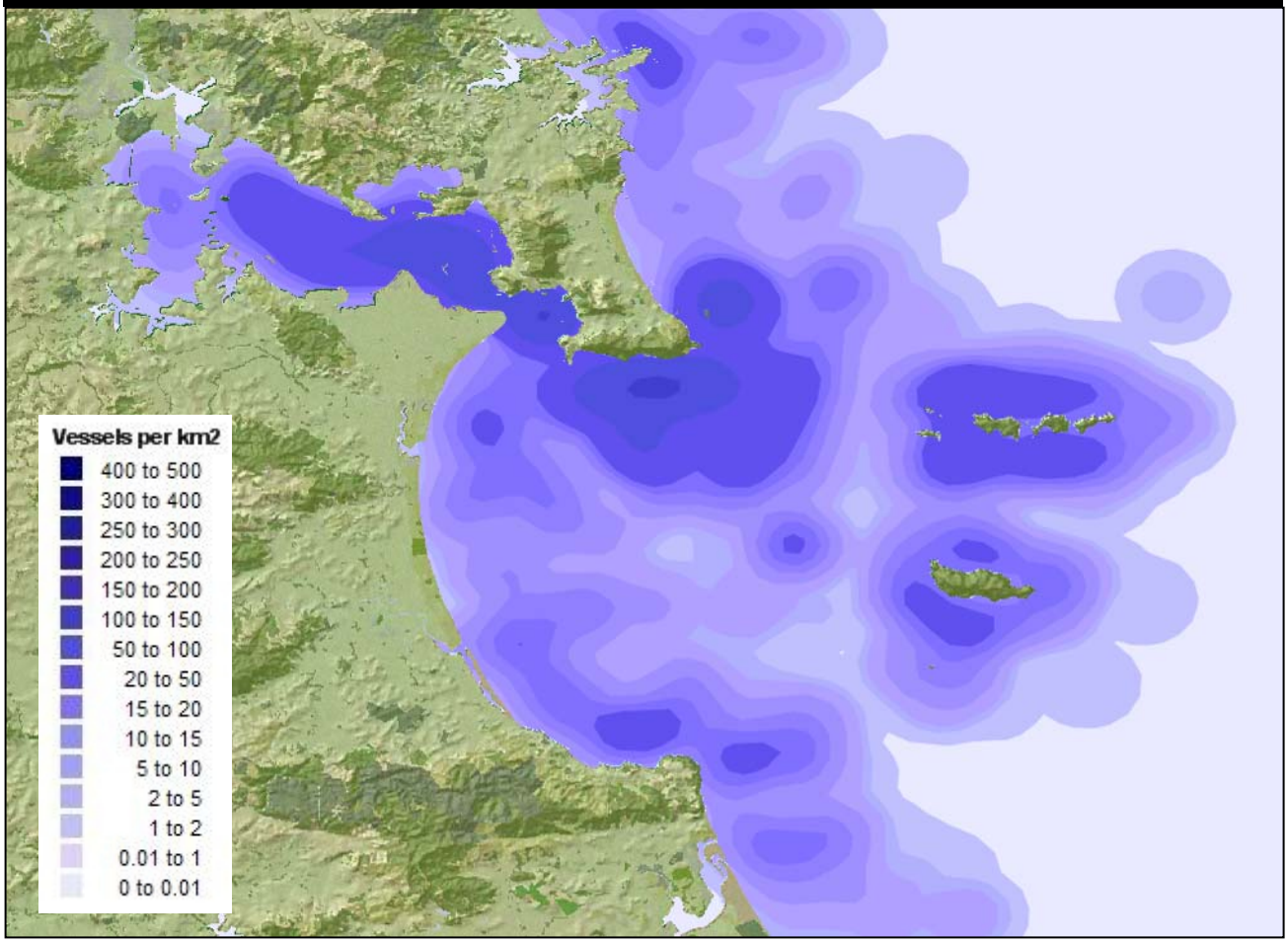


Figure 21: Recreational fishing effort in the study area. MPI NABIS data



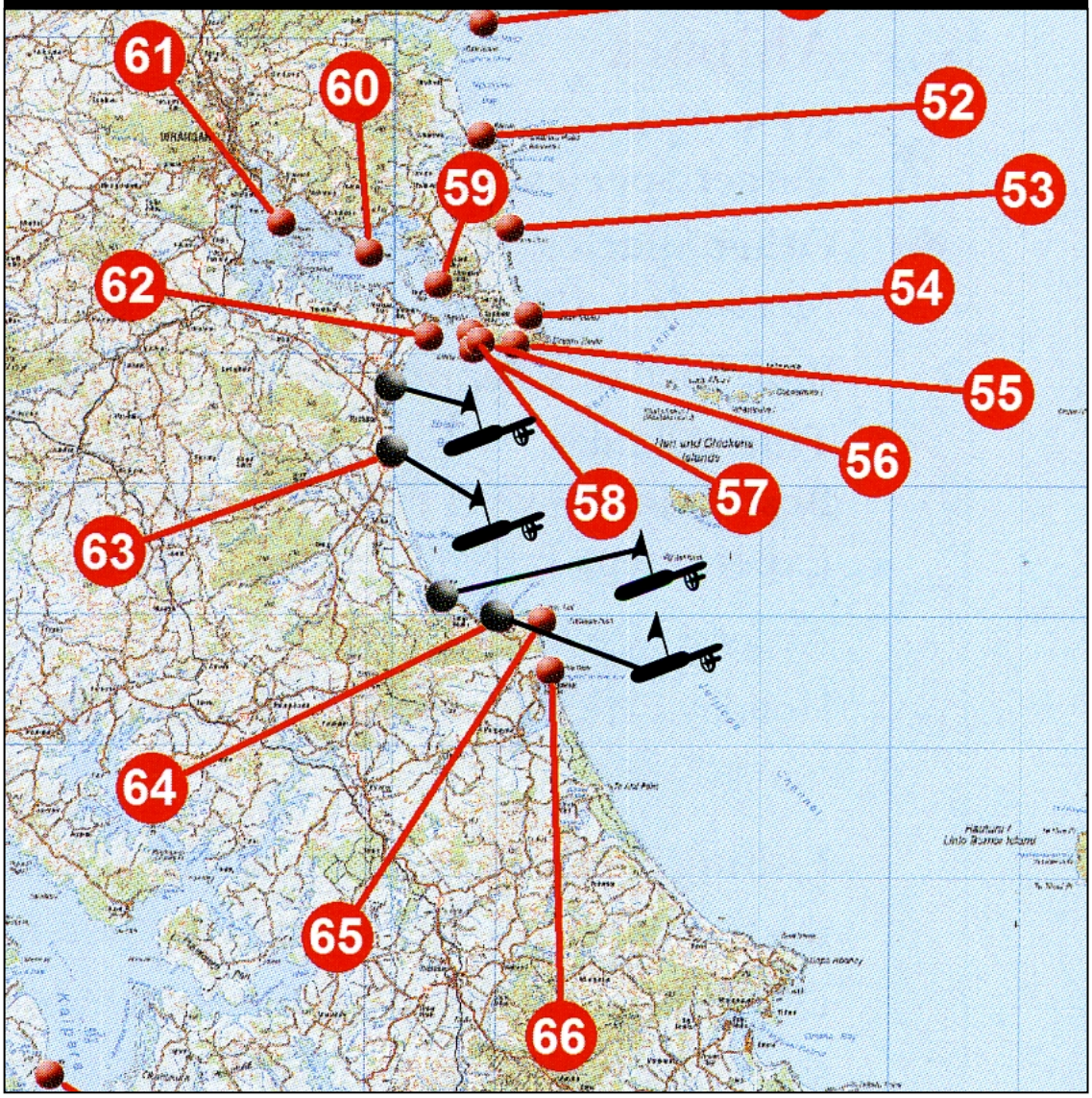
area for snapper, john dory, kingfish, trevally, kahawai and baitfish. Airey (2012) notes (p59):

> *Whangarei, Tutu kaka and the surrounding districts are noteworthy for being extraordinary fishing destinations, including excellent harbour fishing (particularly Whangarei Harbour) along with surf, rick, boat and big-game fishing.*

Reviewed sites 8 (Snake Bank Channel) and 9 (Bream Islands) in Appendix 3 are described as best fished in November and 'all year' respectively.

Figure 22 shows surf casting opportunities at (by marked number): 54 – Ocean Beach (snapper, kahawai, kingfish and trevally, autumn and winter); 55 – Peach Cove (snapper, john dory, kahawai, kingfish and trevally, autumn and winter); 56 – Smugglers Bay (snapper, kahawai and trevally, all year); 57 – Busby Head (snapper, kahawai and trevally, all year); 58 – Home Point (kingfish, kahawai, mackerel snapper and trevally, autumn and summer); 59 – McLeod Bay Jetty (baitfish, kahawai, kingfish, snapper and trevally, all year); 60 – Manganese Point (snapper, mackerel and trevally, all year); 61 – Onerahi Wharf (kahawai, john dory, kingfish snapper and trevally, all year); 62 – Marsden Point (Snapper, kahawai and trevally, autumn); 63 – Uretiti Beach (snapper, gurnard, kahawai and trevally, autumn and summer); 64 – Langs Beach (snapper, kahawai, kingfish and trevally, all year).

Figure 22: Surfcasting guide recommendation, Draper & Airey (2012)



Fishing competitions in the study area include:

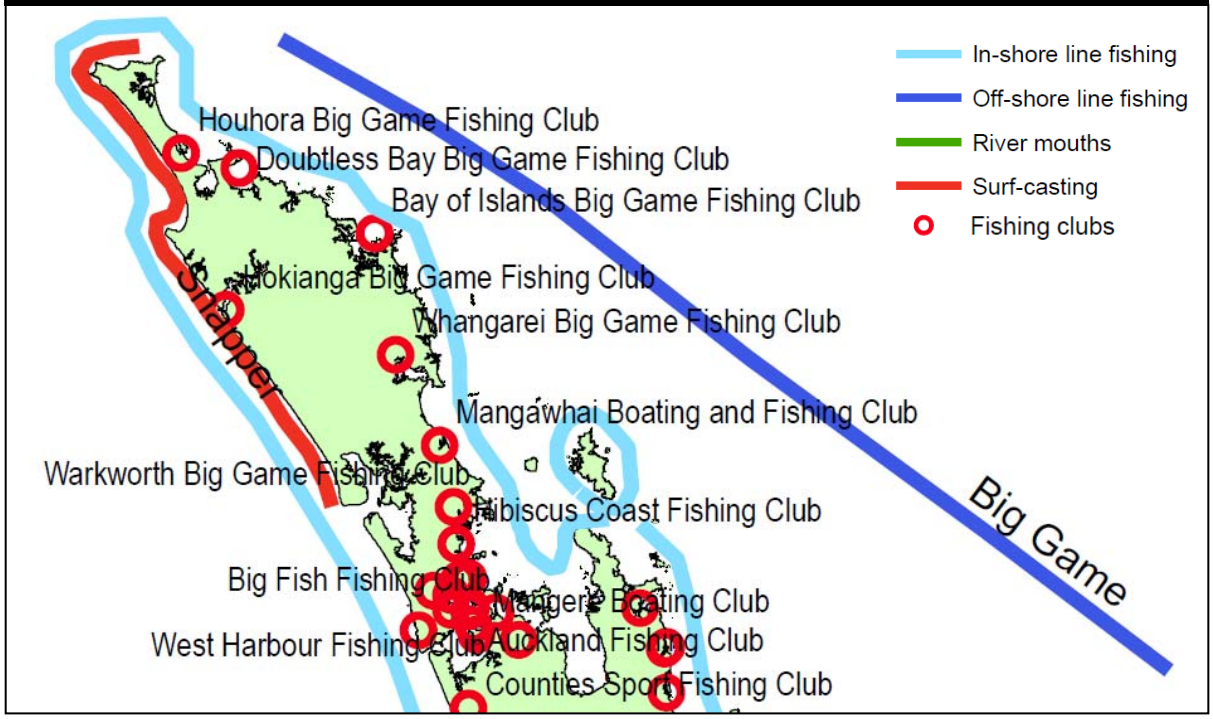
- Beach and Boat – February – based out of the Marsden Cove Marina[9]
- Orton Events New Zealand Northland Cove to Cape Kayak Fishing Challenge out of Whangarei Harbour – August[10]
- Funky Fishing Family Fishing and Diving Competition at Whangarei Heads – March[11]
- Tutukaka Light Tackle Yellowtail Kingfish Tournament – June[12]

Eight fishing clubs are identified on the 2CU online database, each of which is likely to operate fishing competitions.[13]

Allen *et al* (2009) identified in-shore and off-shore line fishing in the study area, but no surf-casting (Figure 23).

[9] http://www.beachandboat.co.nz/info/
[10] http://ortoneventsnz.co.nz/2015/cove-to-cape/index.php
[11] http://funkyfishing.co.nz/
[12] http://www.sportfishing.co.nz/Dynamic.aspx?id=11900
[13] http://2cu.co.nz/northland/listings/find/fishing%20clubs/whangarei

Figure 23: Recreational line fishing locations and fishing clubs from Allen *et al* 2009



4.3 Shellfishing

Airey (2012) shows in the charts in Appendix 3 many shellfish gathering sites in the study area. These include pipi and scallops around Snake Bank, pipi at Marsden Point and at Mair Bank, and scallops to the north of Urquharts Bay, south of Home Point, in Smugglers Bay and offshore from Langs Beach. Additional diving sites for scallops are identified in Enderby & Enderby (2007) (see section 4.4), including: Bream Head Boulder Bank; Peach Cove; Smugglers Cove; within Whangarei Harbour; and Bream Bay.

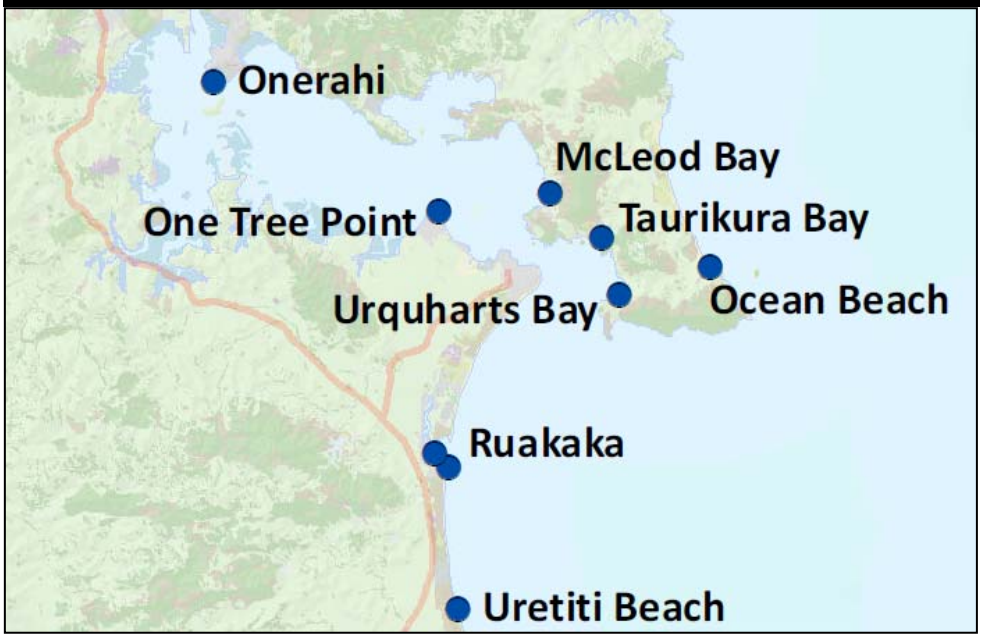
The NRC carries out an annual faecal coliform testing regime for recreational shellfish gathering at 23 sites in the Whangarei District. The sites within the study area are listed below and for the Harbour in Figure 24[14], with an indication of whether they passed or failed the relevant MfE water quality standards over the 2015/16 season:[15]

- Langs Beach (fail)
- McLeod Bay (pass)
- One Tree Point (pass)
- Onerahi (pass)
- Ruakaka Beach near surfclub (pass)
- Taurikura Beach (pass)
- Uretiti Beach (pass)
- Urquharts Bay (pass)
- Waipu Cove (pass)

[14] http://www.nrc.govt.nz/contentassets/76e6569bd9524f2b96558dd186f941b1/swimming-sites-map-2016-2017.pdf retrieved January 2017
[15] http://www.nrc.govt.nz/contentassets/a5411dade42c494cafbae094e186efab/summary-of-shellfish-gathering-results-2015-16.pdf retrieved January 2017

Ocean Beach was monitored prior to the 2015/16 season. Species gathered at these sites are not identified. Other shellfishing sites identified by the NRC are shown in Figure 14 on page 26.

Figure 24: NRC water quality monitoring sites 2016/17, Whangarei Harbour



The Northland Harbour Board (1989) noted (p113):

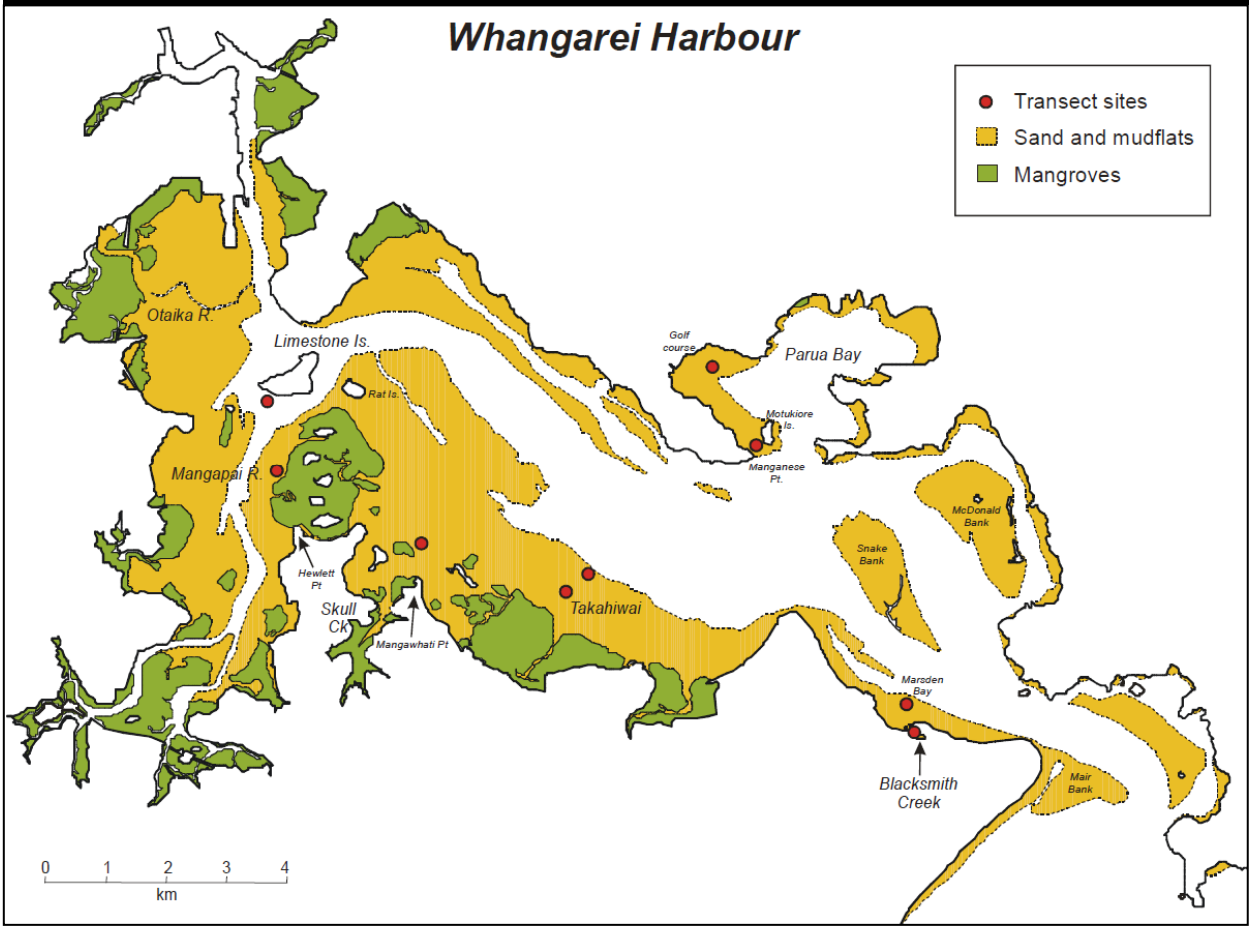
> *A variety of shellfish are gathered recreationally within the harbour. Cockles are scattered throughout the lower harbour and beds are found at Snake Bank, McLeod Bay and to a lesser extent in Parua Bay. Small beds of pipi also occur in harbour bays but the most popular area for gathering pipi is Mair Bank where large pipi are found in high densities.*

Cummings and Hatton (2003) of NIWA report on a reseeding assessment for pipi and cockles in Whangarei Harbour for the NRC. Figure 26 shows the sites considered suitable in their assessment for shellfish reseeding (the transect sites). The NIWA assessment identified two sites for cockles (Skull Creek and the Takahiwai mid-shore area) and a potential site for pipi (outer Skull Creek).

The authors noted (p iv):

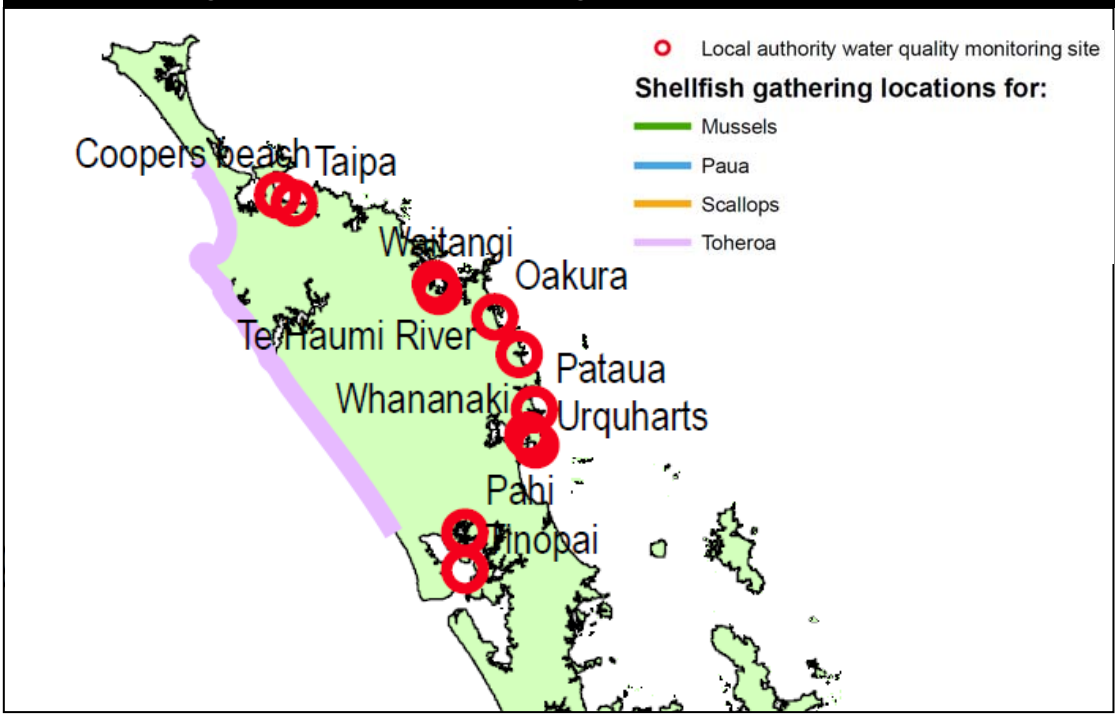
> *The areas visited are good examples of their present habitat type, with a good diversity and abundance of shellfish and other fauna present, and an abundance of bird life. However, old reports and discussions had during the course of this study indicate that some areas now have very different habitats compared to that of many years ago. Unfortunately, these habitat changes mean that cockles and pipi are unlikely to grow as large or be as abundant in these places as they were in the past.*

Figure 26: Sites assessed for suitability of future shellfish reseeding in Cummings and Hatton (2003)



Allen et al (2009) identifies no shellfish gathering sites on the east coast of Northland (Figure 25).

Figure 25: Recreational shellfishing locations from Allen *et al* 2009



Coffey (2017) reports the most recent data on shellfish abundance on Mair Bank and the Harbour (p27):

> *The most recent study commissioned by RNZ is by Pawley (2016) who reported that:*
>
> - *the bathymetry of Mair Bank appears to have changed since the 2010 and 2014 surveys. Mair Bank is no longer separated from neighbouring Marsden Bank by a channel, and the northern edge now extends further (compared to 2014). This view is supported by Williams and Hume (2014),*
> - *both the total abundance and biomass of pipis have reduced significantly since his 2010 survey. The total population has declined from around 460 million (2010) to around 4.95 million individuals, and the 2016 estimate of absolute biomass, 44.7 t, is around only 1% of the 2010 estimate (4,450 t) and less than 1% of the 2005 estimate (10,542 t).*
>
> *Between 1986 and 2010, the average commercial landings of pipi from Whangarei Harbour was 176.6 tonnes per annum (Report from the Fisheries Assessment Plenary, May 2014). It is now non-existent (Pawley, 2016). This report did not consider cockle populations.*
>
> *In recent years, an expanding bed of green-lipped mussels (Perna canaliculus) has established on Mair Bank (Pawley, 2016 and pers. comm. Riaan Elliot, Refining NZ).*
>
> *Moreover, seagrass beds at One Tree Point are currently recovering from a former dieback event (NIWA, 2004, 2005), so it is important to benchmark these changes that are not associated with the proposed dredging programme.*

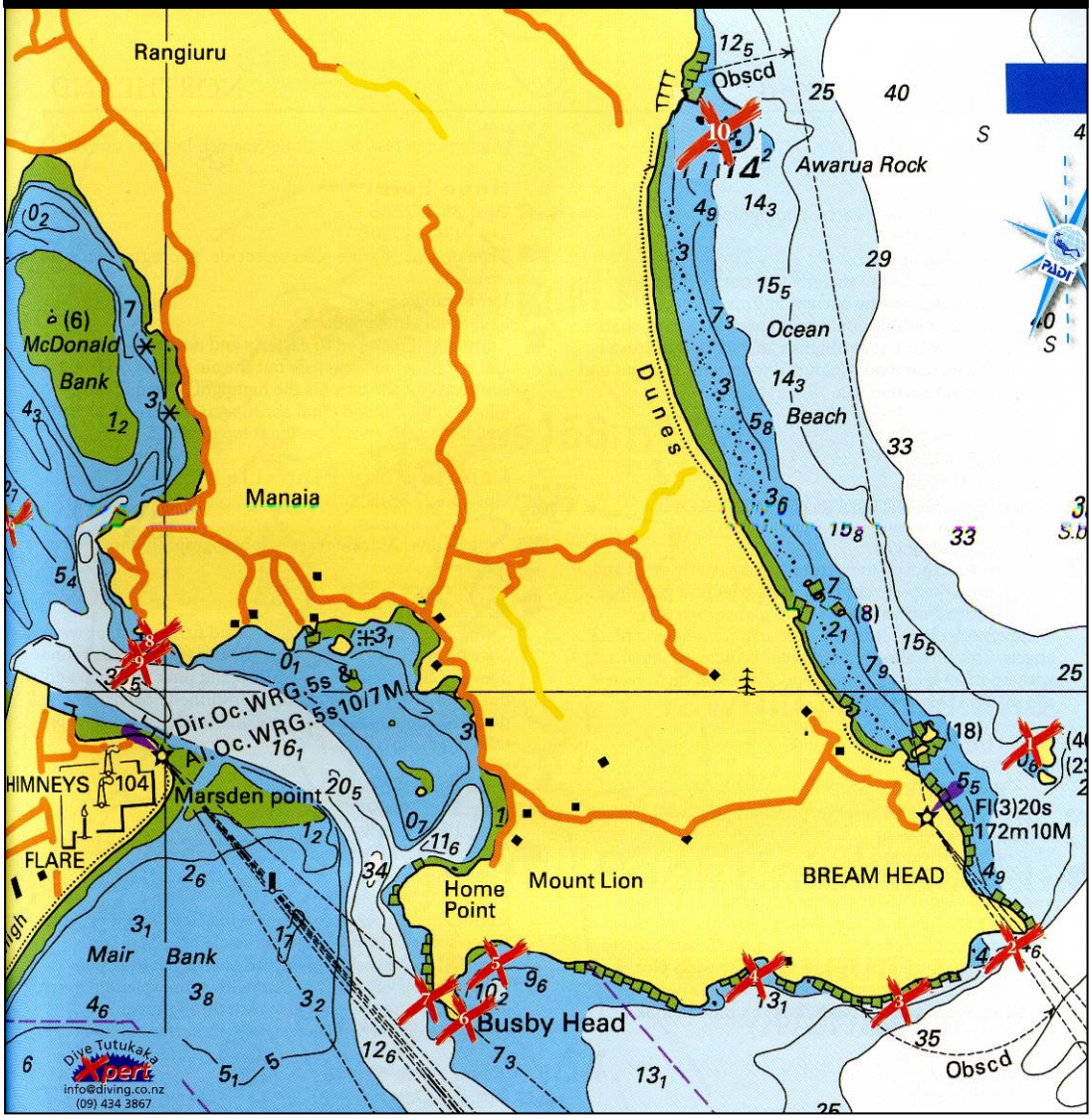
4.4 Diving

Figure 27 shows the recommendations for diving in and around the Whangarei Heads from Enderby & Enderby (2007). The numbered sites are, from the north and then anti-clockwise: 10 – Awarua Rock (crayfish, snorkelling, wall); 1 – Bream Islands (crayfish, spearfishing, wall); 2 – Bream Head (crayfish, wall); 3 – Bream Head Boulder Bank (crayfish, scallops, snorkelling); 4 – Peach Cove (crayfish, scallops, snorkelling); 5 – Smugglers Cove (crayfish, scallops, snorkelling); 6 – Busby Head (crayfish, spearfishing, wall); 7 – The Frenchman (crayfish, scenic, wall); 8 – Motukaroro South (marine reserve, photographic, wall, snorkelling); 9 – Motukaroro Northeast (marine reserve, photographic, snorkelling); 10 (hard left of figure, in page binding) – Whangarei Harbour (scallops). No sites are shown in the Harbour west of those shown in Figure 27. Dive depth ranges from zero to 30 metres. Water clarity issues are only identified for site 10 within Whangarei Harbour ("Strong current and poor visibility"). Boat traffic warnings are given for sites 4 to 10 (Whangarei Harbour).

Dive sites near Bream Tail are shown in Figure 28: 1 (on left edge) – Bream Bay (scallops, noting "Not much fish life, apart from occasional stingray and gurnard."); 2 – Waipu Cove (crayfish, spearfishing, snorkelling); 3 – Langs beach (crayfish); 4 – Bream Tail (crayfish).

The Northland Harbour Board (1989) noted (p113):

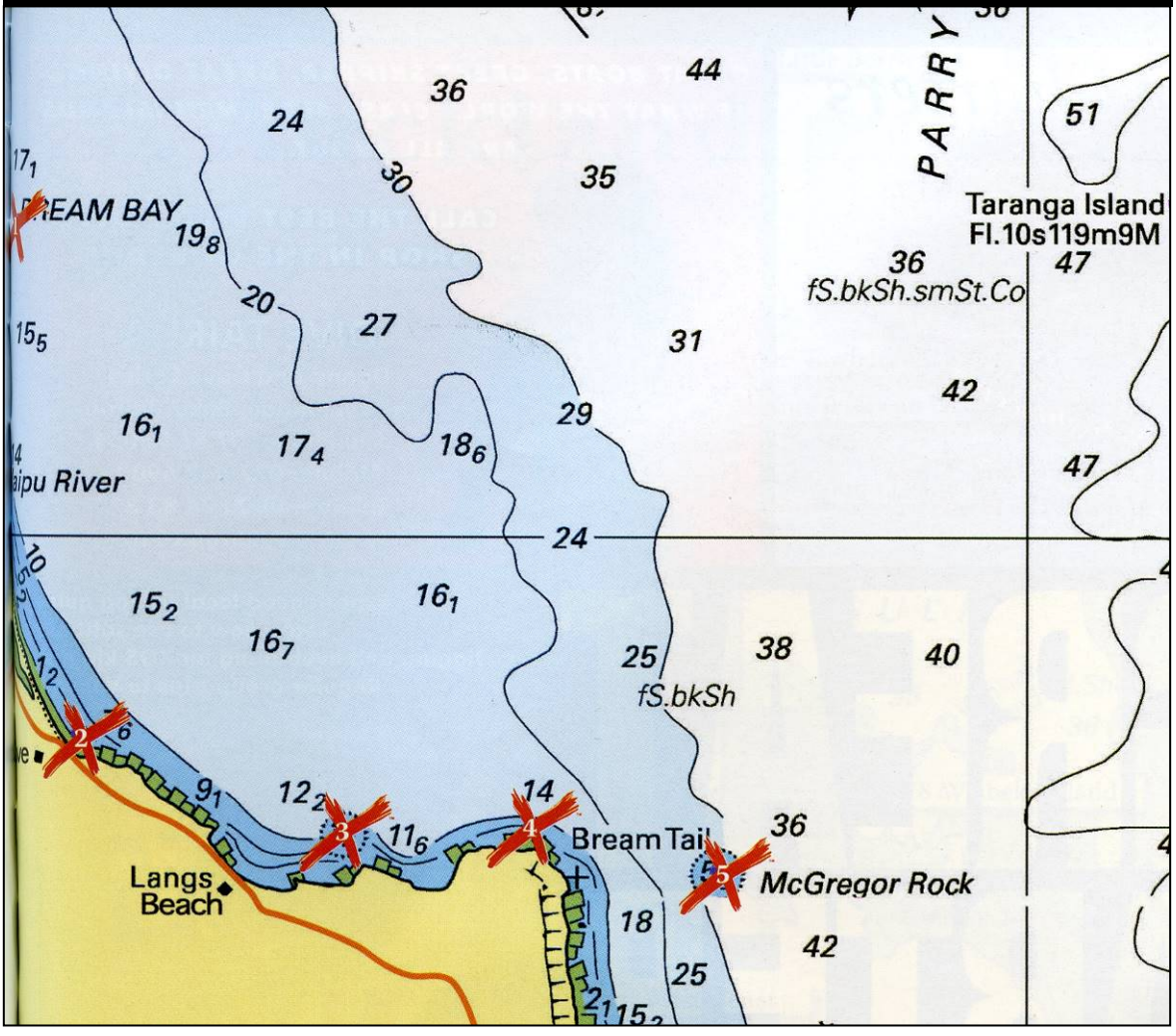
Figure 27: Diving recommendations near Bream Head, Enderby & Enderby (2007)



The most popular areas for recreational diving in the Whangarei Harbour are the northern shores near the harbour entrance. In these areas, particularly McLeod Bay, Urquharts Bay, Woolshed Bay and Smugglers Bay, scallops are found. This scallop resource is subject to heavy pressure from divers during the scallop season, which currently extends from approximately mid-July to mid-February. Large numbers of boats are launched from Urquharts Bay or McLeod Bay and divers also snorkel or dive from the shore. Due to the swift tidal currents at the harbour mouth, most diving takes place around the turn of the tide.

With the exception of scallop areas, there is very little scuba diving within the harbour. Occasional night dives take place under the Northland Harbour Board's Marsden Point wharf organised by the Whangarei Underwater Club. The major use of the harbour by dive groups is as a base from which to conduct excursions to dive spots such as the Hen and Chicken Islands . However, the coast between Smugglers Bay and Bream Head is used as an important diving area by local divers. This area provides exciting underwater scenery, scallops, crayfish and pelagic fish and thus appeals to all categories of divers from photographers to crayfish hunters and spear fishermen.

Figure 28: Diving recommendations near Bream Tail, Enderby & Enderby (2007)



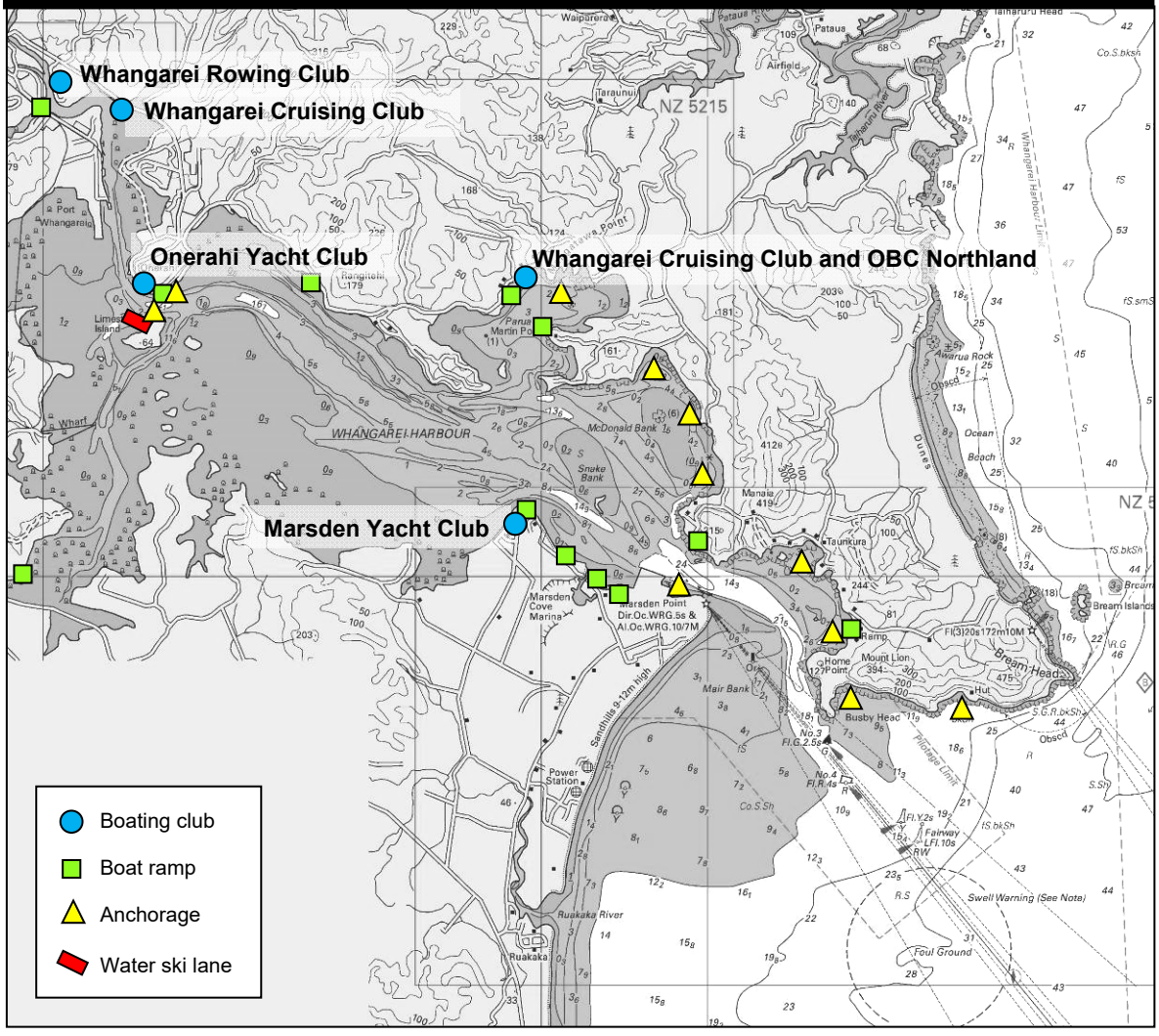
4.5 Boating

Figure 29 shows:

- Casual boat anchorages in the study area identified in *The Royal Akarana Yacht Club Coastal Cruising Handbook* (RAYC 2012). Those within Whangarei Harbour are generally identified as reliable in most conditions. Those at Smugglers Bay and Peach Cove are described as open to southerly swells (pp106 – 117).
- Boat launching ramps identified by the WDC and NRC.[16] A ramp off the map but within the study area is available on the Waipu River on Nova Scotia Drive.
- Water ski lanes (only one at Limestone Island) identified by the NRC and provided for in the NRC Navigation Safety Bylaw 2012.[17] (Northland Harbour Board (1989) described three ski lanes in the Whangarei Harbour in 1989: Limestone Island, Marsden Bay and Urquharts Bay.)
- Four boat clubs.

Mooring areas are identified in the *Operational Regional Policy Statement for Northland* planning maps in Appendix 1 to this report. Two marinas are located in the Harbour Basin

Figure 29: Anchorages, boat clubs and boat launching around Whangarei Harbour

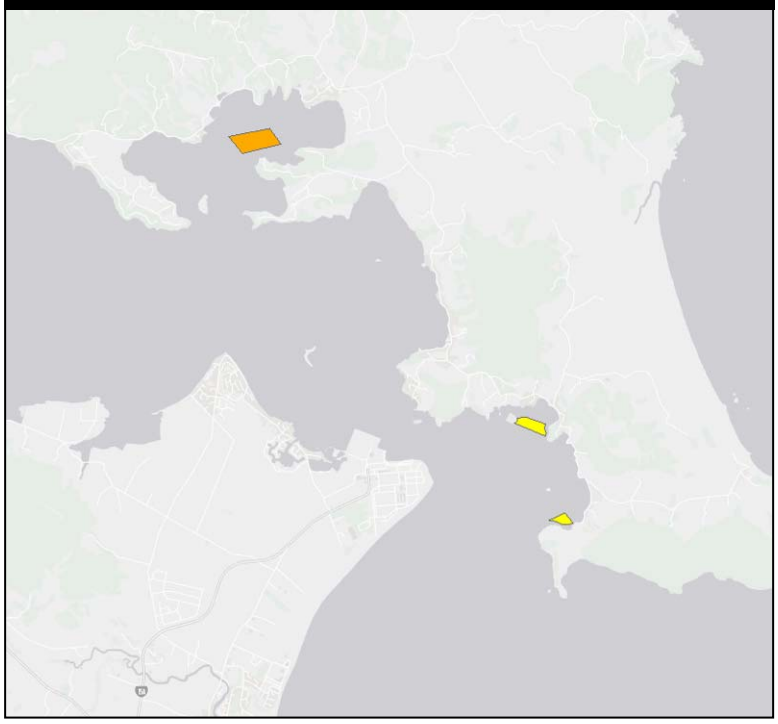


[16] http://www.nrc.govt.nz/Maritime/Boat-ramps-and-maps/#whangarei and http://www.wdc.govt.nz/FacilitiesandRecreation/Beaches-and-Coastal-Facilities/Pages/Default.aspx
[17] http://www.nrc.govt.nz/Resource-Library-Summary/Publications/Coast/Navigation-Safety-Bylaw-2012/Access-Lane-Maps/#whang

(Whangarei Marina and Riverside Drive Marina) and in Marsden Bay (Marsden Cove Marina).

The *Draft Regional Plan for Northland* (August 2016) proposes two regionally significant recreational anchorages in Taurikura and Urquharts Bays and one regionally significant storm anchorage in Parua Bay (Figure 30).

Figure 30: Draft Regional Plan regionally significant moorings



The Northland Harbour Board (1989) noted (p118):

> *The Northland Canoe Club uses the longer reaches of the upper harbour for training purposes, particularly the area from Kaiwaka Point to Kissing Point. When there is a high tide or the Hatea River is in flood, the upper Hatea River is also used. The Whangarei Rowing Club uses the same area for its activities. The group, which consists mainly of secondary school students, has a clubhouse on Northland Harbour Board land adjacent to the Pohe Island landfill.*
>
> *Sea scouts also use the harbour regularly. The Onerahi Sea Scout group has a clubhouse on Northland Harbour Board land near the foreshore at Stevens Point. The group has two boats, although their use is sometimes restricted by the exposure of the area to wind and tide conditions. Further upstream are the Shackleton Sea Scouts who have a scout den on Northland Harbour Board land near Orams Marina. Both sea scout groups take part in regattas in Parua Bay. The equivalent girls' group is the Young Mariners Club which currently uses the Whangarei Cruising Club clubrooms at Kissing Point*

The Northland Canoe Club remains active in the Harbour:[18]

> *Northland Canoe Club holds regular paddles on the Whangarei Harbour and around Northland's beautiful coastline. The most regular paddle is held on Wednesday evening, leaving form the public boat ramp next to the Onerahi Yacht Club.*

As are the Shackleton Sea Scouts (various weblinks).

The Northland Harbour Board (1989) noted (p119):

> *Windsurfing is becoming increasingly popular as a recreational activity in the harbour, particularly in the vicinity of Onerahi and at Parua Bay. There are approximately 25 members of the Whangarei Boardsailing Club, who organise races at Onerahi and also take part in the combined yacht clubs race series. The Onerahi area is not considered ideal for windsurfers especially for beginners, due to problems with mud at low tide and strong tidal flows. However, members use the area in preference to the more sheltered Parua Bay, because of its more*

[18] https://www.facebook.com/pages/Northland-Canoe-Club/165129820303461?sk=info&tab=page_info

central location to the City. The club has no club facilities and members use the public toilets along the Onerahi foreshore as changing facilities.

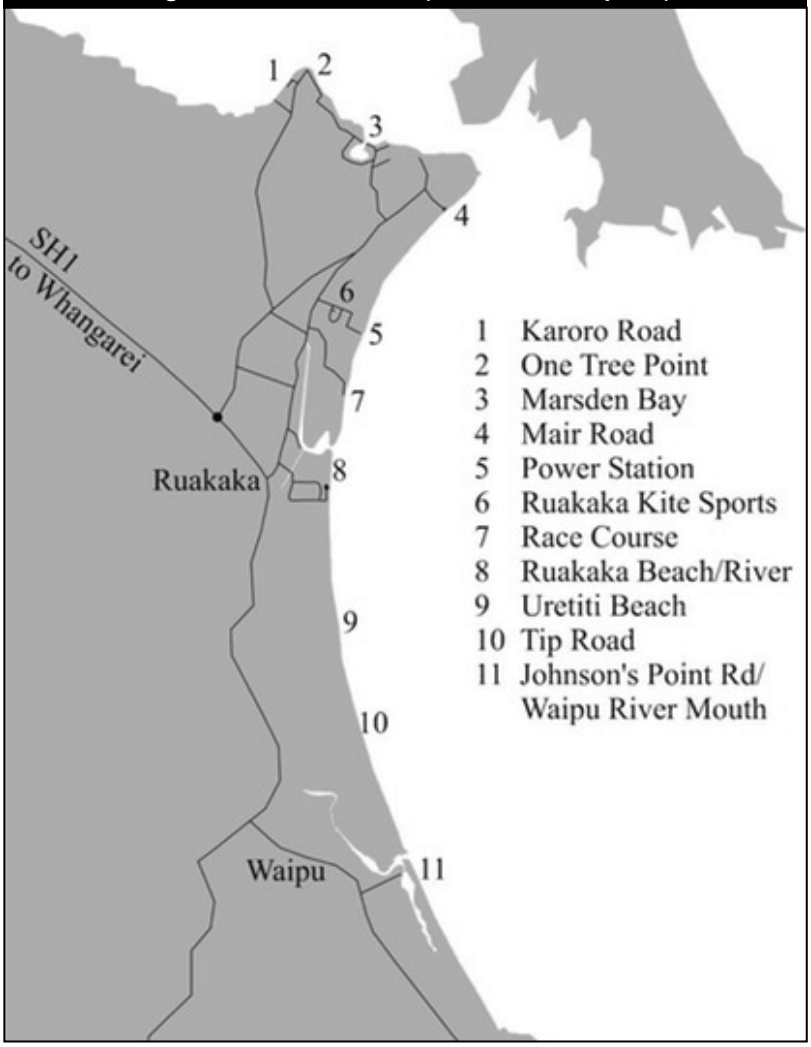
Windsurfing New Zealand identifies three sailing sites in the Harbour (Figure 31) – One Tree Point (1), Onerahi (2) and Bream Bay (3).[19]

Ruakaka is described as a 'kitesurfing paradise', and a commercial operator (Ruakaka Kite Sports) recommends the 11 kite sites shown in Figure 32. Full details for the use of each site is provided on the company's website.[20]

Figure 31: Windsurf sites



Figure 32: Kitesurf sites (Ruakaka Kite Sports)



[19] http://www.winzurf.co.nz/windsurf/wgtnz/wgtnz11.htm
[20] http://www.ruakakakitesports.co.nz/where-to-kite.html

4.6 Surfing

The NZ Coastal Policy Statement (DOC 2010) does not identify any surf breaks of national significance in the study area (three such sites in Northland are on the west coast).

The *Wavetrack New Zealand Surfing Guide* (Morse & Brunskill 2004) identifies a number of surfing sites between Ocean Beach and Bream Tail (Figure 33 and Figure 34). The scale on Figure 34 shows the authors' assessment of the quality of the surf when it is running at each site. The text for Marsden Point notes "Find longer waves and walls after harbour dredging". It is unclear to what this refers considering that the nearest dredging occurs at Northport in the upper Harbour. Section 5.2.2 of this report considers wave effects from the Project.

The comprehensive online surf information service 'surf-forecast.com' offers information on the same sites. It describes the Ocean Beach break's reliability as 'fairly consistent', and Marsden Point as 'inconsistent'.

The *Draft Regional Plan for Northland* proposes all these breaks as regionally significant (Figure 36).

Figure 33: Whangarei area surf breaks (Morse & Brunskill 2004)

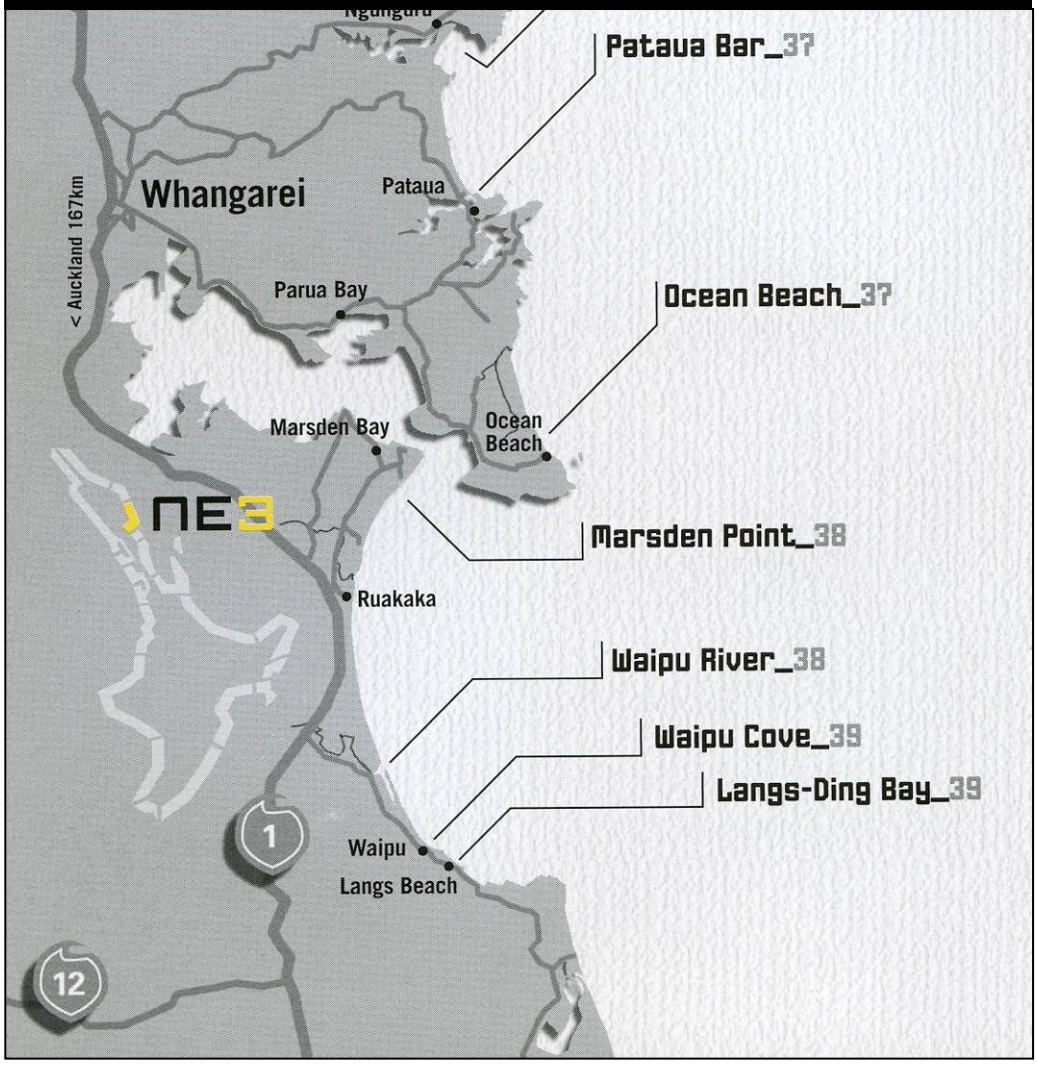


Figure 34: Surf break details (Morse & Brunskill 2004)

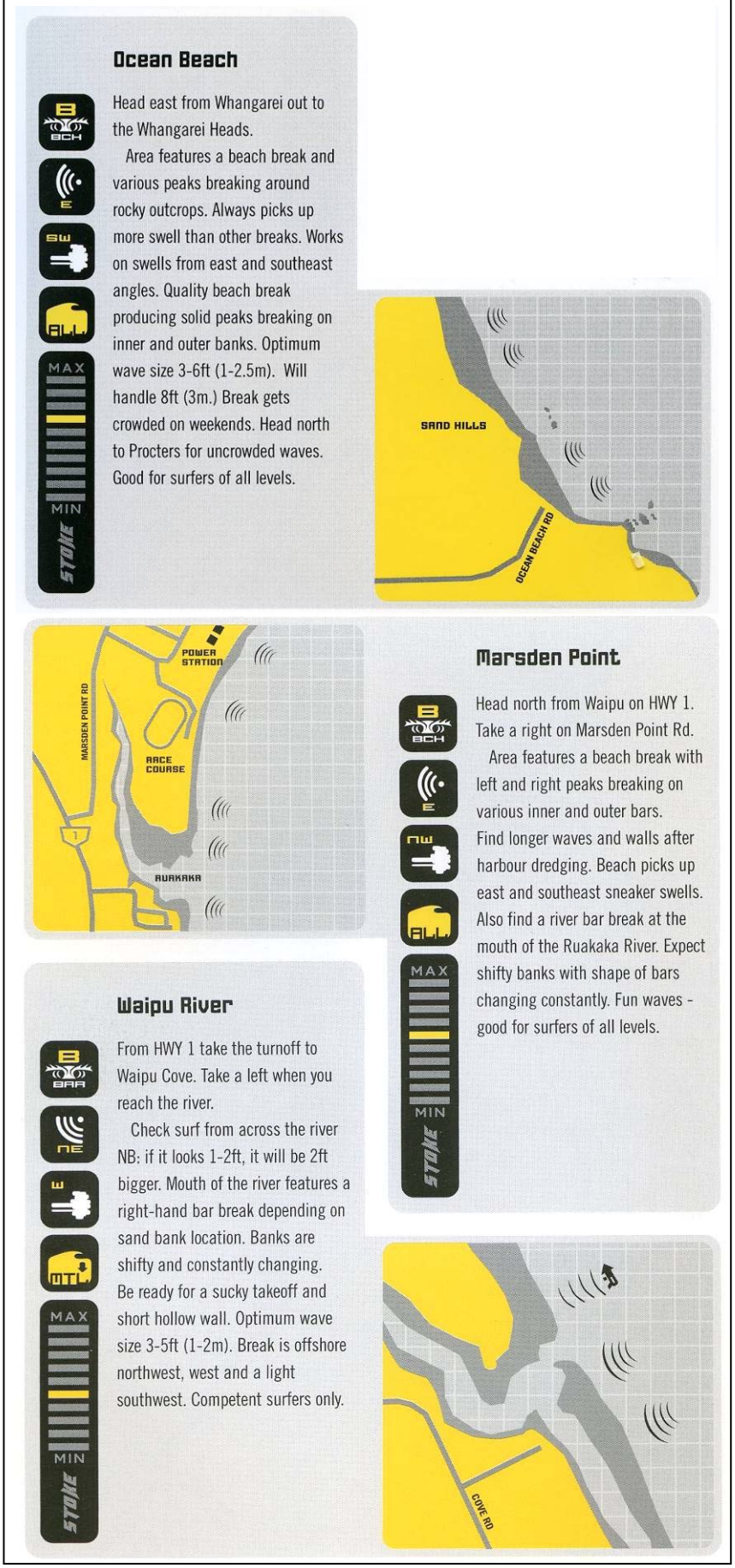


Figure 35: Surf break details (Morse & Brunskill 2004)

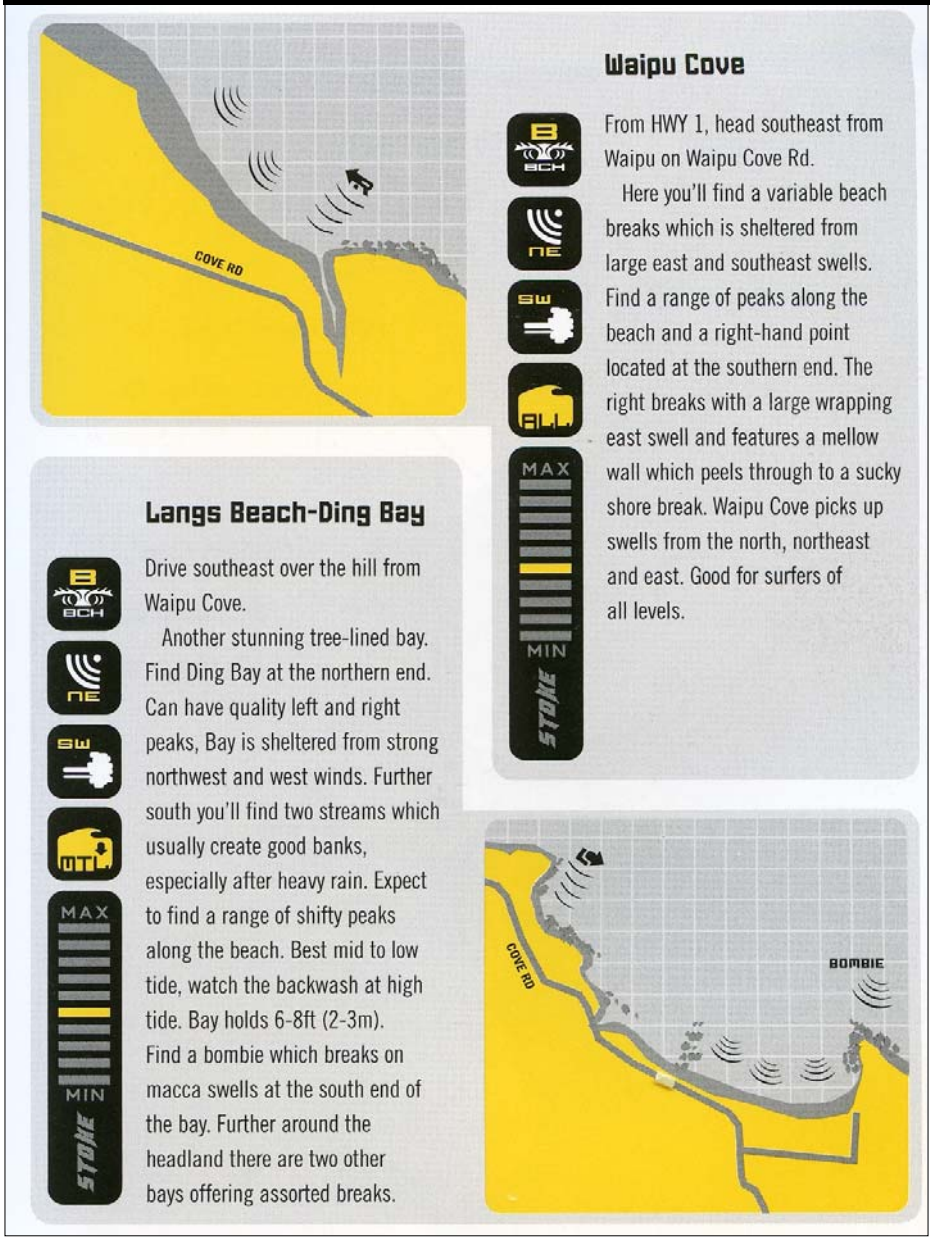
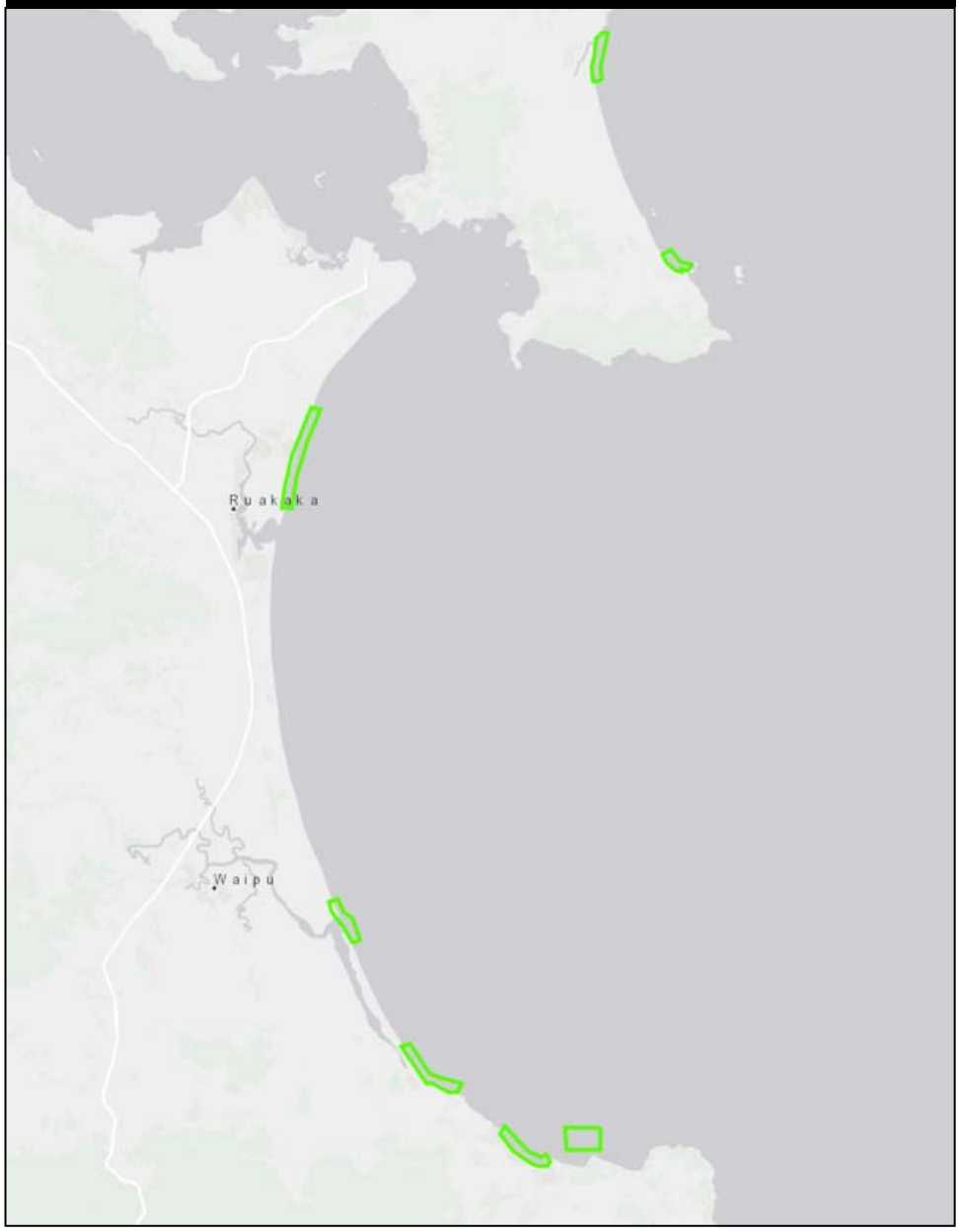


Figure 36: Regionally significant surf breaks – Draft Regional Plan for Northland



4.7 Tourism and commercial marine recreation

The Ministry of Business, Innovation and Employment has upgraded is methodology for its Domestic Visitor Survey and International Visitor Surveys and specific activity participation data for the two markets are no longer provided at the regional level.

At the national level, water-based activities are some of the most popular. Unfortunately, the relevant data are not subdivided by marine and freshwater settings. This means that while 4% of domestic tourism trips included swimming in 2012 (that is, 1.68 million domestic 'trips' included swimming as an activity), this includes swimming in pools, rivers, lakes and the sea. Fishing, with 3% participation for domestic tourists (1.41 million 'trips') similarly includes trout and salmon as well as purely marine species. Boating (marine and fresh) was carried out on 517,000 trips (1.1% of all trips) and dolphin watching was enjoyed on 41,104 'trips' (0.09%). Dining (31%), visiting friends and relatives (21%) and shopping (21%) are the prime domestic tourism activities.

International tourists undertake more activities than domestics, with, for example, 92% of visitors dining and 80% shopping in 2013. Boating (marine and fresh) was undertaken by 23%, swimming by 12%, bird watching by 7%, and fishing and dolphin watching by 5%.

In Whangarei, several providers of tourism and commercial recreation activities can be located online, including:

- A-Oakura Fish Dive & Cruise
- Bream Bay Charters on CARA*J
- Cronin Fishing Charters
- Marsden Cove Fishing Charters Ltd
- El Pescador Charters
- Lady Jess Charters
- Oceandivesity Sea Adventures
- Whangarei Harbour Cruises

No references to cruise ship activity in Whangarei has been located, although there are online references indicating a desire to see them visiting the Harbour in the future:

> **Northern Advocate Oct 6 2012**[21]
>
> *Mr Jongejans* [chairman of Northland Tourism Development Group] *said Whangarei needed to get in on the "fantastic" cruise-ship industry: "Something like 40 per cent of cruise-ship passengers will come back on another, longer visit, to spend more time here."*
>
> *Though there was nowhere for the ships to berth in Whangarei at the moment, in future they could be put on a new berth at Marsden Pt and passengers taken around the district by bus or smaller boat.*
>
> **Northern Advocate Sept 22 2014**[22]
>
> *Dr Reti* [MP for Whangarei] *said he also wanted to get a slice of the cruise ship repair industry for Whangarei.*
>
> *"We've got $24 million worth (of cruise ship repairs) that are just sailing past to New Plymouth or elsewhere and while I don't want to take work from other parts of the country, I want to grow that industry so that we get a slice of the pie in Whangarei. We built the navy frigates here and have an extensive history of ship building in Whangarei and we can do it." he said….*
>
> *He would eventually like to see cruise ships stop at Marsden Pt, but first Whangarei needed a major attraction to take cruise ship passengers to.*
>
> *"We need a major attraction first, but what that is up to the council and public to decide. I don't care if it's something like the Hundertwasser Centre or the (proposed Hihiaua) Maori Cultural Centre, but once it is decided on I will help get Government support for the council's plans."*

[21] http://www.nzherald.co.nz/northern-advocate/news/article.cfm?c_id=1503450&objectid=11077392
[22] http://www.nzherald.co.nz/northern-advocate/news/article.cfm?c_id=1503450&objectid=11329210

4.8 Hunting

Wildfowl hunting is identified in Northland Harbour Board (1989) at Skull Creek, Mangapai River and Otaika Creek (p119). Manning (2001) notes (p216):

> *About 5770 hectares (80%) of the* [Whangarei] *harbour area is designated as Wildlife Refuge, which prohibits hunting and deliberate disturbance to wildlife, but does not restrict public access.*

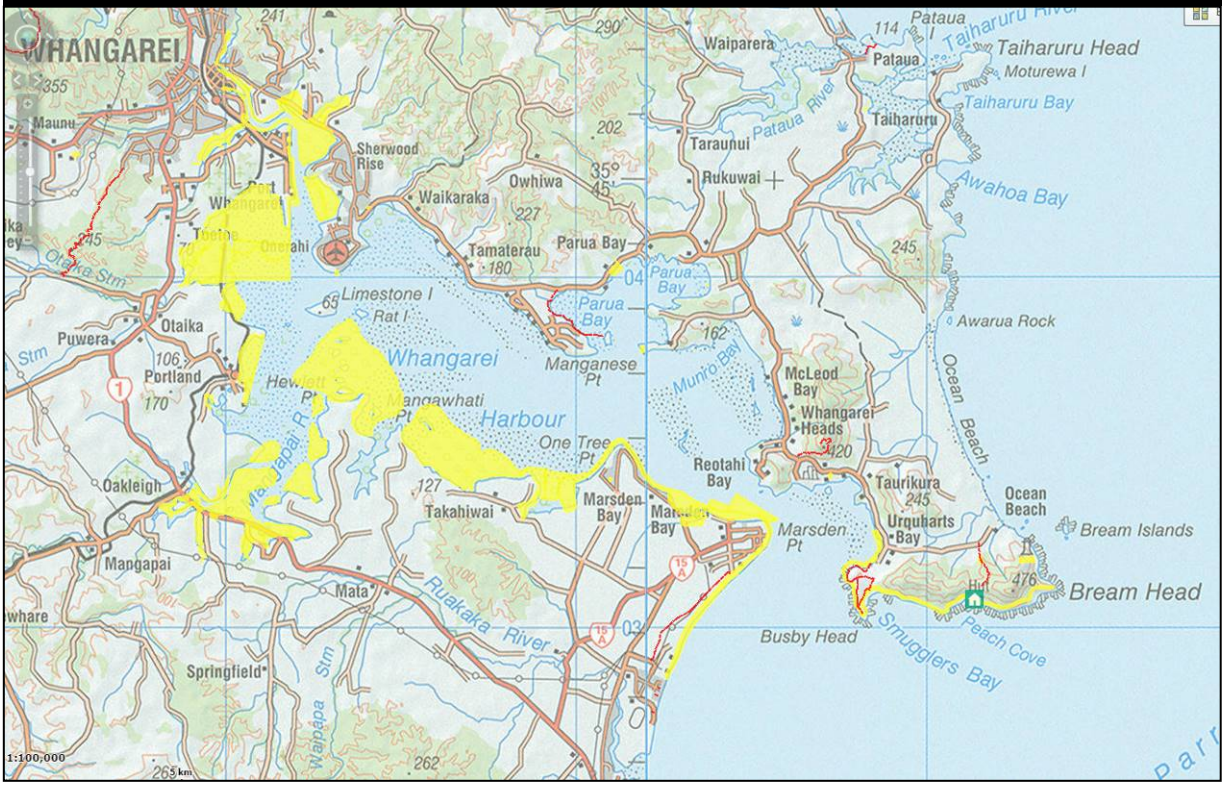
A definition of the refuge boundaries is not available online. Pierce (2005) describes the whole harbour as a wildlife refuge (p1). Refuges are also located at Ruakaka and Waipu.[23] There are no references to hunting on the Whangarei Harbour on the NZ Fish and Game Council website.

4.9 Terrestrial recreation and access

The Walking Access Commission's online Walking Access Mapping System (WAMS) describes the public access opportunities in the study area (Figure 38, next page).[24] These recreation opportunities are largely the same as those reviewed in section 3 of this report (with lands administered by DOC and WDC).

The WAMS system identifies extensive areas of 'Crown Land' in Whangarei Harbour and around Marsden Point and Bream Head (Figure 37). The status of these areas for public access will depend upon which government department manages them (if that is the case), for what purpose, and whether there is any lease or licence to occupy in place.

Figure 37: Crown Land (yellow) around Whangarei Harbour. Source: WAMS



[23] See here for a discussion about conflicts with kite surfers: http://www.doc.govt.nz/about-doc/news/media-releases/2009/kite-boarding-activity-in-ruakaka-wildlife-refuge/
[24] http://wams.org.nz/

Figure 38: Public access around Whangarei Harbour and Bream Bay excluding legal roads. Source: WAMS



5 Assessment of effects

This section results in the identification of likely adverse effects on recreation potentially caused by the Project, and a review of possible mitigations. This is based on:

- An identification of all potential adverse effects on recreation amenity (identified via parallel technical assessments and the consultation process),
- A review of the technical reports which assess those effects, and the identification of the scale and relevance of each effect,
- A summary of the effects which have the potential to change recreation amenity,
- A discussion of the scale of those effects and their potential for mitigation.

5.1 Potential adverse effects

The following potential effects of the proposal are of interest to recreation. Effects are considered for: dredging and spoil disposal periods ('construction and maintenance'); and for the ongoing effects resulting from the modified marine settings ('operation'). These potential effects and the relevant recreation activities are summarised in Table 1.

Construction and maintenance

- Turbidity effects on recreation settings (particularly swimming and diving areas) and visual amenity at and near the Harbour entrance,
- Mobilisation of contaminants and potential effects on shellfish and other seafood, and for water-contact recreation,
- Effects on marine ecology and the quality, abundance and catchability of marine species, in and around the entrance and at and near the spoil dumping site offshore during the dredging period/s,
- Occupation of marine settings by dredges working or in transit and the creation of hazards for, especially, boaters.

Operation

- Changes to tides, currents and wave patterns resulting from altered bathymetry,
- Changes to beach and foreshore profiles resulting from changes to wave patterns, including remobilisation of dumped material,
- Effects on wave energy as a result of the passage of larger vessels,

Effects associated with the location and operation of aids to navigation, such as navigation buoys and markers (*Navaids*).These potential effects are considered individually in the following sections.

The following potential issues are not reviewed further:

- The presence of birds, which are likely to support marine recreation or increase its value. Relevant effects of the Project is considered in the Bioresearches (2016) report on coastal birds, which finds the potential for adverse effects to be low.
- Navigation risk, which is of interest to recreational boaters. Risk for large ships reviewed by Navigatus (2016). There are no apparent issues associated with deepening and realigning the channel, and relocating or adding navigation beacons, which would affect any recreational skipper sufficiently skilled to navigate the Harbour as it is currently.

- Noise effects on people, which are assessed by Styles Group (2016). Their report considers effects on residents who remain exposed to noise for long periods, and makes recommendations to ensure compliance with relevant noise standards. Recreational visitors may venture closer to dredge activities than residents, but are mobile and temporary visitors. Compliance with required noise standards for residential areas is considered appropriate, otherwise exclusion zones could be required to prevent, for example, a recreational vessel passing within a potentially noisy environment. In any case, Styles Group (2016, p15) finds that "compliance with the relevant noise limits for permitted activities will be achieved generally by a large margin".
- Commercial fishing, which is reviewed by Boyd (2017).

Table 1: Activity by potential effect considered

	Turbidity	Waves	Tides	Beaches	Marine ecology	Contaminants	Dredge activity	Navaids
Swimming	♦	♦	♦	♦		♦		
Beach use				♦				
Fishing	♦	♦	♦		♦	♦		
Shell fish	♦	♦	♦		♦	♦		
Diving	♦	♦	♦		♦	♦		
Boating*		♦	♦	♦			♦	♦
Surfing	♦	♦	♦					

* includes small and large craft, yachts, launches, SUP, kite surfing

5.2 Technical review findings

5.2.1 Turbidity

Dredging activity will disturb the sea floor and release sediment as dredge material is removed and disposed of in spoil grounds. Released sediment may reduce water clarity and decrease amenity for contact recreation.

The NRC Regional Coastal Plan defines water clarity standards for contact recreation based on the ANZECC (2000) water quality guidelines for visual clarity and colour (RCP Appendix 4). The ANZECC guidelines as used by the RCP for contact recreation are:

> *To protect the aesthetic quality of a waterbody:*
>
> • *the natural visual clarity should not be reduced by more than 20%;*
>
> • *the natural hue of the water should not be changed by more than 10 points on the Munsell Scale.*

Contact recreation is not anticipated in the dredge disposal areas, and effects of interest relate to increased turbidity in the swimming and diving areas within the Harbour and near the entrance.

Turbidity effects are considered in Coffey (2017). Of note are the following findings:

- Water clarity, as measured by Secchi depth visibility, is generally very good east of Tamaterau (more than 2 metres) but declines further up-harbour. Bream Bay water is generally very clear (pp18, 20).
- Hard-bottom reef communities of high intrinsic, conservation and recreational value are located near the dredge channel (these include the key dive sites near the entrance).

> Real-time monitoring of turbidity is proposed to avoid effects on these habitats. The objective is to ensure adverse effects do not occur (p50).

Coffey (2017 p43) notes:

> *…. video footage of a smaller, distinct, dredging operation undertaken by Refining NZ in December 2016 - February 2017 to undertake urgent emergency works around its berthing 'dolphins' did not reveal any oil or grease films, scums or foams, and no floatable materials. Moreover, video of the plume generated by the dredge indicated the plume was not associated with a conspicuous change in the colour or visual clarity after reasonable mixing*

Plume modelling carried out by MetOcean (2017, p102) indicates that while dredging plumes within the channel could extend for up to 1200 m from the dredge site, the plume is confined to the harbour channel. There was no indication of plume dispersion to adjacent beaches, sand banks, Marine 1 (Protection) Management Areas or Marine Reserves.

Summary for turbidity

The dispersal of sediment from the dredging activity is likely to be strongly confined to the dredge channel and has a low chance of dispersal to any contact recreation setting. However, real-time monitoring is planned to ensure there are no effects on important marine ecosystems near the dredge channel. There is therefore likely to be very little if any adverse effect on recreational dive and swimming sites, including on the marine life that attracts most divers. While ANZECC guidelines for contact recreation might be exceeded near the dredge sites, they are very unlikely to be breached (or approached) in contact recreation settings. Turbidity in and near the spoil disposal grounds will not present effects on recreation amenity (beyond those considered for fishing).

5.2.2 Waves

Changes in bathymetry have the potential to alter the direction and size of waves entering the harbour. Changes to wave energy may then have consequent effects on beach profiles and inshore marine ecology. These effects may change the existing level of amenity for swimming, surfing, fishing, shellfish gathering, boating and diving.

Consultation identified a query as to whether larger ships entering the Harbour could result in larger wakes affecting beach users and boats. However, wake size is dependent on ship speed more than size or draught. As all large vessels are at reduced speeds within the harbour limits, there is no change to wake size as they get larger or have a deeper draught (R. Reinen-Hamil, Tonkin + Taylor, pers comm).

MetOcean (2017) reviews modelled effects of changes in bathymetry on tides and waves and sediment transport processes; and Tonkin + Taylor (2017) use these and other data to identify effects on coastal processes.

MetOcean (2017, p33) indicate no potential change in mean wave heights, as result of channel deepening, at Ruakaka Beach river mouth, Ruakaka Beach, Mair Bank - middle area and Mair Bank - eastern edge. The Ruakaka Beach – northern area is modelled to have a mean reduction of 1cm from an existing mean wave height of 45cm, and the Marsden - Mair Bank beach area to have an increase of 1cm from an existing mean wave height of 11cm. Slight increases are also modelled for Busby Head (+2cm from a mean of 42cm) and the western side of Smugglers Bay (+3cm from a mean of 26cm). Effects are confined to swell waves and not locally generated wind waves.

Tonkin + Taylor (2017) state in their summary:

The predicted change in wave height resulting from the dredged channel in average and moderate wave climate conditions are negligible (less than ± 0.02 m). This variation is an order of magnitude less than the annual variability in mean wave heights over the 35 year hindcast of 0.31 m (i.e. from 0.68 m to 0.99 m). Change to average wave heights resulting from placement of sand in the disposal areas are negligible.

For extreme storm events there is some channel refraction effect which may result in slightly higher waves breaking on the edge of Mair Bank and towards Busby Head (between 0.1 m and 0.3 m increase with waves around 5m high). Again, comparing the inter-annual variability on wave heights, the relative change is an order of magnitude less than the annual variability of 1.36 m for the 99% wave height currently experienced. Change to storm wave heights resulting from placement of sand in the disposal areas are negligible.

Summary for waves

Preferred wave heights for surfing range between 1 and 3 m (see section 4.6). Changes which might be noted by surfers only accrue during storm events with wave heights around 5 m and only at the northern end of the Marsden Point surf break at Mair Bank. This is very unlikely to affect surfing amenity.

Increases in wave energy could have adverse effects on diving and swimming, but effects (as small as they are modelled to be) only occur when there is little natural amenity for recreation due to natural wave action (that is, there needs to be waves in action for there to be an effect on them, and the smaller the wave, the less effect).

More heavily laden vessels will not increase ship wakes.

5.2.3 Tides

Changes in bathymetry have the potential to alter tide direction and strength. These may affect the existing level of amenity for swimming, surfing, fishing, shellfish gathering, boating and diving.

The Tonkin + Taylor (2017) report on coastal processes is relevant. This states in its summary:

There is generally a very small reduction in tidal velocities as a result of the channel modifications (generally less than 0.02 m/s) except along the channel between Marsden Bank and Mair Bank, within the channel between Mair Bank and Home Point and between Home Point and Busby Head. In these areas the changes are in the order of 0.1 m/s.

Summary for tides

An acceleration in tidal strength could pose a hazard for boaters in the harbour channel. However, by deepening the channel, tidal speed generally decreases, albeit by a very small amount. There are therefore no adverse effects resulting from changes in tidal speed. The Tonkin + Taylor report also notes the potential for a minor change in timing of high and low tides, which will not affect recreation participation (timing of tides change every day).

5.2.4 Beaches

Changes to wave energy within the harbour have the potential to alter beach profiles. Gains or reductions in the height of beaches may change the availability of sand for general beach recreation and the usability of boat launching ramps.

The Tonkin + Taylor (2017) report on coastal processes is relevant. This states in its summary that no changes are anticipated to existing coastal processes on the open coast from Marsden Point to Ruakaka River or along the rocky coast from Home Point to Smugglers Bay, on the ebb tide shoal and Mair Bank or within the inner harbour area. However, there is the potential for the proposed maintenance dredging to add to the existing trend of a loss of sand at Mair Bank and the coastline extending southward from Marsden Point. It is therefore proposed to deposit a portion of the suitable dredged material within the ebb tide shoal area to enhance the supply of sand to both the shoal and the adjacent shoreline; and to monitor change in these settings over time. The conclusion is that, with this mitigation in place, any effects of dredging on shoreline processes are 'less than minor'.

Summary for beaches

The potential for changes to beach profiles – albeit slight and within a naturally dynamic setting – is confined to at and near Mair Bank and as a result of long-term maintenance dredging activity. The local recreation values are predominantly shellfish gathering. Mitigation options are proposed, via augmenting the local sand supply via depositing some suitable dredge material in the ebb tide shoal area, with an associated monitoring programme. Any changes of relevance to recreation are therefore effectively managed.

5.2.5 Marine ecology

Sedimentation, spoil deposition and changes to the sea floor at the dredging site have the potential to modify marine habitat and the availability of sea food for harvesting.

Coffey (2017, p47 ff.) reviews potential effects of the activities on fish and shellfish species and their habitats and notes:

- Local finfish are expected to avoid areas where feeding grounds have been disturbed but will return once they have recovered.
- The proposed dredging and disposal activities are likely to result in in an initial reduction of the population of species such as snapper, kahawai, shark and kingfish using the disturbed sites, but a progressive recovery would be expected to be complete with 6 to 12 months of capital dredging in the dredged channel and inshore/ebb tide shoal disposal area, and within 12 to 24 months in the offshore disposal area, although at the latter an 'ecologically constructive benthic community' (one able to provide feeding grounds for fish) is expected to re-establish within 12 months (meaning all affected areas will be supporting recreational fish species within 6 to 12 months).
- The effects of maintenance dredging are likely to be more confined than capital dredging, with smaller areas disturbed and more rapid recolonisation.
- Maintenance dredging may need to occur every 2 to 5 years in the berth pocket area and in targeted areas of the inner and mid channel to maintain navigable draft around the jetty dolphins. The outer channel may requiring maintenance work after between 5 and 10 years.

Coffey (2017, p51) recommends monitoring and control methods to avoid effects on sensitive hard bottom ecological communities adjacent to the dredging footprint.

There is likely to be some temporary increase in local finfish activity as the dredging activity exposes food sources, but this is not considered to be a mitigating effect.

Summary for marine ecology

Coffey (2017, p50) indicates that the scale of effect on benthic biomass (food sources for recreationally taken fish) are expected to be 'minor to moderate', short-term, and to progressively ameliorate within 6 to 12 months. This is likely to similarly result in some local

displacement of fishing activity from the dredge and disposal footprints during the recovery period. The dredge channel is within a popular fishing area – although anchoring and fishing within the channel itself is not wise boating behaviour – as is part of the disposal footprint.

Although 80% of dredge activity will occur beyond Home Point, both the inner and outer dredge sites are within popular fishing areas.

The total regional level of participation in recreational fishing is unlikely to be affected due to the popularity of the activity and the high number of alternative fishing areas, but local displacement may increase fishing pressure in those alternative sites, particularly areas sheltered by Busby Head and within the Harbour, and accessible sites around Bream Head. No data have been encountered to indicate that these areas suffer recreation conflict or over-crowding, although most anglers prefer less fishing competition than more.

Due to the scale of the local fishing resource, the mobility of finfish, the lack of effect on biota beyond the activity footprints, the progressive recovery of the benthos, and the temporary nature of the effect, the net outcome for recreational fishing from capital dredging is likely to be adverse but also minor. Maintenance dredging will have a lower scale of effect during each event, but due to its frequency (2 to 5 yearly) its net effect will also be adverse but minor.

There is likely to be some temporary increase in local finfish activity as the dredging activity exposes food sources, but this is not considered to be a mitigating effect.

5.2.6 Contaminants

Mobilising these has the potential to affect contact recreation activities in the Harbour.

The RCP also requires for contact recreation:

> *No conspicuous oil or grease film, scums or foams, floatable or suspended materials, or emissions of objectionable odour.*

Coffey (2017, p50) states that the material to be dredged is not contaminated with any toxins and also has very low levels of organic matter (which, if present, could lead to a drop in dissolved oxygen levels due to spikes in algal growth). This means there are no water quality issues associated with the activity.

5.2.7 Dredge activity

The presence of a dredge operating within the Harbour channel has the potential to compete for marine space with recreational craft and to present a hazard. The capital dredging programme is likely to last up to six months, with maintenance dredging involving smaller vessels and much shorter timeframes. Eighty-percent of dredge activity will be in the outer channel beyond Home Point, where there is ample navigation space.

The dredge will be operating within a defined Commercial Vessel Route within the Harbour as defined by the Northland Regional Council (Figure 39)[25]. The use of these routes by large vessels – particularly east of Portland and leading from the harbour limits to Northport and Marsden Wharf – are well-established activities.

The NRC Navigation Safety Bylaw 2012 requires:

> *2.12.1 The master of every vessel shall, when navigating within harbour limits, ensure that:*
>
> *(a) automatic steering 'pilot' devices, if fitted, are not used, unless a helmsman is standing by in the immediate vicinity of the helm station or wheel. Otherwise, vessels are to be in hand-steering mode; and*

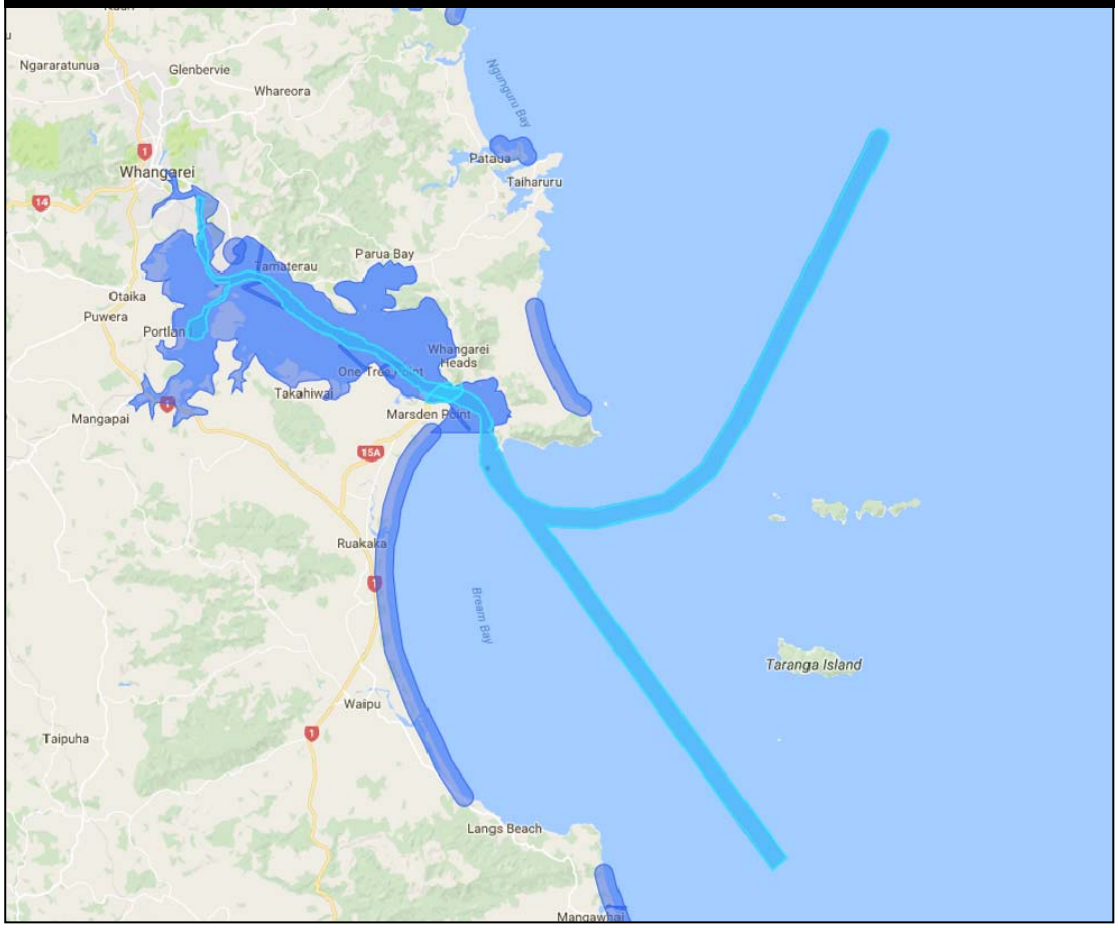
[25] https://koordinates.com/layer/3226-northland-coastal-information-polygons-coastal-use-and-value/data/14/

(b) the vessel's main engine(s) is immediately available for reducing speed, stopping or going astern at all times and without delay; and

(c) the vessel's anchors are immediately available for use in an emergency and capable of being used without power….

2.12.3 The master of every vessel under 500 gross tonnage or under 24 metres in length must not impede the navigation of any vessel of 500 gross tonnage or more when operating within harbour limits.

Figure 39: Commercial Vessel Route, Whangarei Harbour – cyan. NRC data



Rule 2.12.3 would apply to most small commercial dredge vessels operating in New Zealand. The Pelican and Kawatiri, for example, have gross tonnages of approximately 1000 tonnes.[26]

Required maritime practice means the dredge will be appropriately lit at night and will obey all marine navigation rules.

Summary for dredge activity

Any recreation skipper operating in or near the harbour entrance would expect to encounter large ships and to comply with harbour navigation rules. While the presence of a dredge is an additional navigational issue, it should not limit recreation participation by large and small recreational vessels. However, it is recommended that RNZ place on its website information about dredge activities (location and duration of activity), and promote the location of the data to boating clubs and via local print media. This will be of interest to boaties generally, and may assist cautious skippers. Advice should also be given to the regional harbourmaster who can then make judgements about the importance of additional maritime notifications –

[26] Marinetraffic.com data

including whether it warrants a Notice to Mariners (via LINZ). The net effect on recreation participation is likely to be minor or less and the presence of dredges is unlikely to limit recreation participation compared with now.

5.3 Navaids

The reformatting of the location and type of navigation aids is described by Royal Haskoning DHV (2017) and are shown in Appendix 1 to this report,

The existing channel demarcation is provided by a safe water mark (often referred to as the fairway buoy) and nine starboard buoys and nine port buoys. Eight of the existing buoys will need to be relocated to accommodate the reconfigured channel alignment. Two additional channel marker buoys (one starboard and one port) will be installed at -17.7m depth, and the existing fairway buoy will be moved to be aligned with the starboard channel markers at -25.0m depth. An improved Port Entry Light, a modified rear lead light marking the offshore approach channel, and a set of lead lights in Taurikura Bay to assist with night time navigation will also be installed.

The developments are required to mark the new channel alignment and to reduce the risk of marine accidents.

The ecological effects of their installation and operation is reviewed in Coffey (2017), who finds no issues of relevance. The navaids are located on channel edges where tidal currents tend to be strong and not within recreational diving, snorkelling or swimming areas.

The relocation of navaids will require a Notice to Mariners (via LINZ) and updates to LINZ marine charts. Such activities are common practice nationally, although many recreational boaters will be unaware of them, and when navigating familiar territory will rarely refer to charts. However, the beacons will be very obvious on the water, day and night, and there will be no introduction of new submerged marine hazards – meaning reliance on local knowledge rather than charts will remain relevant.

Recreational fishers occasionally tie to navigation aids, but this is not an option considering Maritime Rules (Maritime NZ, 2016):

> *91.14 Damage to navigation aids*
>
> *(1) No person may tie a vessel to any aid to navigation without the written permission of—*
>
> *(a) if the aid to navigation is operated by a local authority or port company, the harbourmaster; or*
>
> *(b) if the aid to navigation is operated by the Maritime Safety Authority, the Director.*
>
> *(2) No person may damage, remove, deface or otherwise interfere with an aid to navigation*

Summary for navaids

Navaids are required structures for safe navigation. They are used by both recreational and commercial craft and need to be in the right locations. The recommendations for their placement as part of the Project are made by Royal Haskoning DHV (2017) for the purposes of navigation safety. This is a necessary response to the Project. Local boaters will rapidly adjust to very obvious changes in beacon location, which should be considered a pre-requisite skill for operating watercraft in a navigation channel. The proposed navaid developments are not considered to be adverse effects on recreation, and any safety improvement in navigation is likely to have a positive effect.

5.4 Cumulative effects

Cumulative effects include those which may exacerbate effects of already consented activities in the same environment which may not have been undertaken, or increasing the scale, intensity or rate of existing environmental changes.

Three currently consented local activities need to be considered, as described in Coffey (2017 pp31-33): Northport Ltd's expansion plans; The Ruakaka Wastewater Treatment Plant Ocean Outfall; and the NIWA Aquaculture Facility seawater supply and discharge.

For recreation, the effects of the proposal are sufficiently slight to make it unlikely for cumulative adverse effects to arise. Indeed, the relocation of sand material on the ebb tide shoal has the potential to reduce the rate of local coastal erosion resulting from climate change. Effects on marina biota are temporary and localised and are therefore very unlikely to add to changes in fish populations, Ongoing recreational and commercial fishing pressure will far outweigh any potential changes to local fish availability. There are no effects on fish breeding grounds or on the habitat of recreational shellfish due to the limited and controlled turbidity and sedimentation. There has been no identified mechanism by which the proposed activity would affect pipi beds on Mair Bank, and the relocation of sand to the ebb tide shoal will support the maintenance of habitat.

There are no locally consented activities identified which have not been implemented which would increase the potential for adverse effects from the proposal.

6 Conclusion

Despite the proximity of the dredging activity to an intensely and extensively used recreation setting, effects of the Project are expected to be confined and slight. This is the result of:

- Dredged material being generally of a coarse and clean nature and confined to the harbour channel when it forms a plume; and therefore little chance for effects on contact recreation and on the marine biota of interest to divers and snorkelers.
- The ability to avoid effects on marine ecosystems outside the dredge and disposal sites; and therefore little chance of adverse effects on diving, snorkelling and fishing beyond those footprints.
- Minimal effects on waves and coastal process (and so no effect on surfing), and the ability to address potential effects from maintenance dredging on sand supply at and around Mair Bank, and to offer an enhancement opportunity.
- The presence of large ships being common in the Harbour channel, and dredges therefore not being an unusual impediment to boating – although ensuring information about dredge activity is available is recommended.

Temporary displacement of fishing activity is likely in the dredge channel and at the spoil site as they recover from disturbance. For recreation, this will be the greatest effect, but due to: the scale of the fishing resource, the number of alternative sites, and the relatively short expected recovery period, the effect is likely to be minor and represented by fishers choosing an alternative fishing site nearby. The use of berley to attract fish is normal practice when boat-fishing, and Brian Coffey (author of Coffey (2017), pers comm) notes that using this method in a disturbed area will remain effective in attracting finfish.

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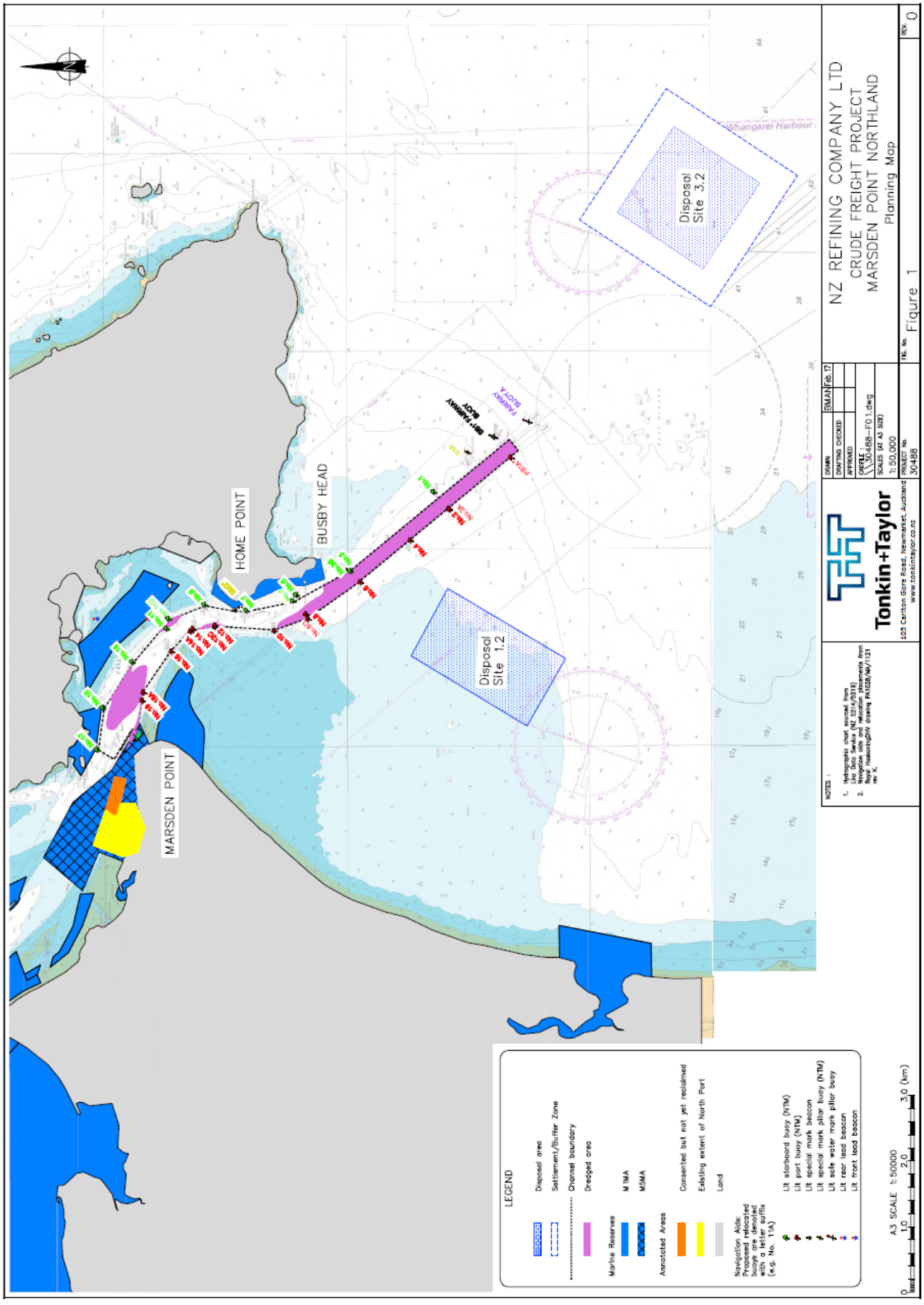
Appendix 1: Project activity maps



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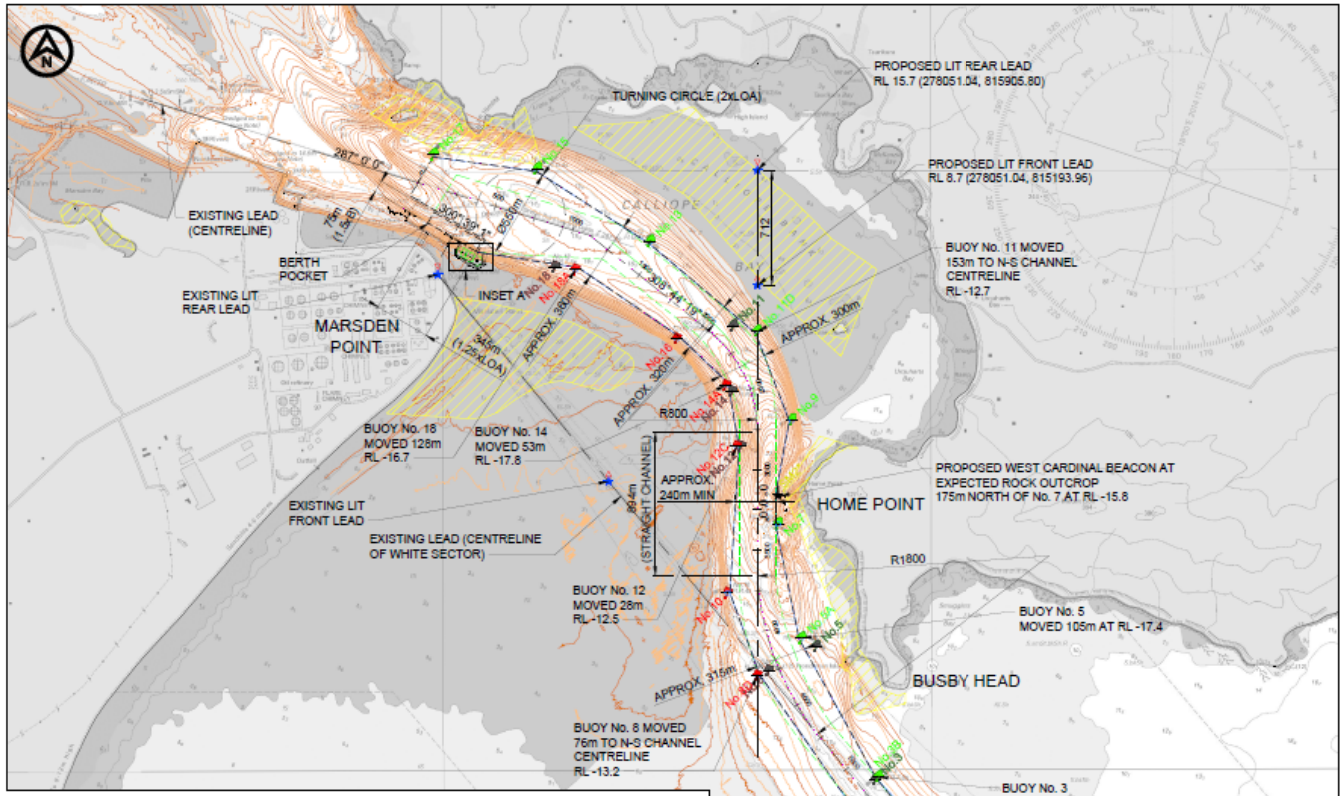

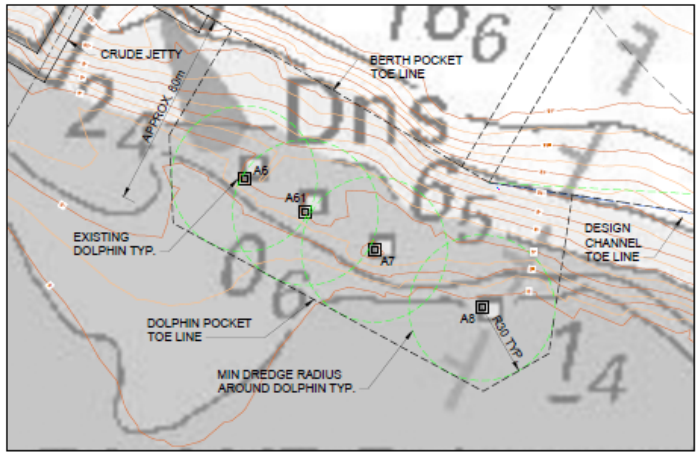

INSET A - DOLPHIN POCKET
1:1,000 (A1)

PLAN - CHANNEL ALIGNMENT
1:15,000 (A1)

LEGEND:

- DESIGN TOE LINE
- DESIGN CHANNEL CENTRELINE
- THEORETICAL TOE LINE
- THEORETICAL CHANNEL CENTRELINE
- BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)

NAVIGATION AIDS:
PROPOSED RELOCATED BUOYS ARE DENOTED WITH A LETTER SUFFIX (e.g. No. 11A)

- LIT STARBOARD BUOY (NTM)
- LIT PORT BUOY (NTM)
- LIT WEST CARDINAL BEACON
- LIT SPECIAL MARK PILLAR BUOY (NTM)
- LIT SAFE WATER MARK PILLAR BUOY
- EXISTING BUOY TO BE RELOCATED
- WAVERIDER BUOY
- LIT REAR LEAD BEACON
- LIT FRONT LEAD BEACON
- LEAD LINE

CONSTRAINTS:

- MM1 BOUNDARY

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF DESIGN CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 276m AND BEAM (B) = 50m.
5. THE DAYLIGHT LEADS ON THE OFFSHORE APPROACH CHANNEL BETWEEN THE FAIRWAY BUOY AND BUOYS 3/6 SHOULD BE MADE MORE SENSITIVE TO ADEQUATELY SHOW THE NAVIGATION LIMITS OF THE NEW CHANNEL AND BE BRIGHT ENOUGH TO SUPPORT OPERATIONS IN ADVERSE ENVIRONMENTAL CONDITIONS. AN ADDITIONAL FRONT LEAD SHOULD BE ESTABLISHED WITH DAY AND NIGHT LIGHTS IN THE CURRENT FRONT LEAD POSITION. THE EXISTING FRONT LEAD SHOULD BE REPLACED WITH A SIMPLE DAY/NIGHT LIGHT LEAD WITH NO DAY SHAPE.
6. NORTHPORT TO REMOVE THE DAY SHAPE TOP STRUCTURE FROM THE EXISTING FORE LEAD STRUCTURE AND PLACE A NEW 1.2m HIGH STRUCTURE (ON TOP) TO HOLD THE PROPOSED LIGHT. LIGHT COLOUR TO BE CONFIRMED.

CHART DATUM

NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m
1:15000 (A1) 1:30000 (A3)

20 0 20 40 60 80 100m
1:1000 (A1) 1:2000 (A3)

M	22.09.15	WEST CARDINAL MARK ADDED	SAH	JGC
L	24.06.15	LEADS AND FAIRWAY BUOY MOVED	SAH	JGC
K	23.06.15	LEADS MOVED	SAH	RH
J	22.06.15	FAIRWAY BUOY MOVED	SAH	RH
H	02.12.15	REISSUED FOR REVIEW	SAH	RH
G	27.10.15	DREDGING AROUND DOLPHINS ADDED	SAH	RH
F	23.10.15	LAYOUT REVISED	SAH	RH
E	22.10.15	REVISED SUEZMAX VESSEL	SAH	RH
D	16.10.15	BUOYS No.2 AND PB1 SHIFTED	SAH	RH
C	13.10.15	CHANNEL CENTRELINE ADDED	SAH	MP
B	12.10.15	PROPOSED N-S LEAD ADDED	SAH	MP
A	10.09.15	REVISED FROM OPTION 4-1	SAH	MP
NO.	DATE	DESCRIPTION	BY	CHK	APVD

REVISIONS

CLIENT
CHANCERYGREEN ON BEHALF OF:
REFINING NZ
Your Energy Hive

PROJECT
REFINING NEW ZEALAND
CRUDE FREIGHT PROJECT

DRAWING TITLE
CHANNEL DESIGN
OPTION 4-2
CHANNEL ALIGNMENT

HASKONING AUSTRALIA PTY LTD
SYDNEY
Royal HaskoningDHV

DRAWN SAH	DATE 20/08/2015	JOB No. PA1028
AUTOCAD REF. PA1028-WA-DP4-2L-0855		
SCALE AT A1 AS SHOWN		
DRAWING No. PA1028/MA/1121		REVISION M

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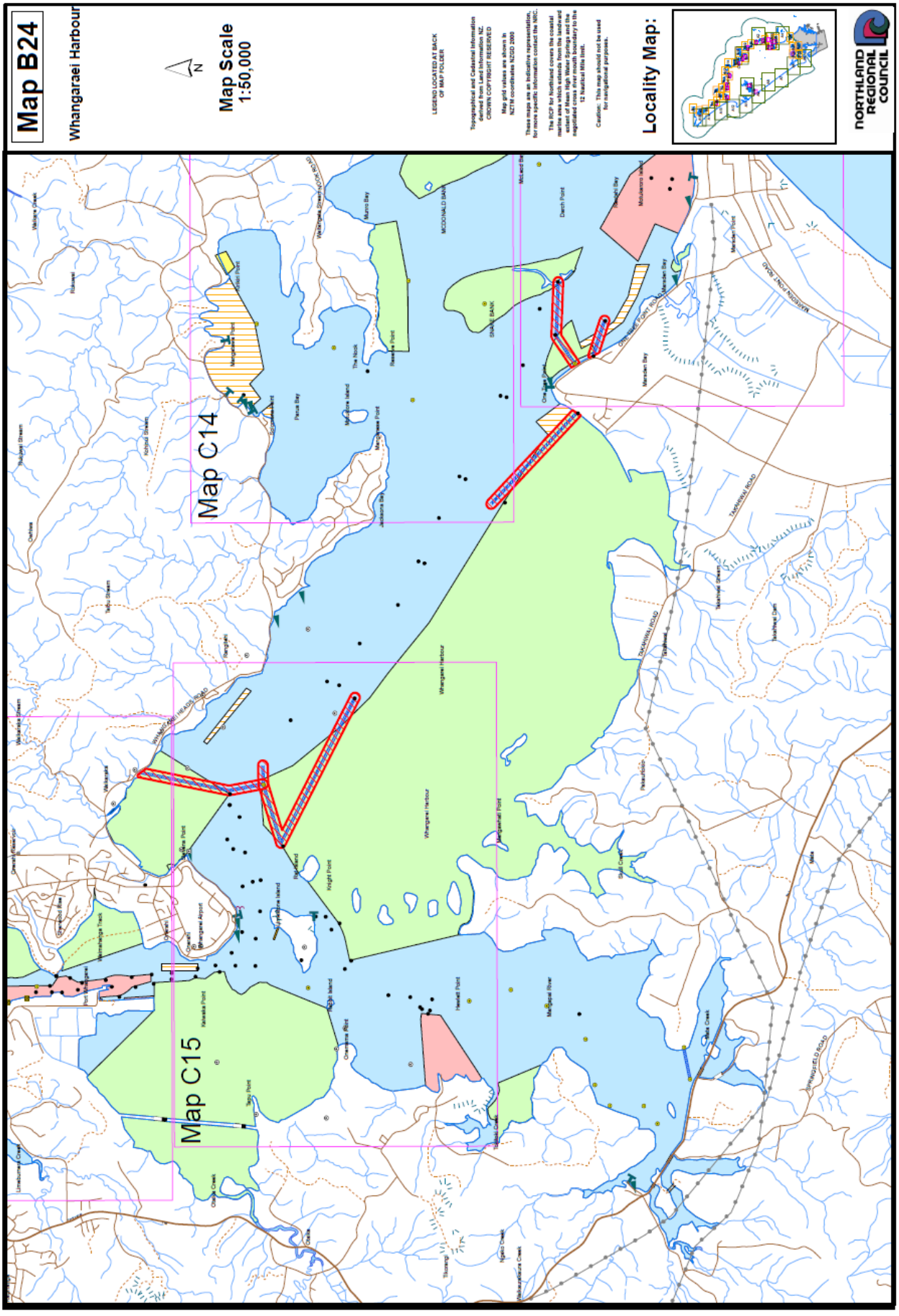
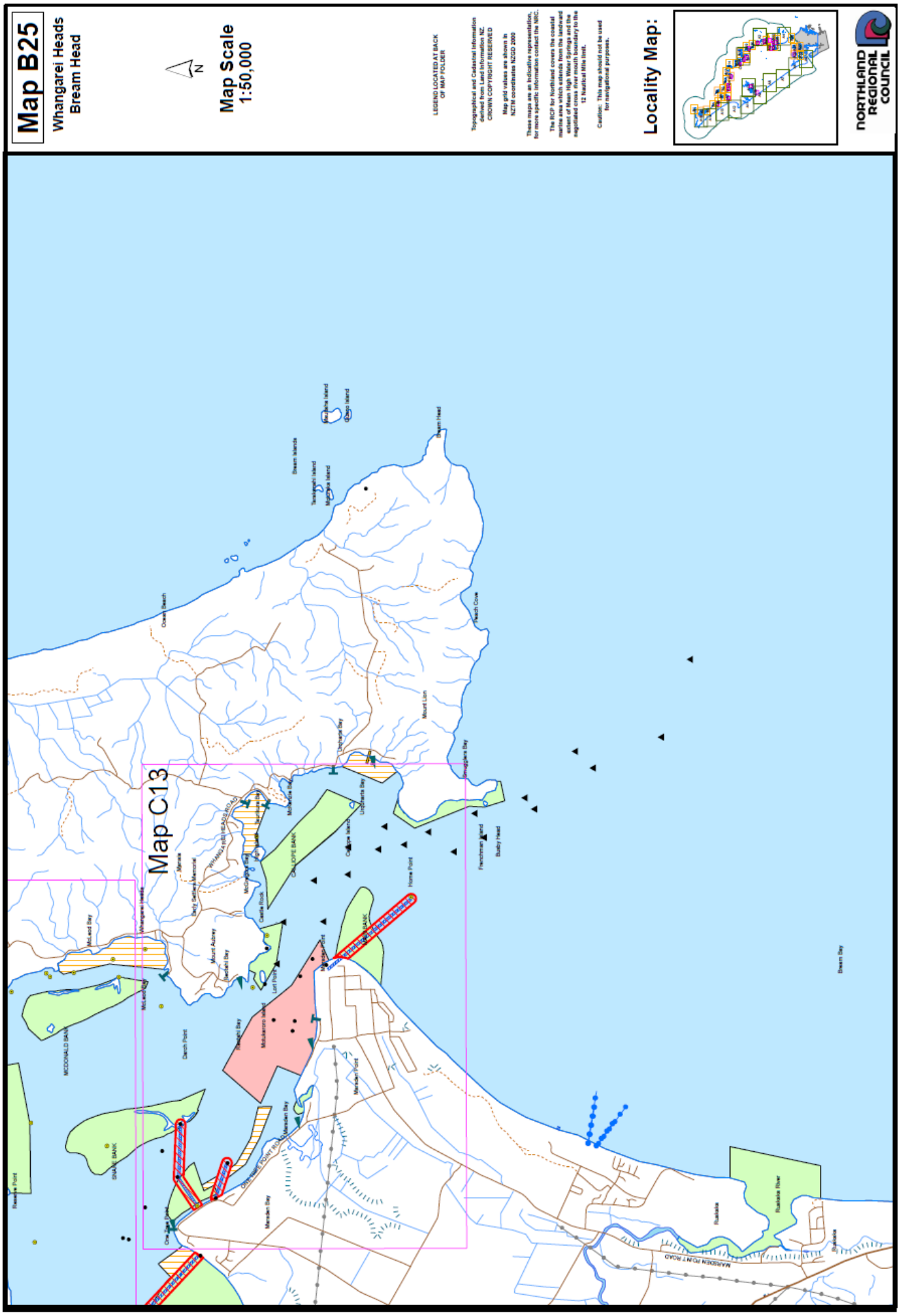
Appendix 2: Northland Regional Council Regional Coastal Plan maps



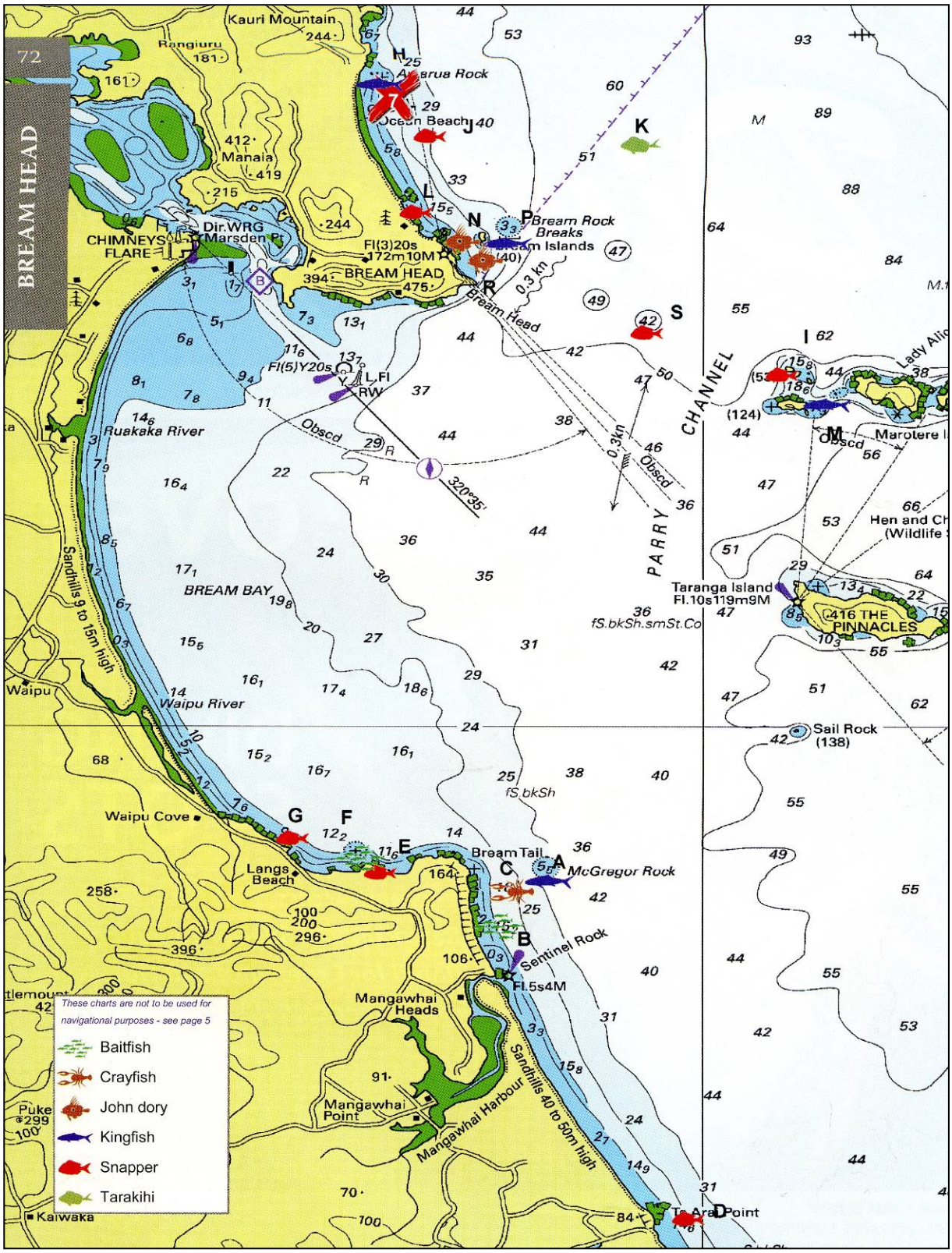

Map B25
Whangarei Heads
Bream Head
N
Map Scale
1:50,000
LEGEND LOCATED AT BACK OF MAP FOLDER
Topographical and Cadastral Information derived from Land Information NZ. CROWN COPYRIGHT RESERVED
Map grid values are shown in NZTM coordinates NZGD 2000
These maps are an indicative representation, for more specific information contact the NRC.
The RCP for Northland covers the coastal marine area which extends from the landward extent of Mean High Water Springs and the negotiated cross river mouth boundary to the 12 Nautical Mile limit.
Caution: This map should not be used for navigational purposes.
Locality Map:
NORTHLAND REGIONAL COUNCIL
Map C13
Bream Head
Bream Islands
Ocean Beach
Peach Cove
Mount Lion
Frenchman Island
Busby Head
Home Point
Bream Bay
Ruakaka
Ruakaka River
MARSDEN POINT ROAD
Marsden Bay
Marsden Point
Darch Point
Mount Aubrey
Lort Point
Castle Rock
Reserve Point
McLeod Bay
McDONALD BANK
SNAKE BANK
Whangarei Heads
Manaia
Early Settlers Memorial
Mokuleroro Island
Lighthorne Bay
Cuttle Island
Uruphoria Bay
Mountain Bay
Tawakipaki Island
Mokuleroro Island
Bream Island
Mau Jaha Island
Ohaco Island

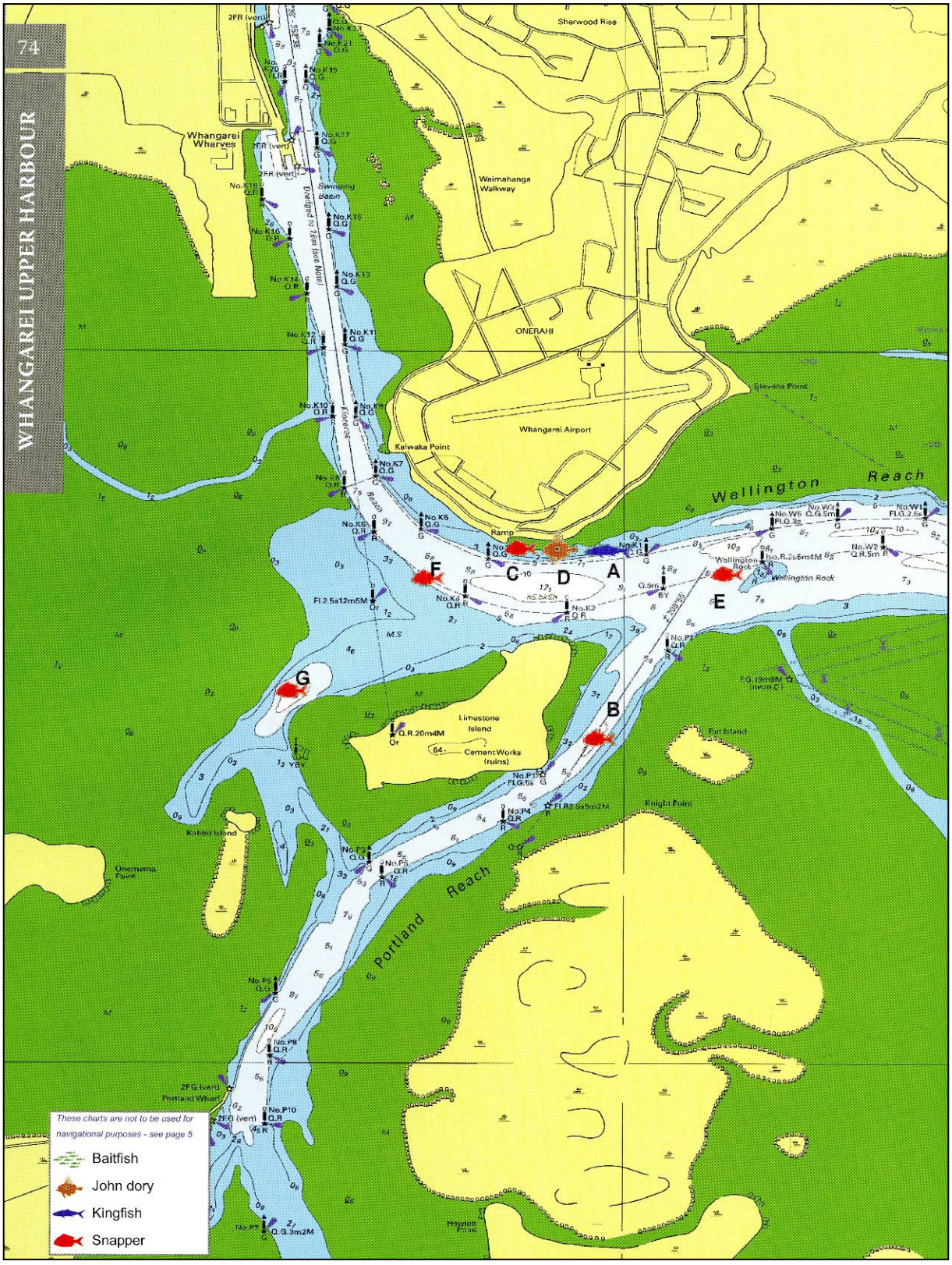
Northland Regional Coastal Plan Map Legend

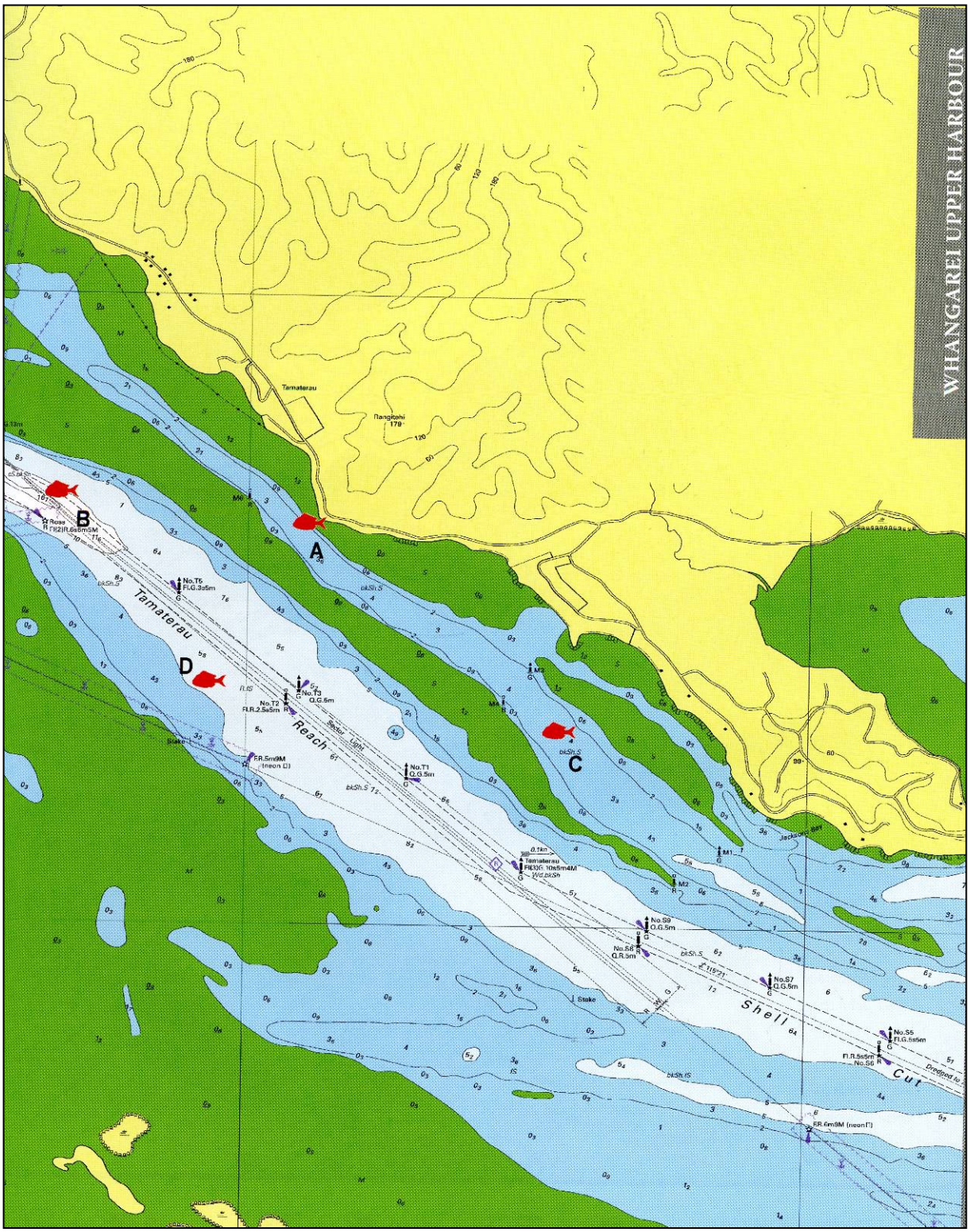


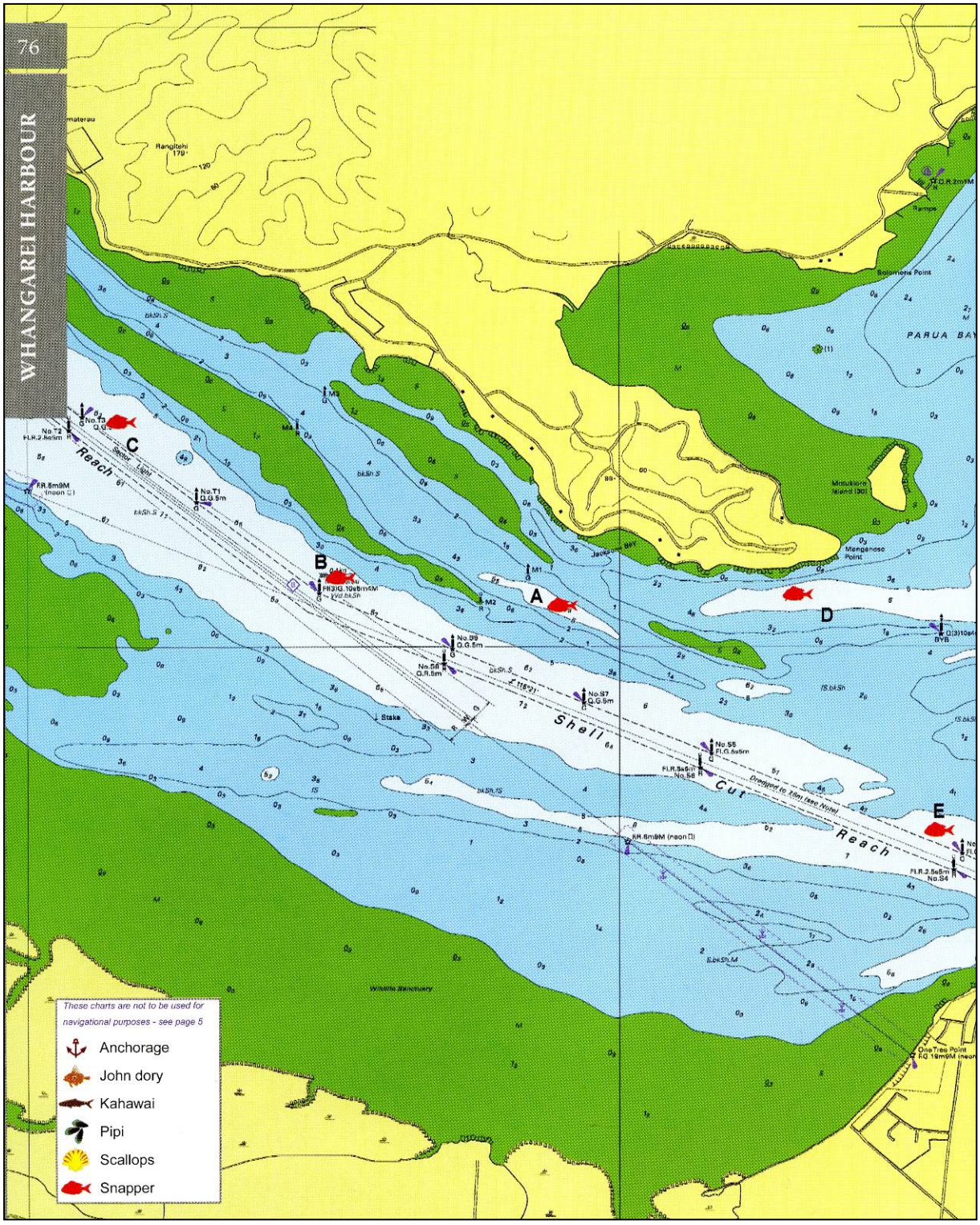
Appendix 3: Spot X fishing guide recommendations

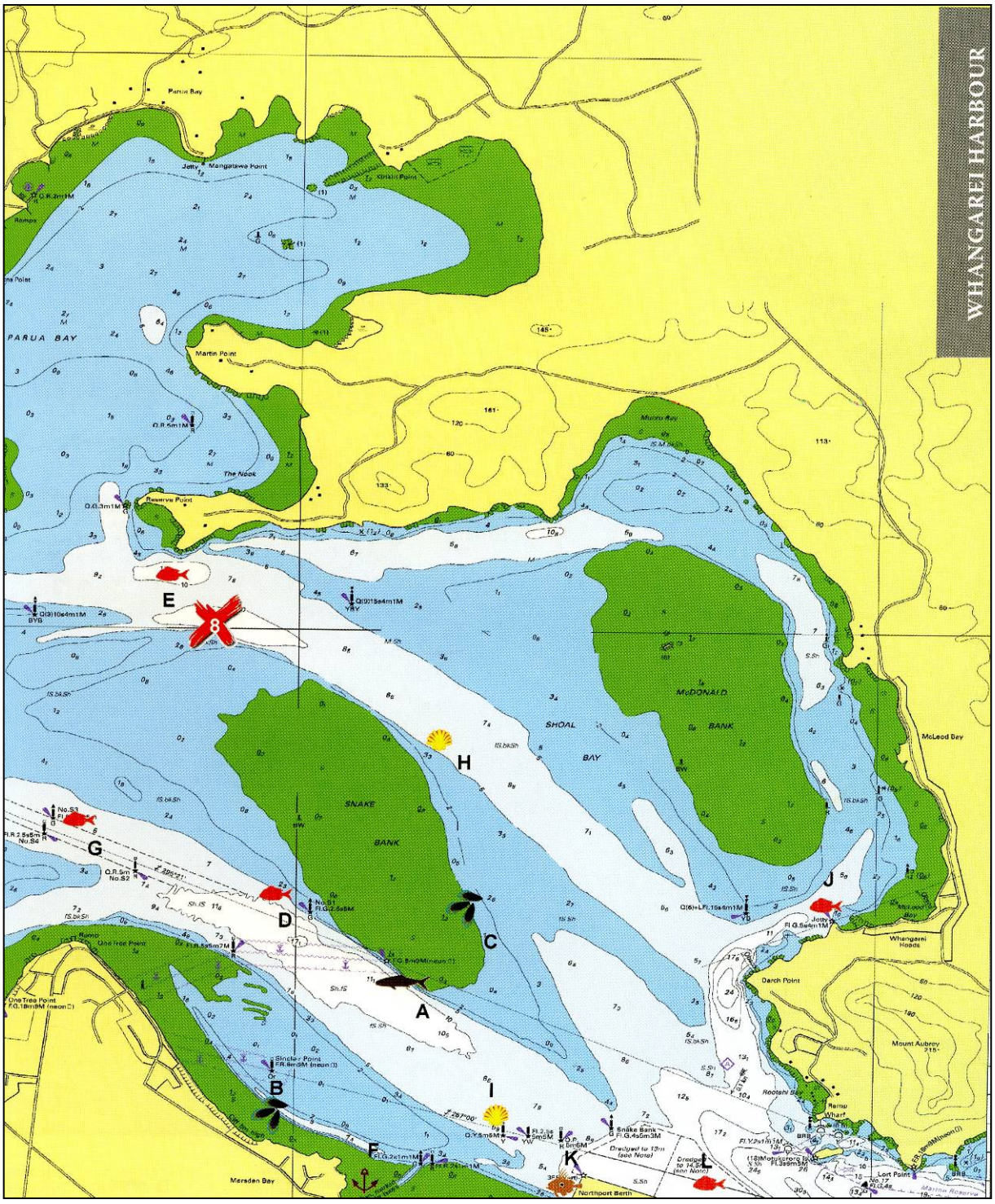
Source: Allen *et al* (2009)

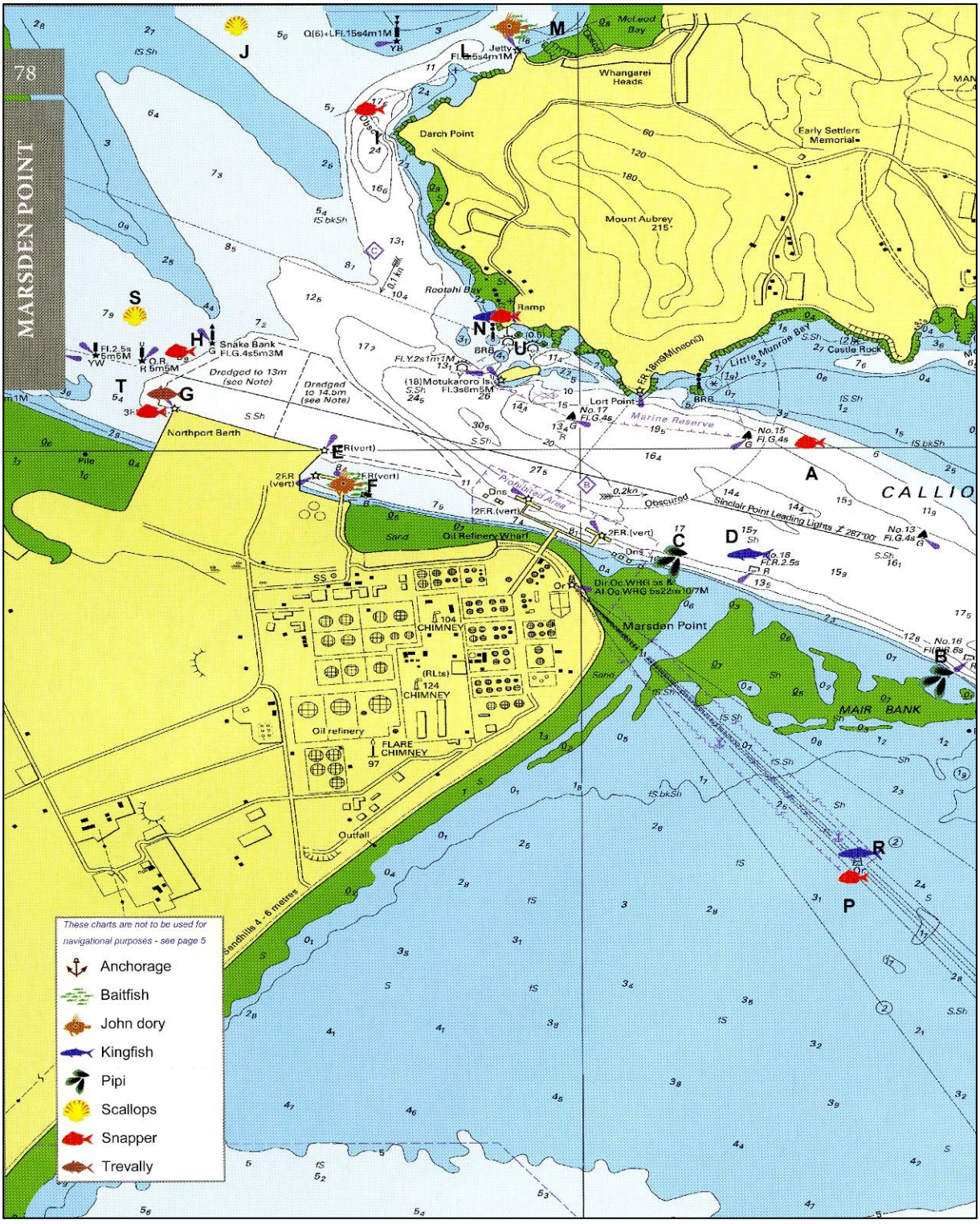


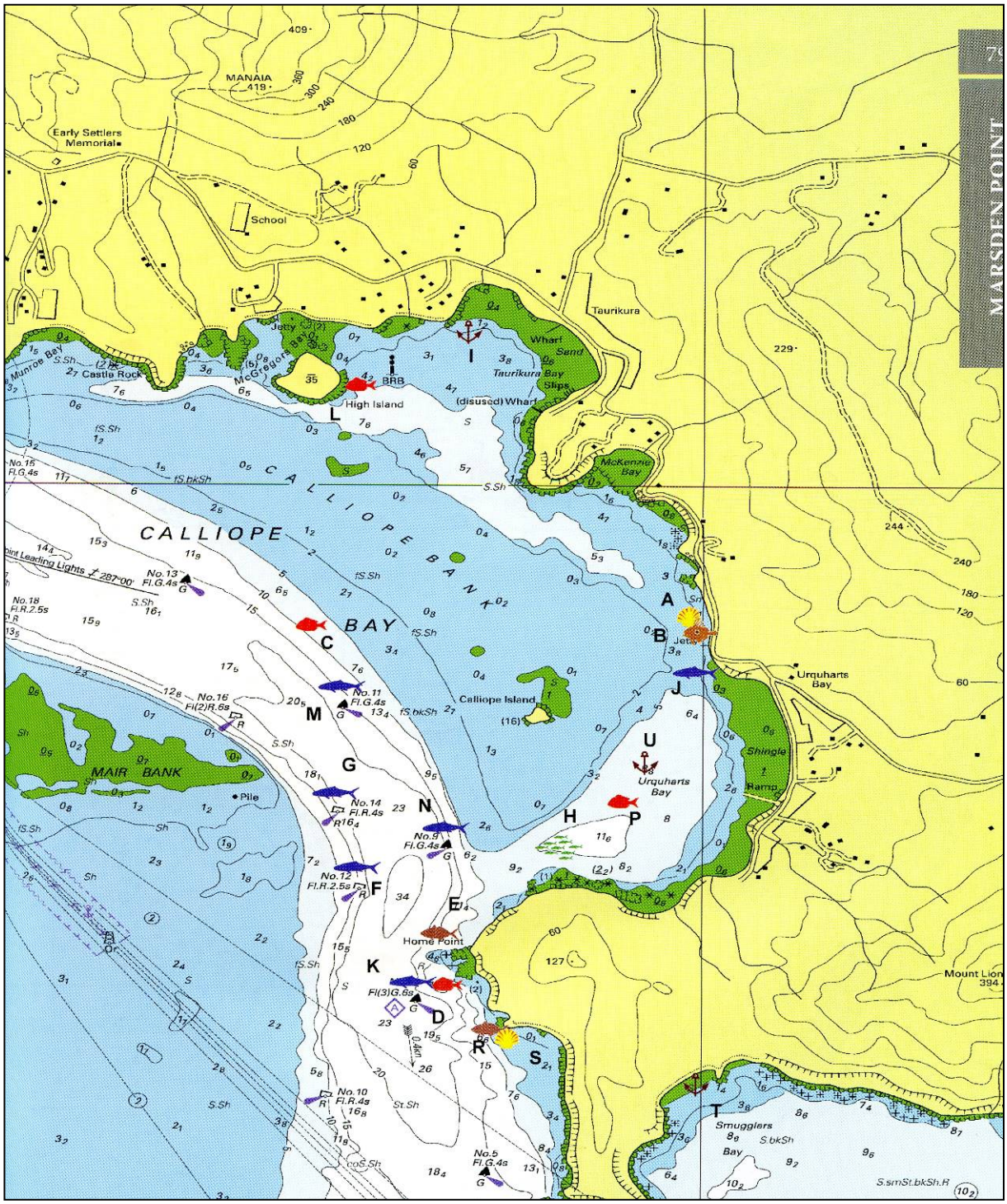

74
WHANGAREI UPPER HARBOUR
Sherwood Rise
Whangarei Wharves
Waimahanga Walkway
Swinging Basin
Dredged to 7.6m (see Note)
ONERAHI
Whangarei Airport
Kiwaka Point
Stevens Point
Wellington Reach
Ramp
Wellington Rock
Limestone Island
Cement Works (ruins)
Port Island
Knight Point
Portland Reach
Onemama Point
Rubber Island
Portland Wharf
Hewlett Point
A
B
C
D
E
F
G
These charts are not to be used for navigational purposes - see page 5
Baitfish
John dory
Kingfish
Snapper

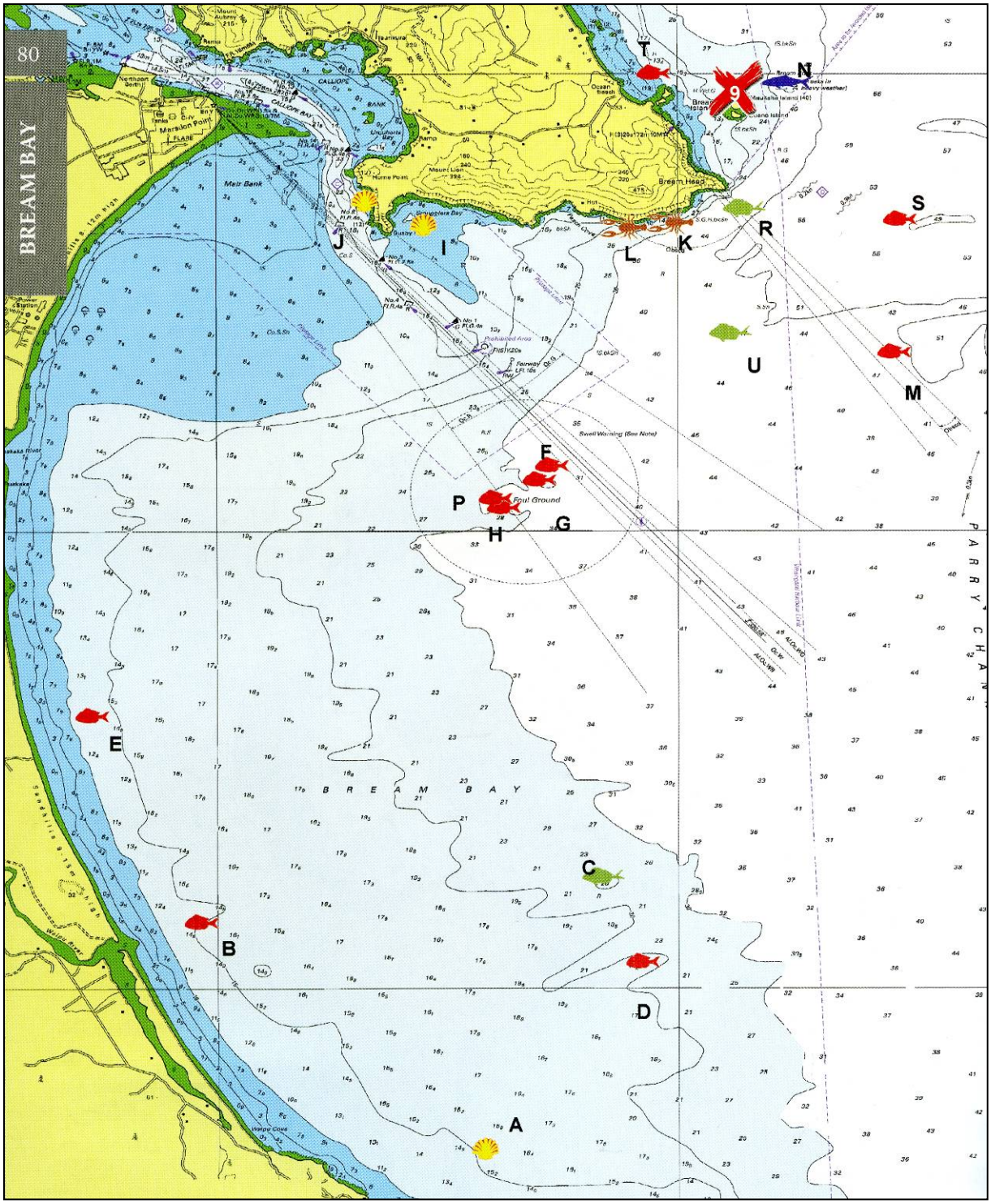

WHANGAREI UPPER HARBOUR
Tamaterau
Tamaterau
Reach
Shell
Cut
A
B
C
D


76
WHANGAREI HARBOUR
Rangitehi
Reach
Shell
Cut
Reach
Stake
Jackson Bay
Mangonese Point
Solomons Point
PARUA BAY
Wildlife Sanctuary
A
B
C
D
E
These charts are not to be used for navigational purposes - see page 5
Anchorage
John dory
Kahawai
Pipi
Scallops
Snapper


WHANGAREI HARBOUR
PARUA BAY
Martin Point
Reserve Point
The Nook
Parua Bay
Jetty
Mangatawa Point
McDONALD
BANK
SHOAL
BAY
SNAKE
BANK
McLeod Bay
Whangarei Heads
Marsden Bay
Northport Berth
Mount Aubrey
Lort Point
A
B
C
D
E
F
G
H
I
J
K
L


78
MARSDEN POINT
Whangarei Heads
Darch Point
Early Settlers Memorial
Mount Aubrey 215
Rootahi Bay
Ramp
Snake Bank
Dredged to 13m (see Note)
Dredged to 14.5m (see Note)
Northport Berth
Lort Point
Marine Reserve
Little Munroe Bay
Castle Rock
Prohibited Area
Obscured
Sinclair Point Leading Lights
CALLIO
Oil Refinery Wharf
Marsden Point
MAIR BANK
Oil refinery
FLARE CHIMNEY
Outfall
Sandhills 4 - 6 metres
These charts are not to be used for navigational purposes - see page 5
Anchorage
Baitfish
John dory
Kingfish
Pipi
Scallops
Snapper
Trevally


MARSDEN POINT
MANAIA
Early Settlers Memorial
School
Taurikura
Jetty
Wharf
Sand
Taurikura Bay
Slips
(disused) Wharf
McKenzie Bay
Munroe Bay
Castle Rock
McGregors Bay
BRB
High Island
CALLIOPE BANK
CALLIOPE BAY
Point Leading Lights 287°00'
No.13 Fl.G.4s
No.18 Fl.R.2.5s
No.15 Fl.G.4s
No.16 Fl(2)R.6s
No.11 Fl.G.4s
Calliope Island
MAIR BANK
Pile
No.14 Fl.R.4s
No.9 Fl.G.4s
No.12 Fl.R.2.5s
Home Point
Fl(3)G.6s
No.10 Fl.R.4s
No.5 Fl.G.4s
Urquharts Bay
Jetty
Shingle
Ramp
Mount Lion
Smugglers Bay
A
B
C
D
E
F
G
H
I
J
K
L
M
N
P
R
S
T
U


BREAM BAY
Mount Aubrey 215
Tauhinauri
Nathan Point
CALLIOPE BANK
Mansion Point
FLARE
Melr Bank
Home Point
Mount Lion 392
Ramp
Ocean Beach
Bream Head
Waiotahe Island (40)
Limeburners Bay
Limeburners Bay
Co.S
Co.S.Sh
Prohibited Area
Fairway Ldg Lts 120°
Fairway Buoy
Swell Warning (See Note)
Foul Ground
Mo.1 Fl.(3).4s
No.1 Fl.R.4s
No.2 Fl.R.4s
No.3 Fl.R.4s
No.4 Fl.R.4s
No.5 Fl.R.4s
No.6 Fl.R.4s
No.7 Fl.R.4s
No.8 Fl.R.4s
No.9 Fl.R.4s
No.10 Fl.R.4s
No.11 Fl.R.4s
No.12 Fl.R.4s
No.13 Fl.R.4s
No.14 Fl.R.4s
No.15 Fl.R.4s
No.16 Fl.R.4s
No.17 Fl.R.4s
No.18 Fl.R.4s
No.19 Fl.R.4s
No.20 Fl.R.4s