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.

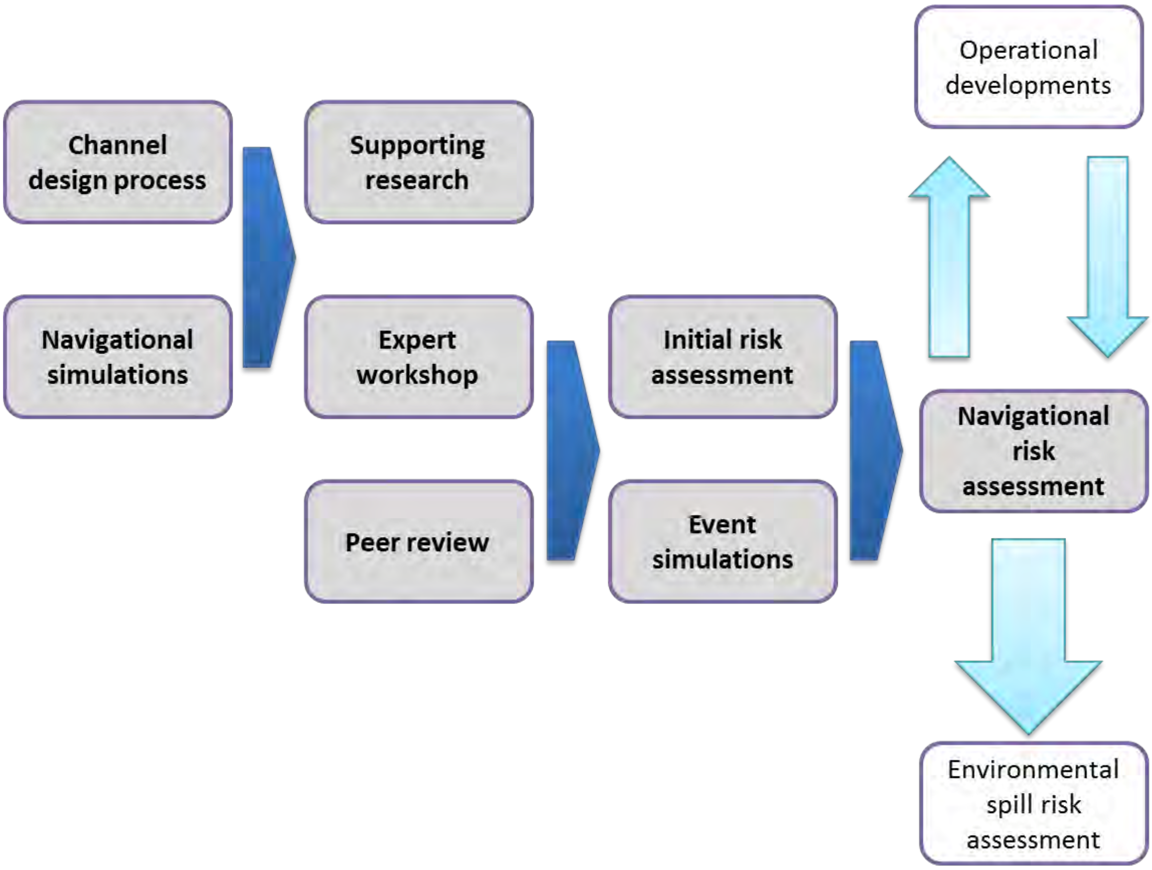

Figure 1 - Overall Process

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.

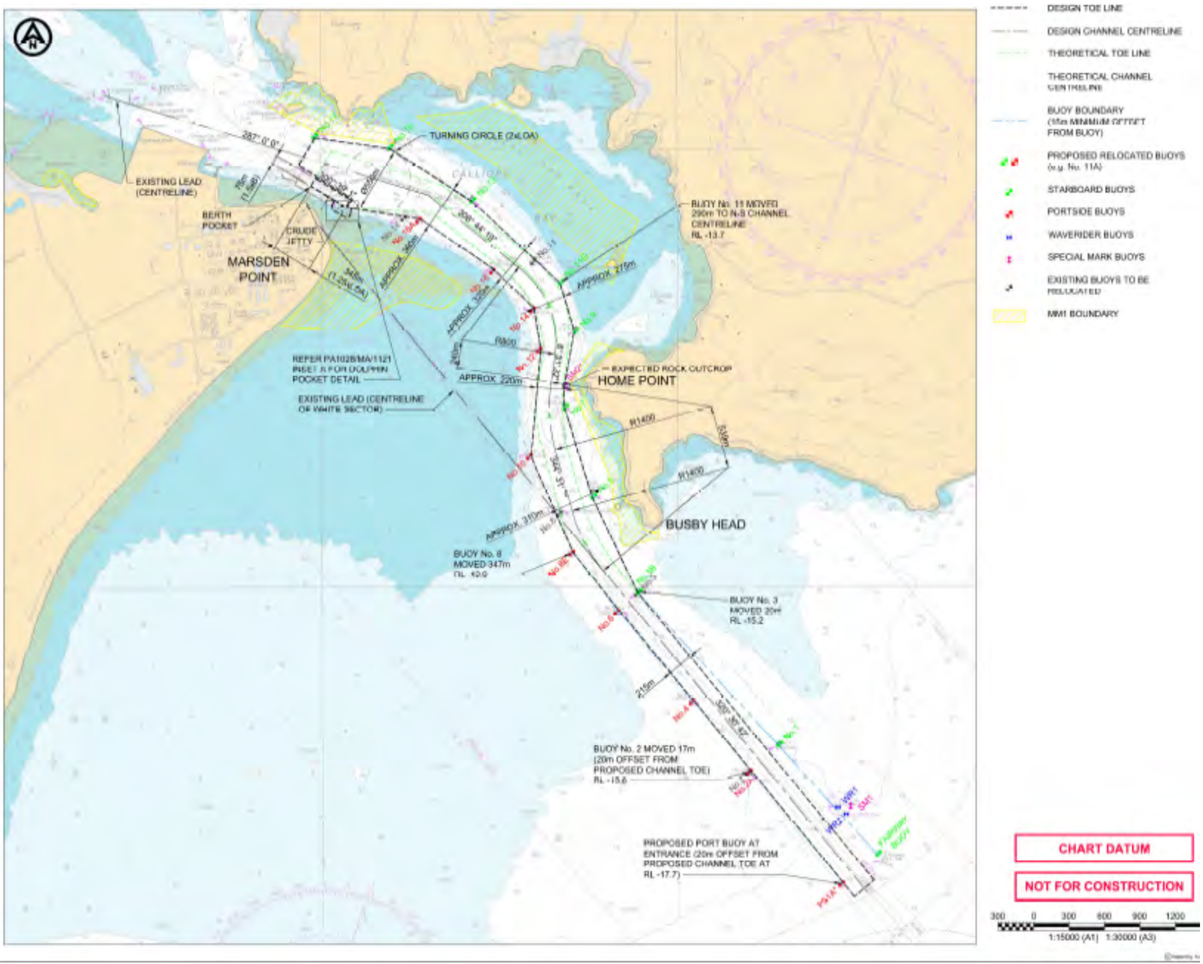

Figure 3 - Option 2 Channel

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.

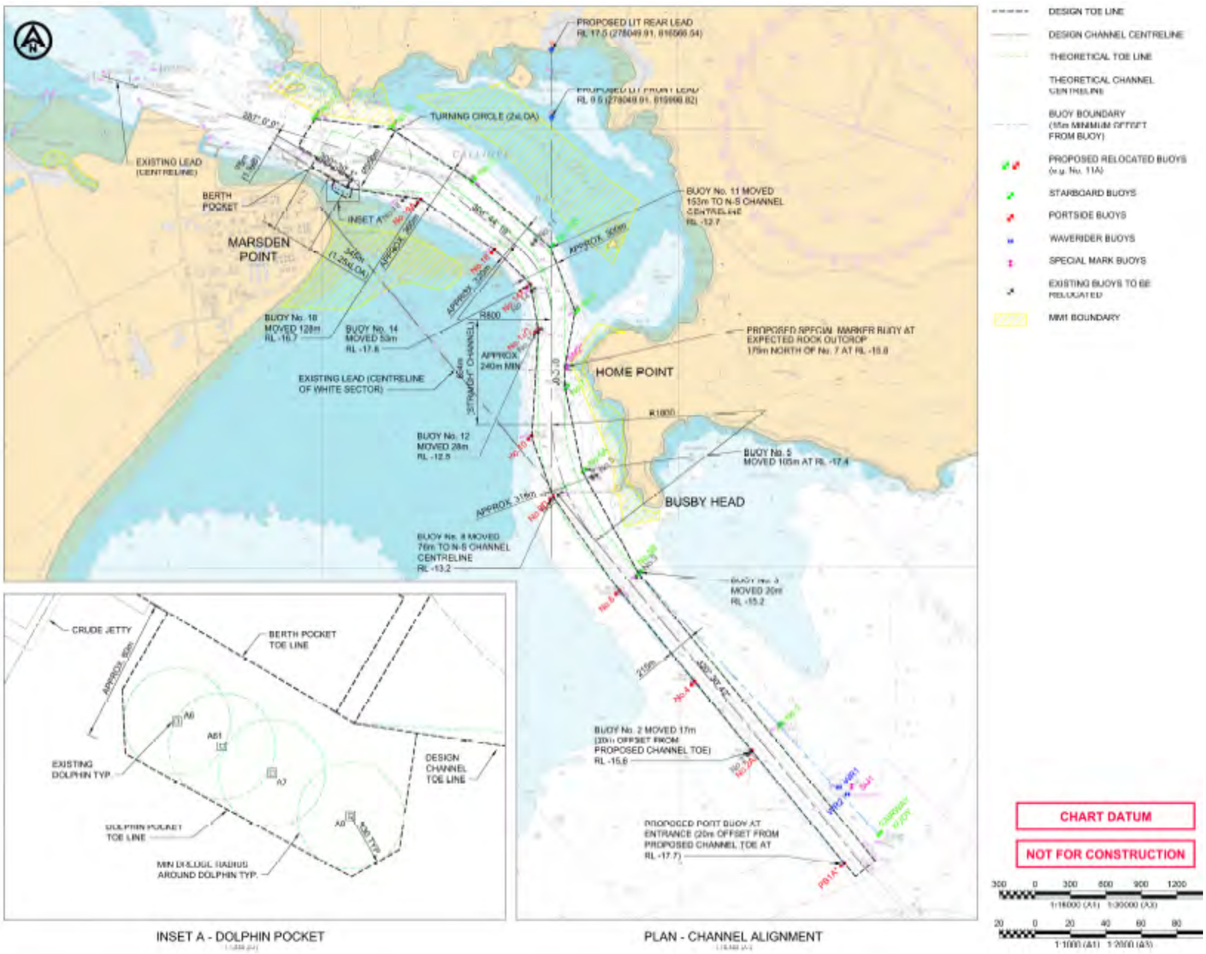

Figure 4 - Option 4.2 Channel

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.

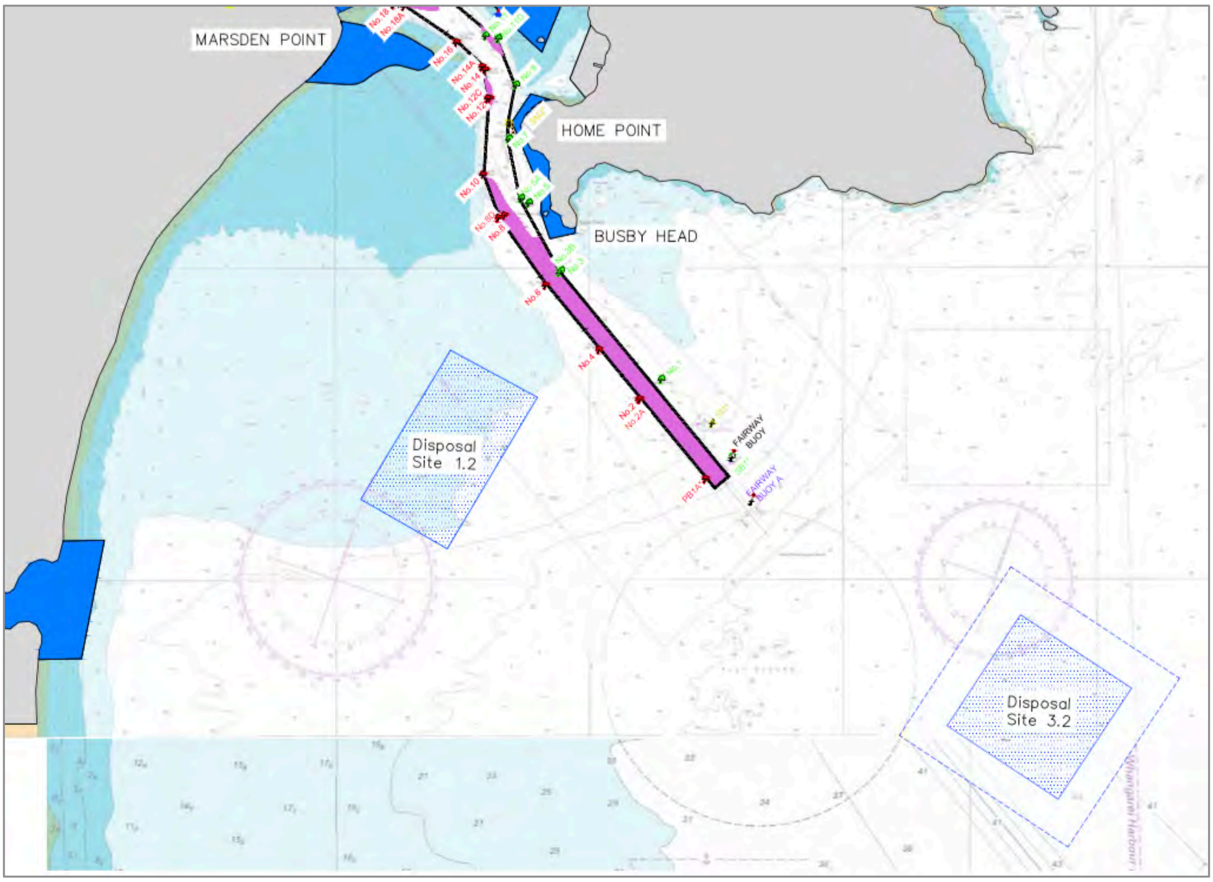

Figure 5 – Dredged material disposal areas

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

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[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.

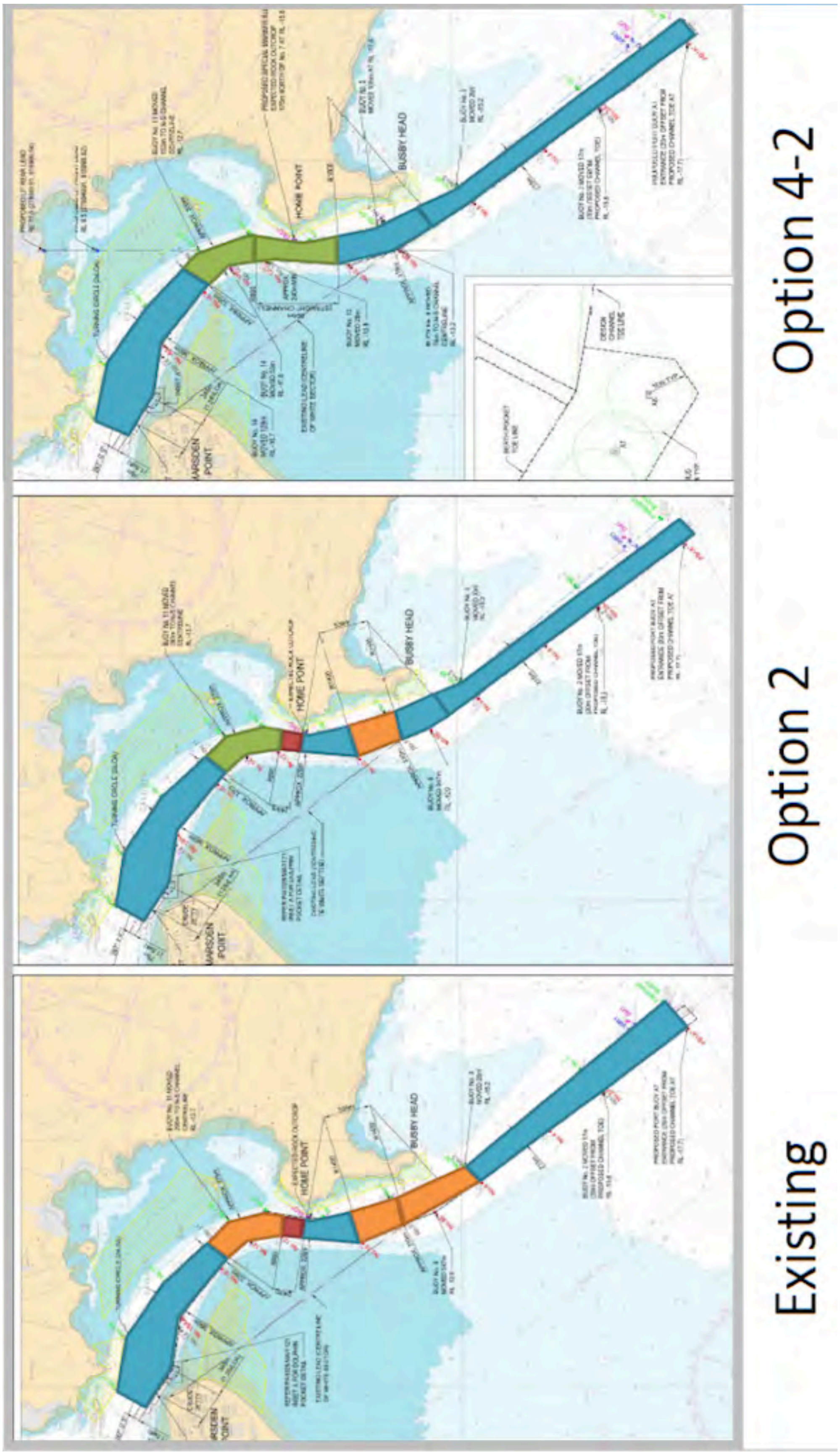


Figure 6 - Channel classification against PIANC

	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

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.

Existing	Option 2	Option 4.2
	Less complexity	**Least Complex**

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

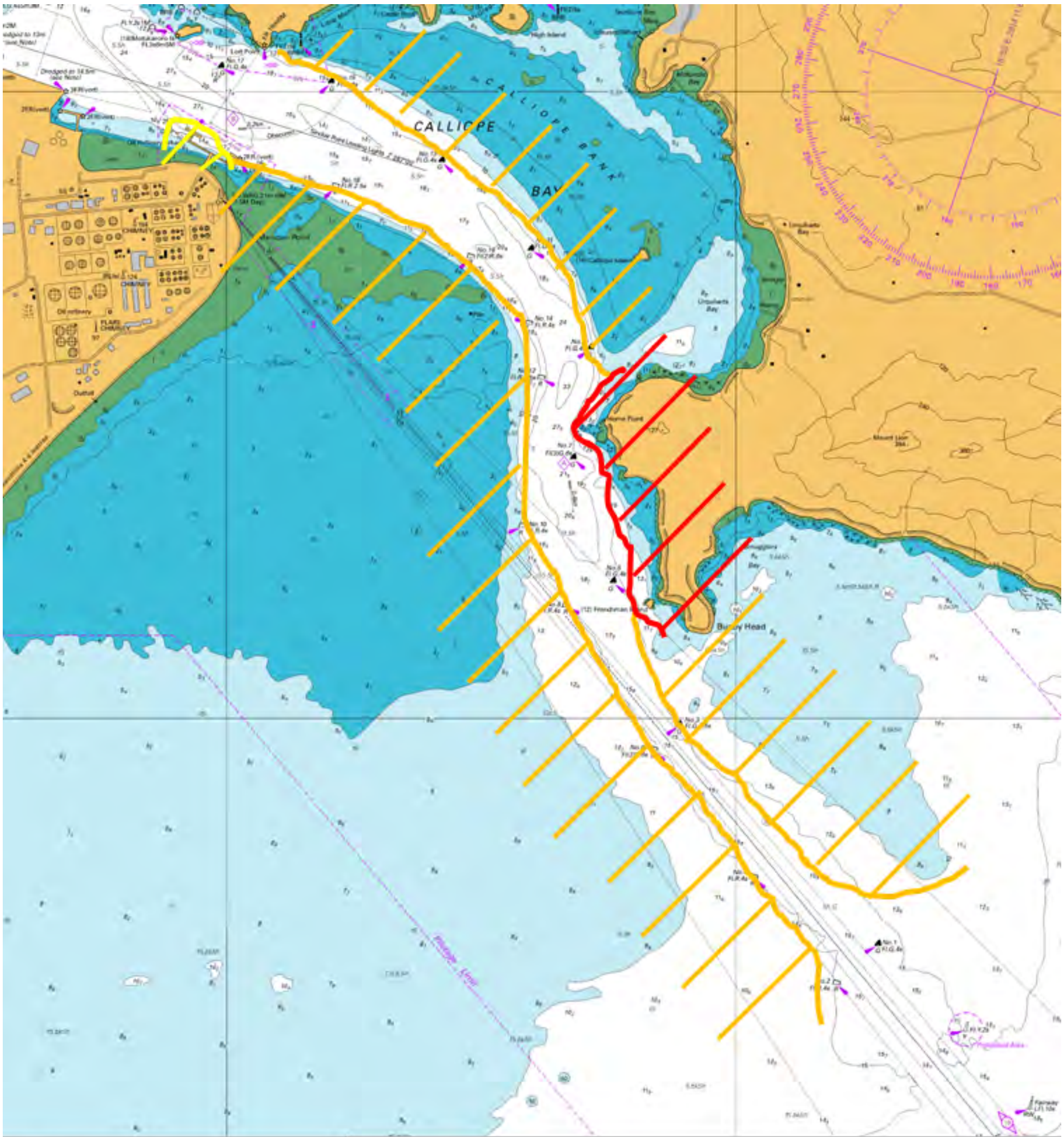
Given the high pressures and potential cutting action, grounding on rock would be expected to cause considerably more damage than grounding on sand. This damage would be to the fore part of the ship, causing major damage to the forward hull plates and structure leading to flooding of the ship's forepeak. 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:



Key:
Red: Rock, higher
Orange: Sand, medium
Yellow: Wharf, lower

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.

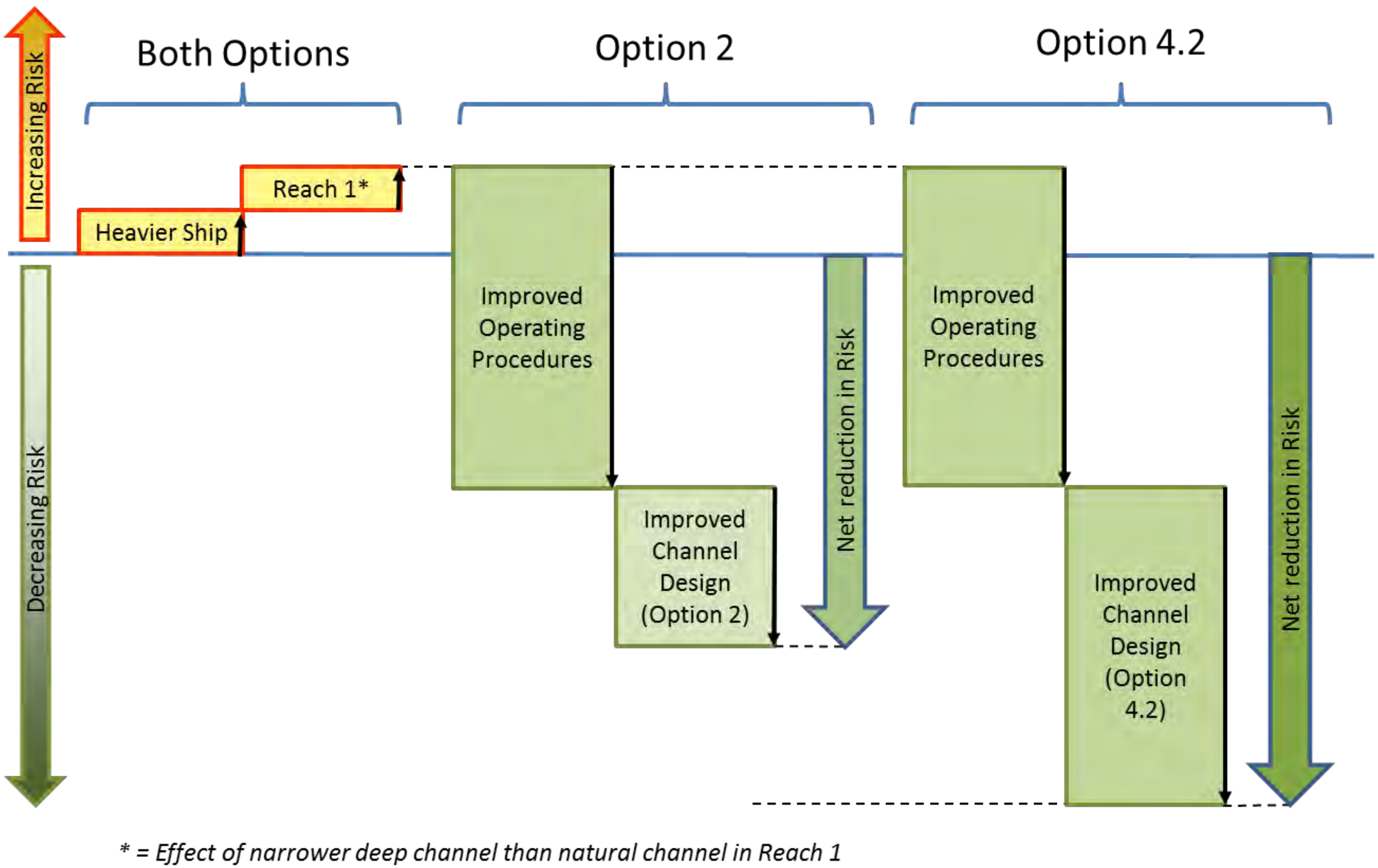


Figure 9 - Overall Change in Risk - Full laden Suezmax Tankers

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

Prepared for:

Refining NZ

Prepared by:

Navigatus Consulting Limited

Level 2, 347 Parnell Road

PO Box 137249

Parnell, Auckland 1052

+64 9 377 4132

www.navigatusconsulting.com

Quality Control

Prepared by: Kevin Oldham and Matt Bilderbeck (Navigatus Consulting)

Reviewed by: Geraint Bermingham (Navigatus Consulting)

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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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.

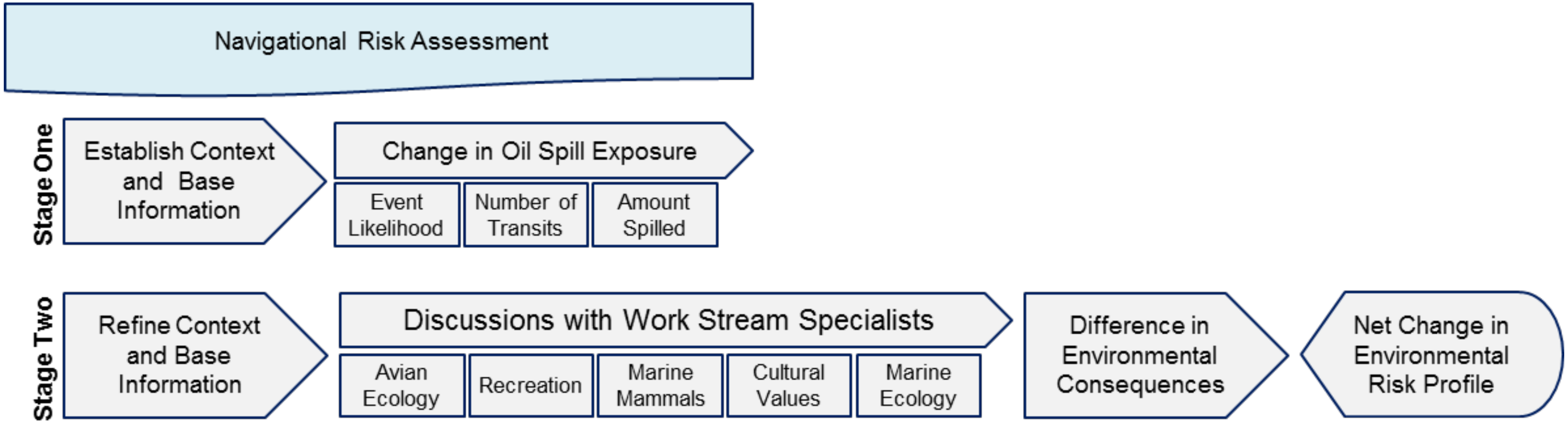
This study employs a differential assessment approach comparing two scenarios: essentially being operations with and without the engineered channel. The assessment addresses operating risk when the channel works are complete and is based on an assumption that any associated operational regime changes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

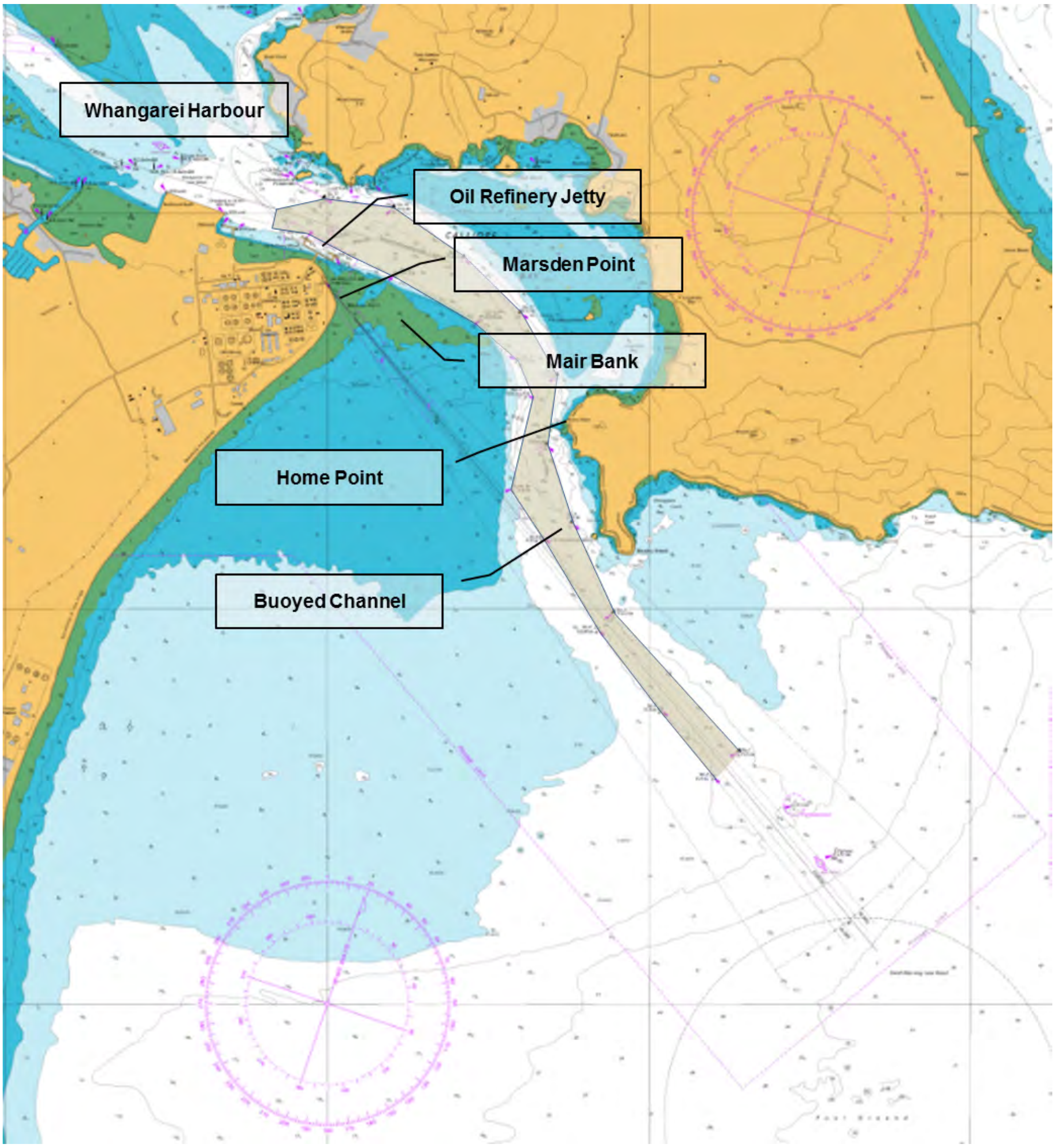
4.1. Background

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

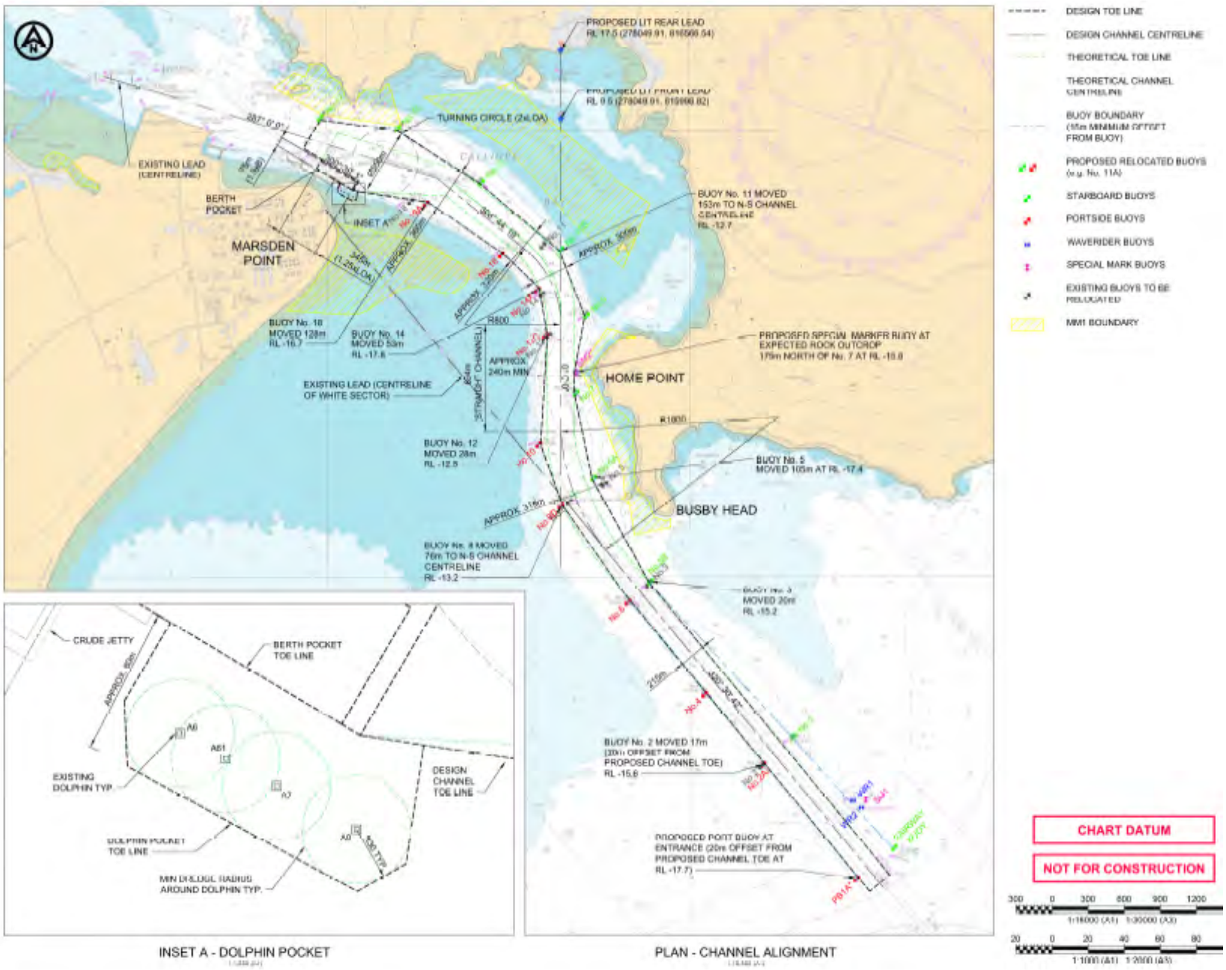
Refining NZ commissioned studies (Royal HaskoningDHV, 2016; Tonkin + Taylor, 2016) that considered several channel design options and led to a shortlist of two designs labelled Option 2 and Option 4-2. The navigational risk assessment undertaken by Navigatus considered the navigational risk profiles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

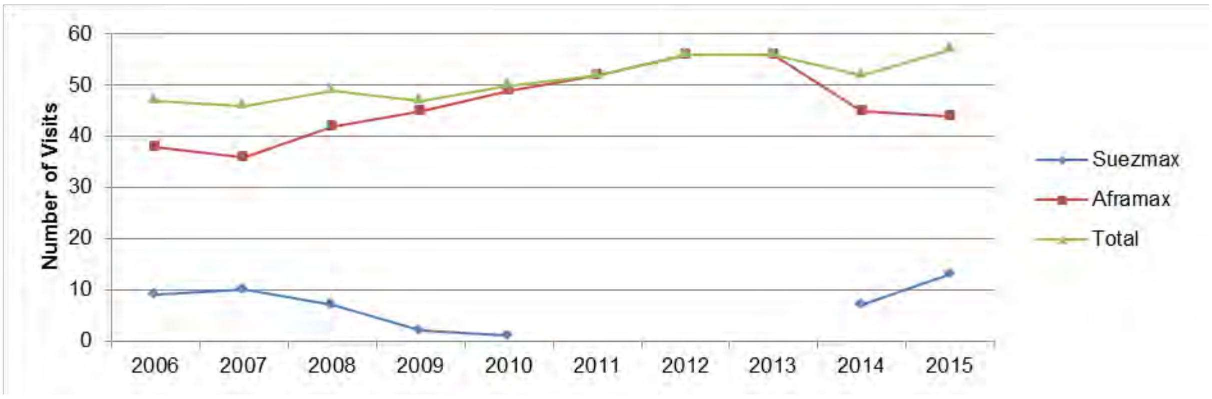
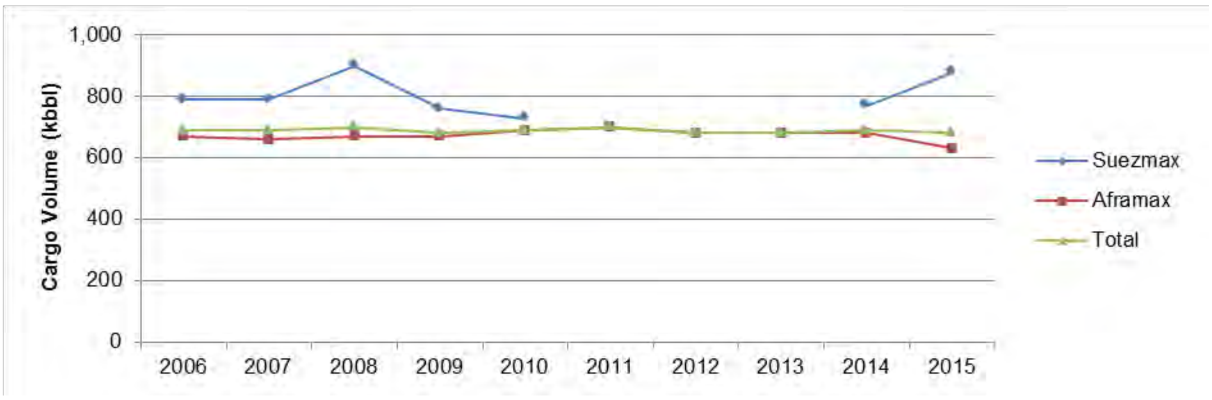


Figure 4.4 – Yearly Average Tanker Cargoes 2006-2015



[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

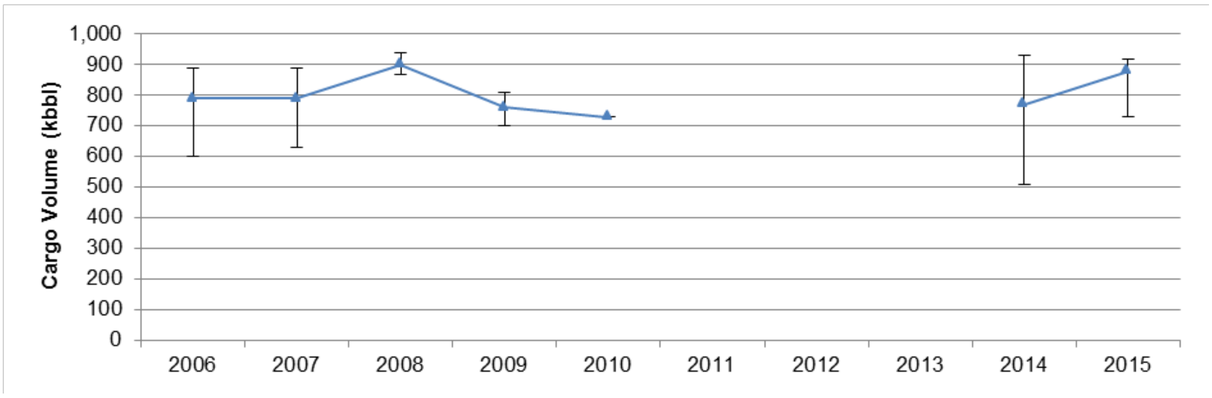
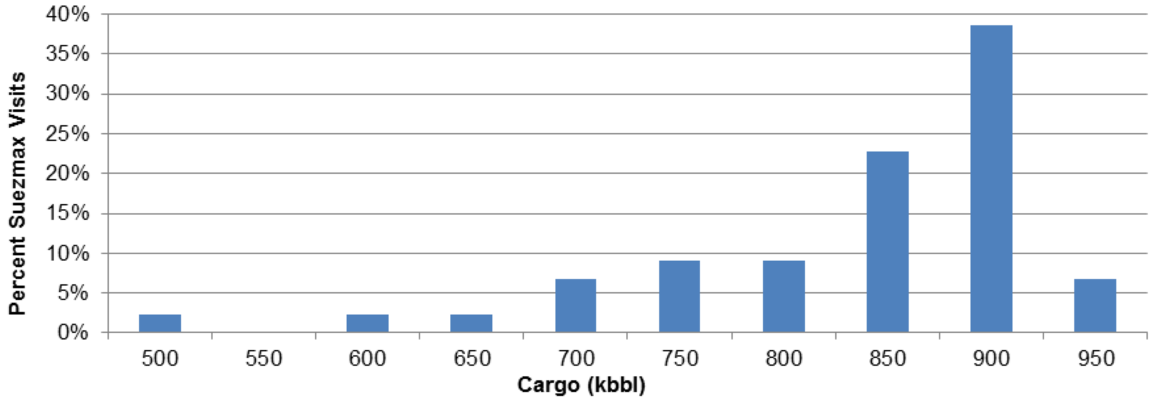


Figure 4.6 shows the distribution of historical Suezmax cargo size from 2006-2015.

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).*

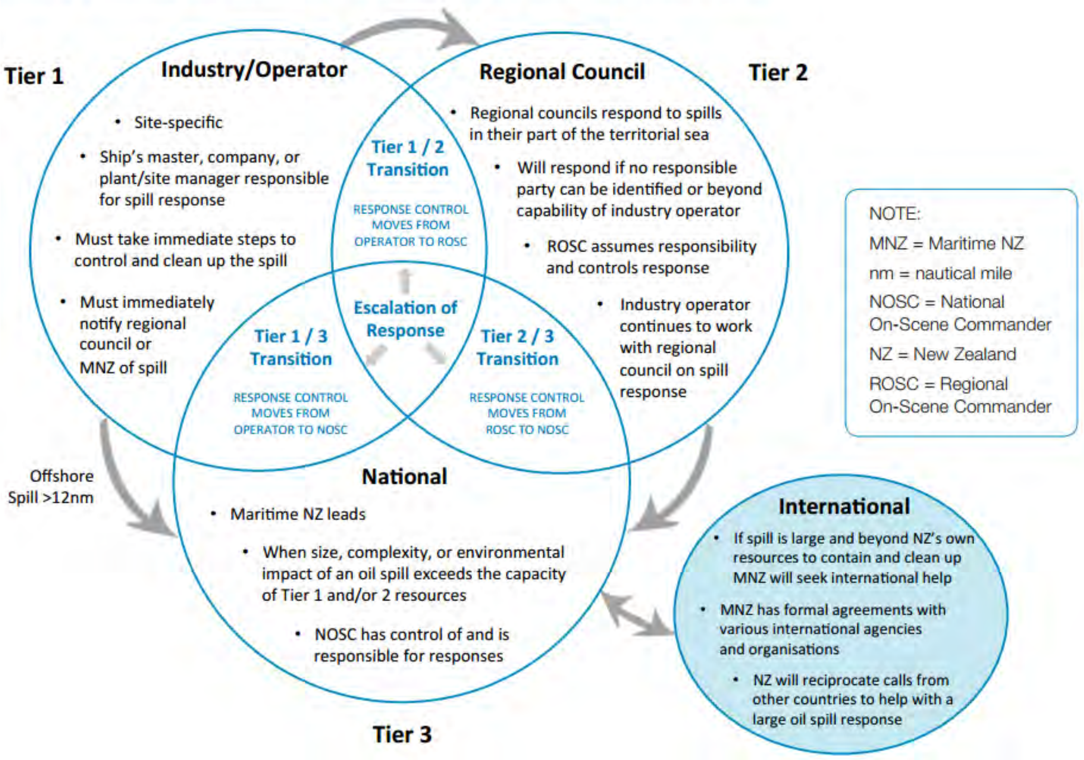
4.4. Response Capability

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.

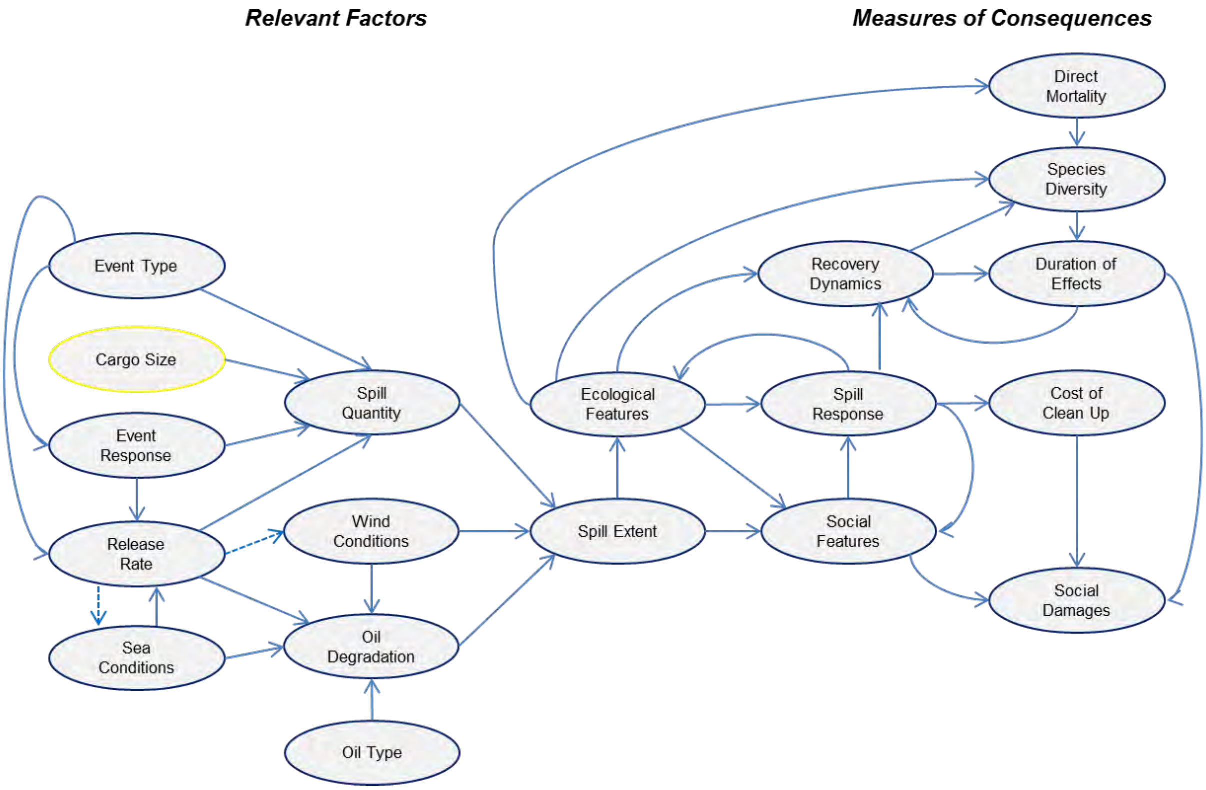
Social damages include:

- 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

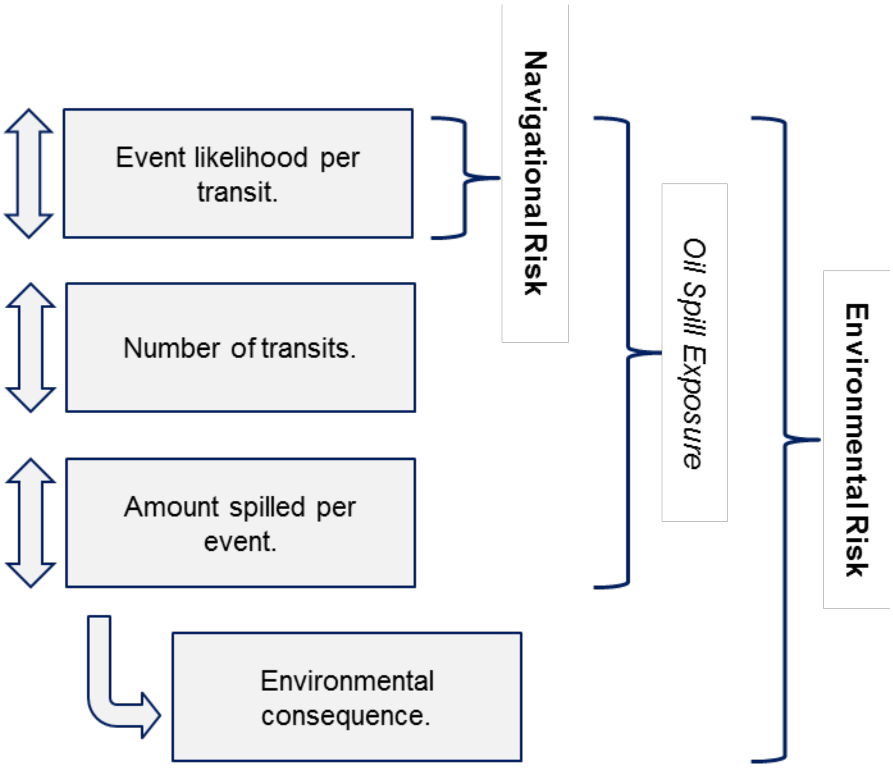
Risk is defined as the combination of likelihood and consequence. In the case of oil spills these elements can be further broken down to improve understanding.

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

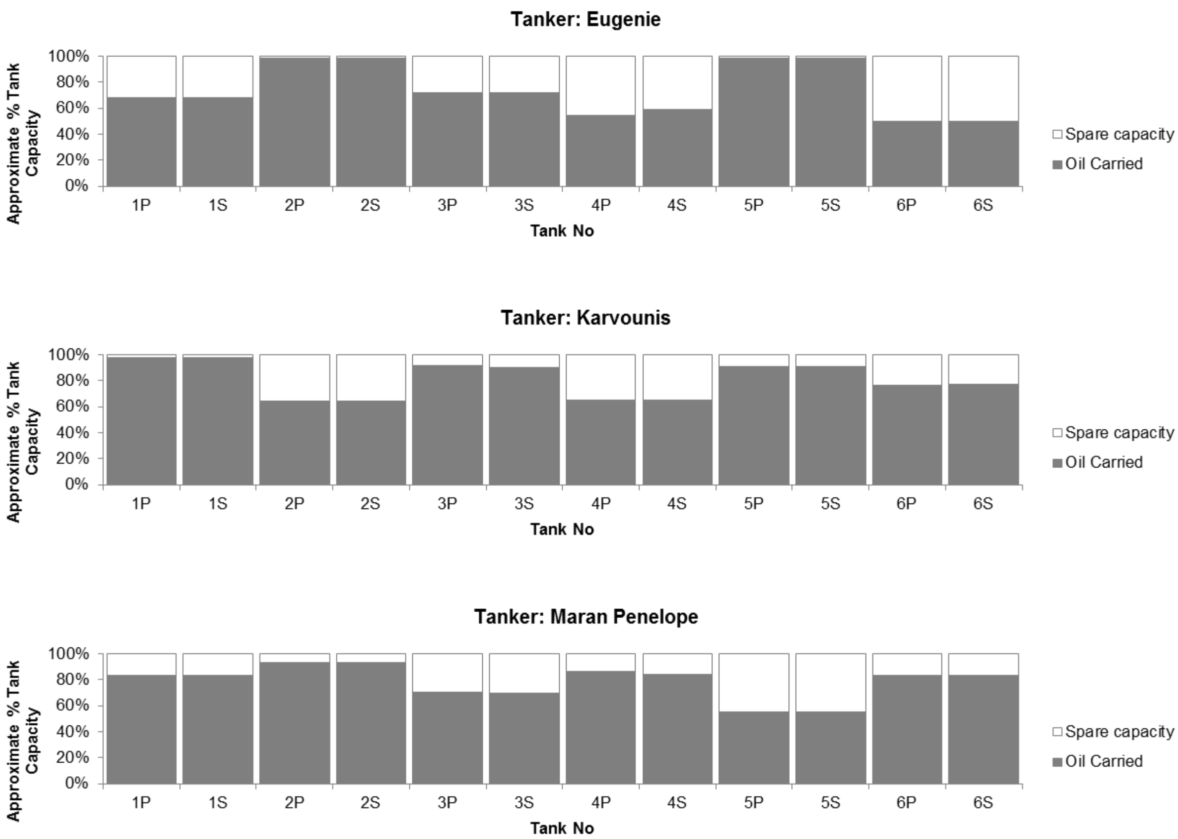
Overview

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.

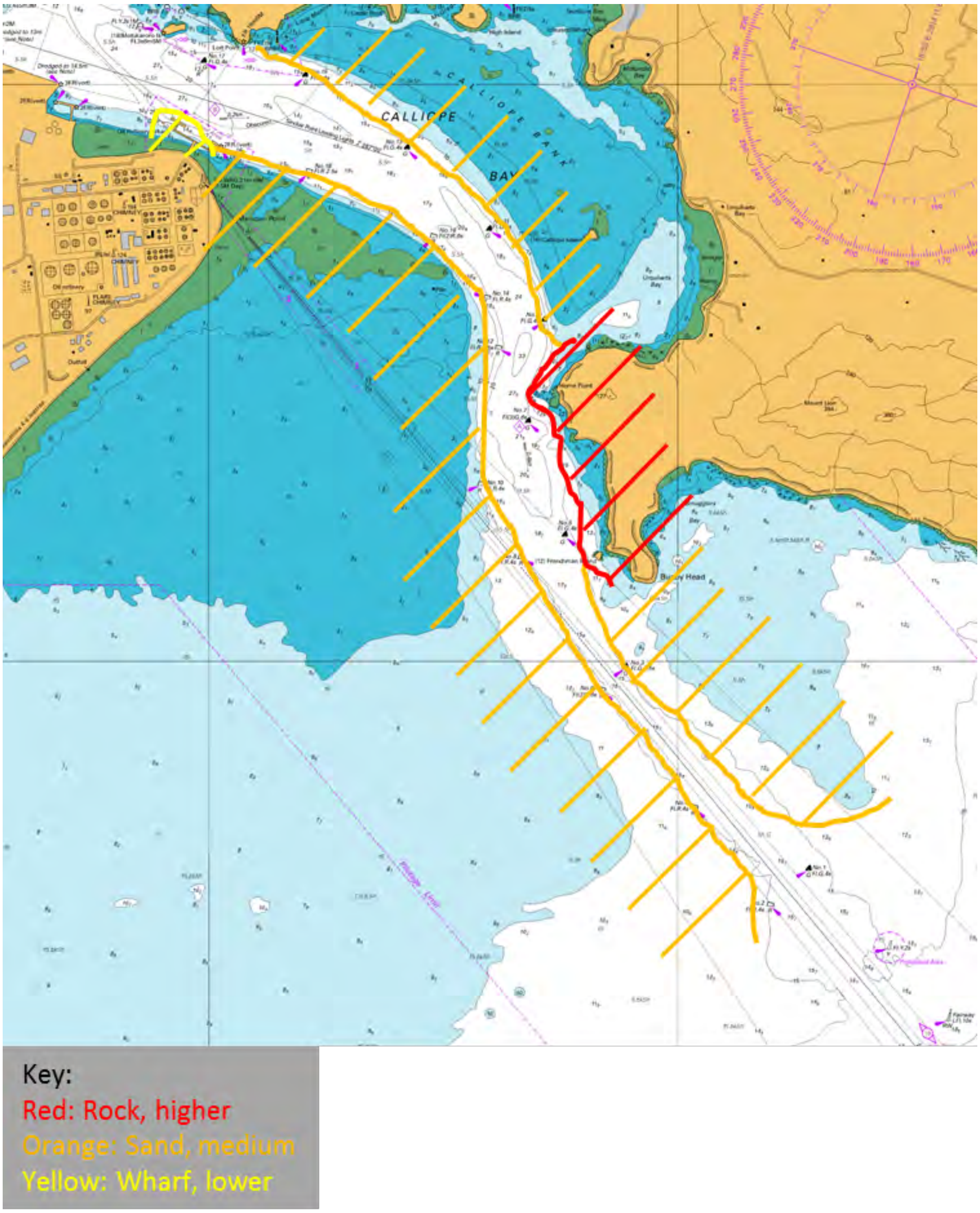
Although this contention has some validity, there are other significant factors to consider such as tides, oil being trapped in the double hull space, the effects of "pumping" due to wave action and the exact nature and location of the event.

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

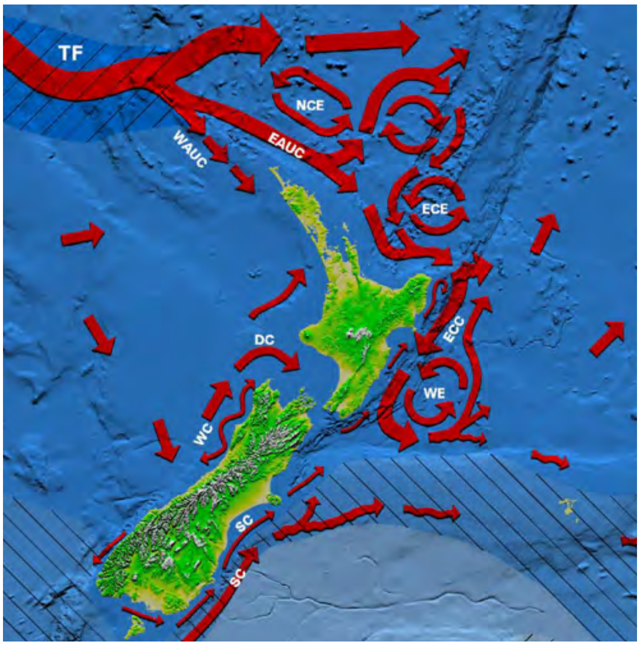
If oil is released at a rapid rate immediately following the spill then much of the oil spilled will travel out to sea on the ebb tide. This provides more time to mobilise oil spill response resources and will result in less oil arriving in the more sensitive inner harbour areas than would be the case 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



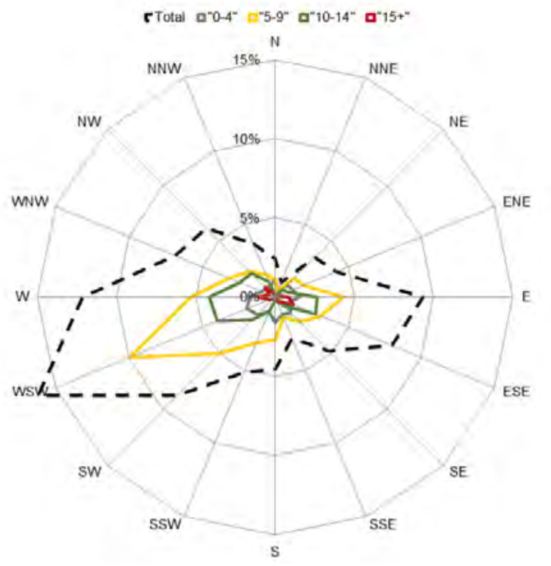
Source: http://calib.qub.ac.uk/marine/currents/NewZealand.html

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.

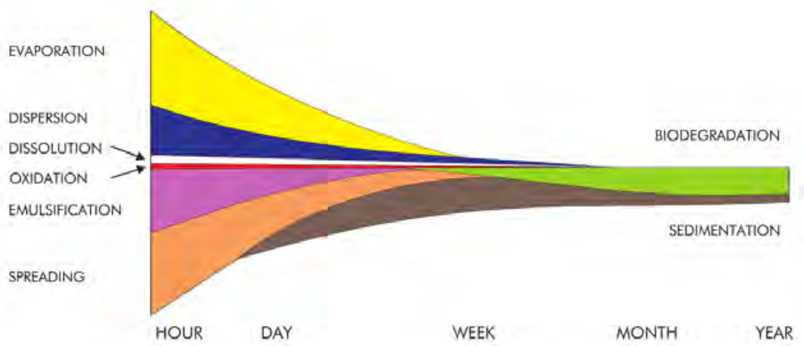
Figure 7.5 - Mokohinau AWS Wind Rose 2000-2012 Inclusive



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

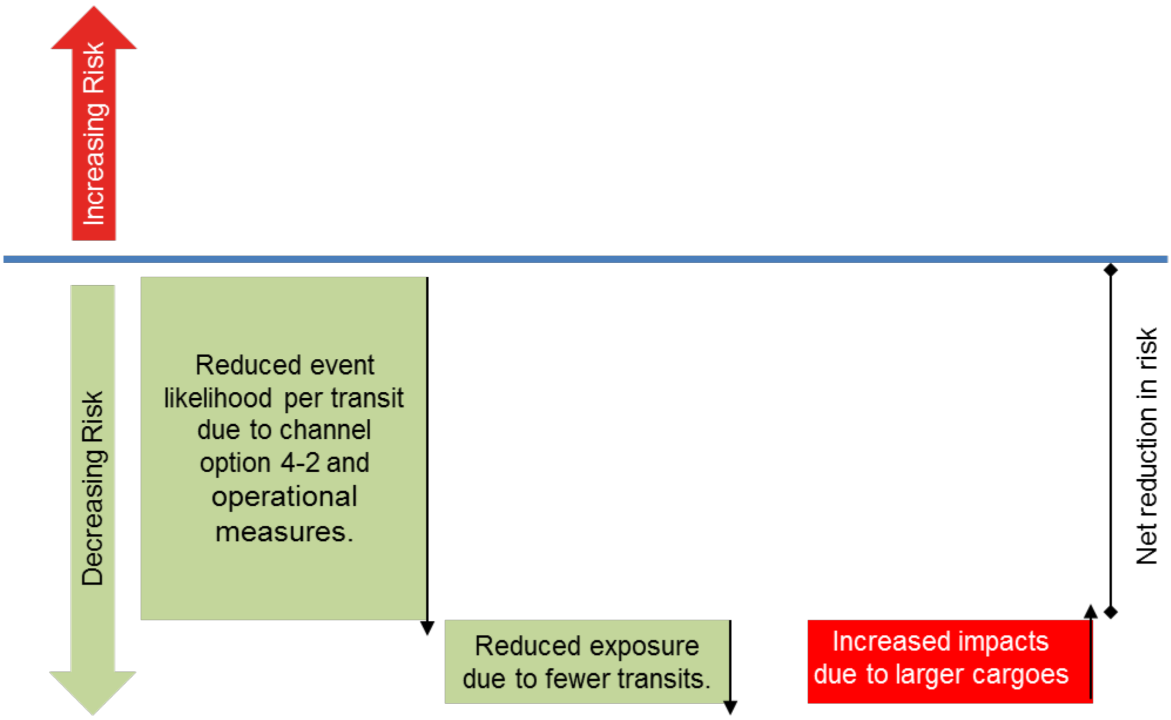
ID	Factor	Comment
A	Difference in event likelihood per transit.	Appendix A.1. Use Case A: Significant reduction in event likelihood. Use Case B: The implementation of Option 4.2 and operational measures will significantly reduce the likelihood of an event for each transit compared to current operations.
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:

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

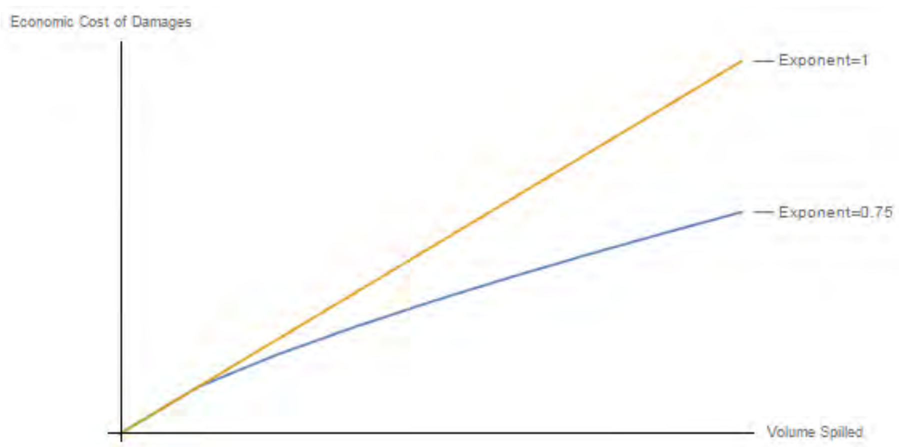


Table 10.1 – Example of Damages vs. Volume Relationship, Exponent = 0.65, 0.75, 0.85

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

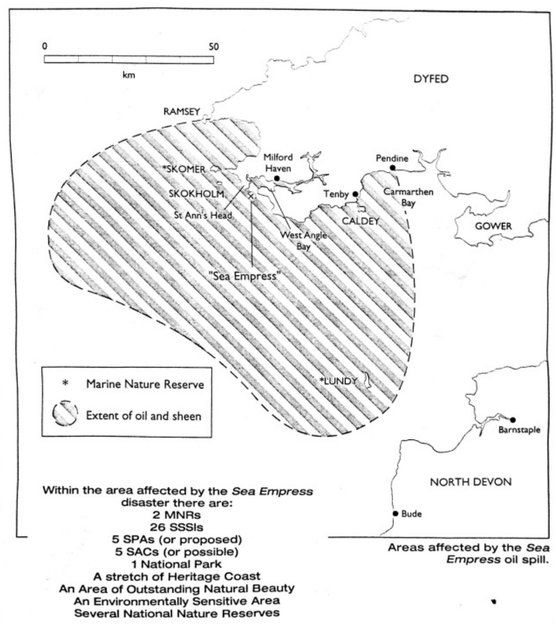
On 15 February 1996, the single hulled oil tanker Sea Empress, carrying 130,000 tonnes of Forties Blend North Sea crude oil, ran aground in the channel to Milford Haven refinery in South-West Wales.

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

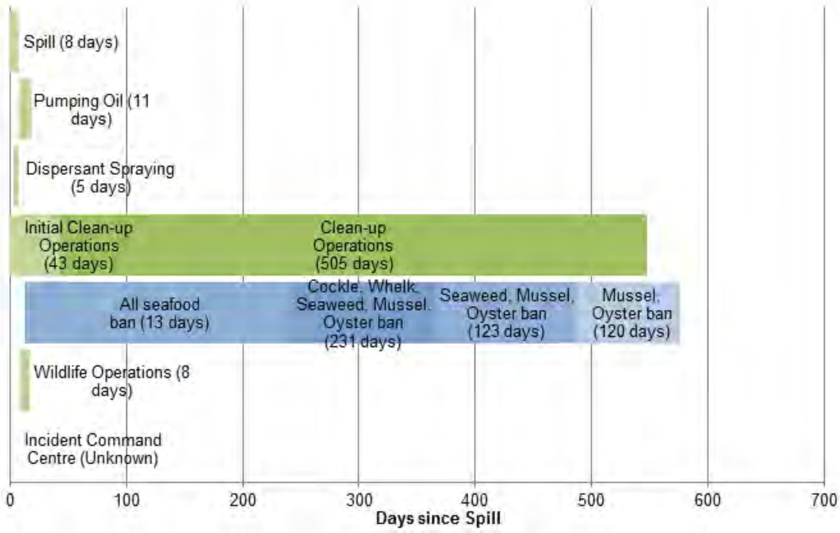
At that time, the site was the only coastal national park in the UK, with 35 Sites of Special Scientific Interest and one of only 3 UK marine nature reserves. It was also a site of special European status to conserve rare and vulnerable birds. Initial operations with 1,000 workers cleaned all amenity 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

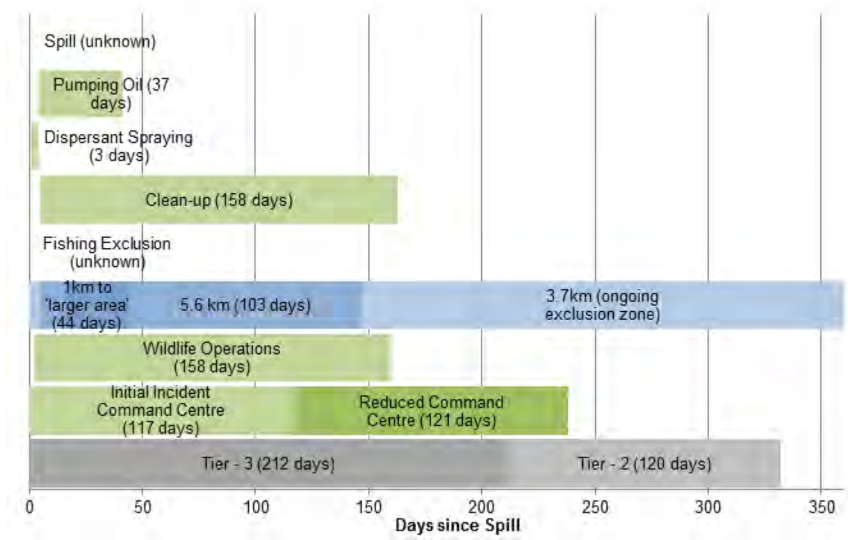
Flora	Short Term Effect	Recovery
Subtidal seagrass (*Zostera marina*)	No discernible effects.	Hydrocarbon analysis of sediment samples from the bed, found that concentrations were low and concluded that the growth of *Z. marina* was not adversely affected.
Intertidal seagrass (*Zostera angustifolia*)	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.

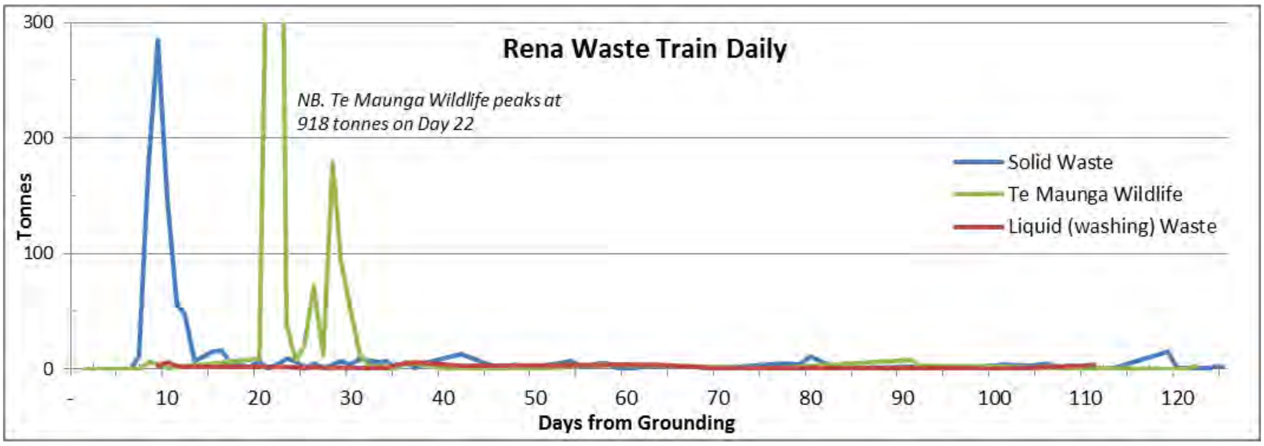
Ship/Installation	Sea Empress	**Location**	Milford Haven, South-west Wales
Relevance	Large volume oil spill in temperate waters.		
Date	15 February 1996		
Timeline			
Spilled Oil	72,000 tonnes of light crude oil was released over a period of 7 days of which 3,700 to 5,300 tonnes reached 200 km of shore (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**

Styles Group
Acoustics & Vibration Consultants

P. 09 308 9015
E. info@stylesgroup.co.nz
W. www.stylesgroup.co.nz
Saatchi & Saatchi Building,
L2, 125 The Strand, Parnell
PO Box 37857, Parnell,
Auckland 1151

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

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.

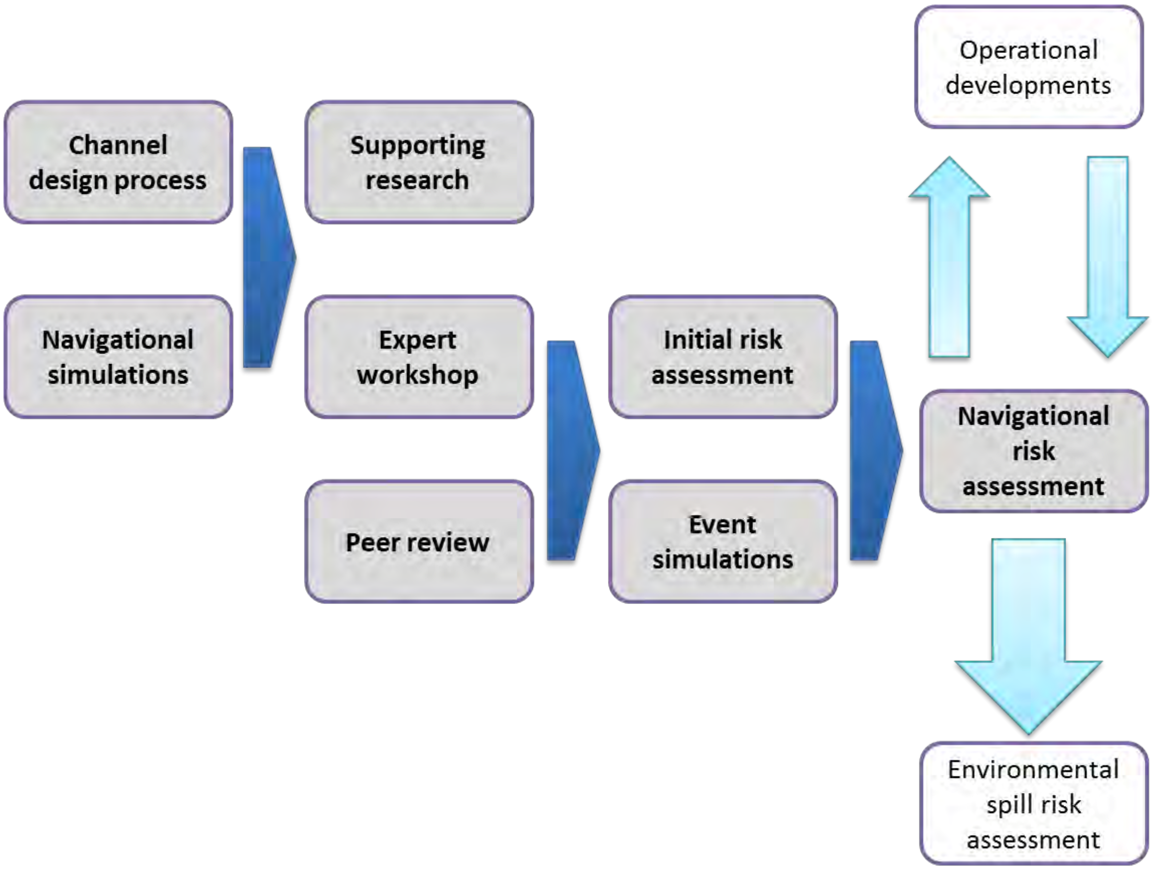


Figure 1 - Overall Process

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.

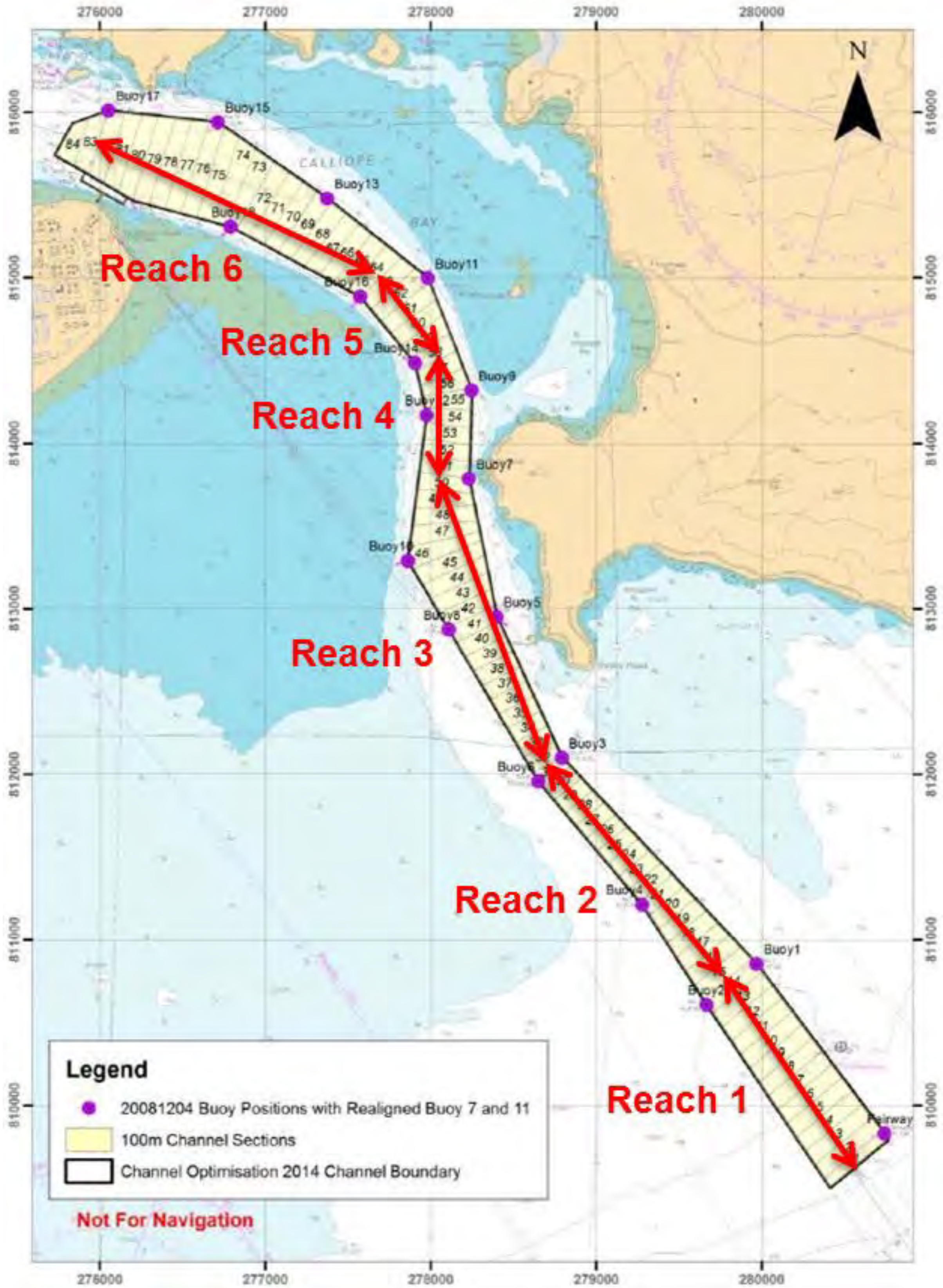


Figure 2 - Existing Channel Design Reaches

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.

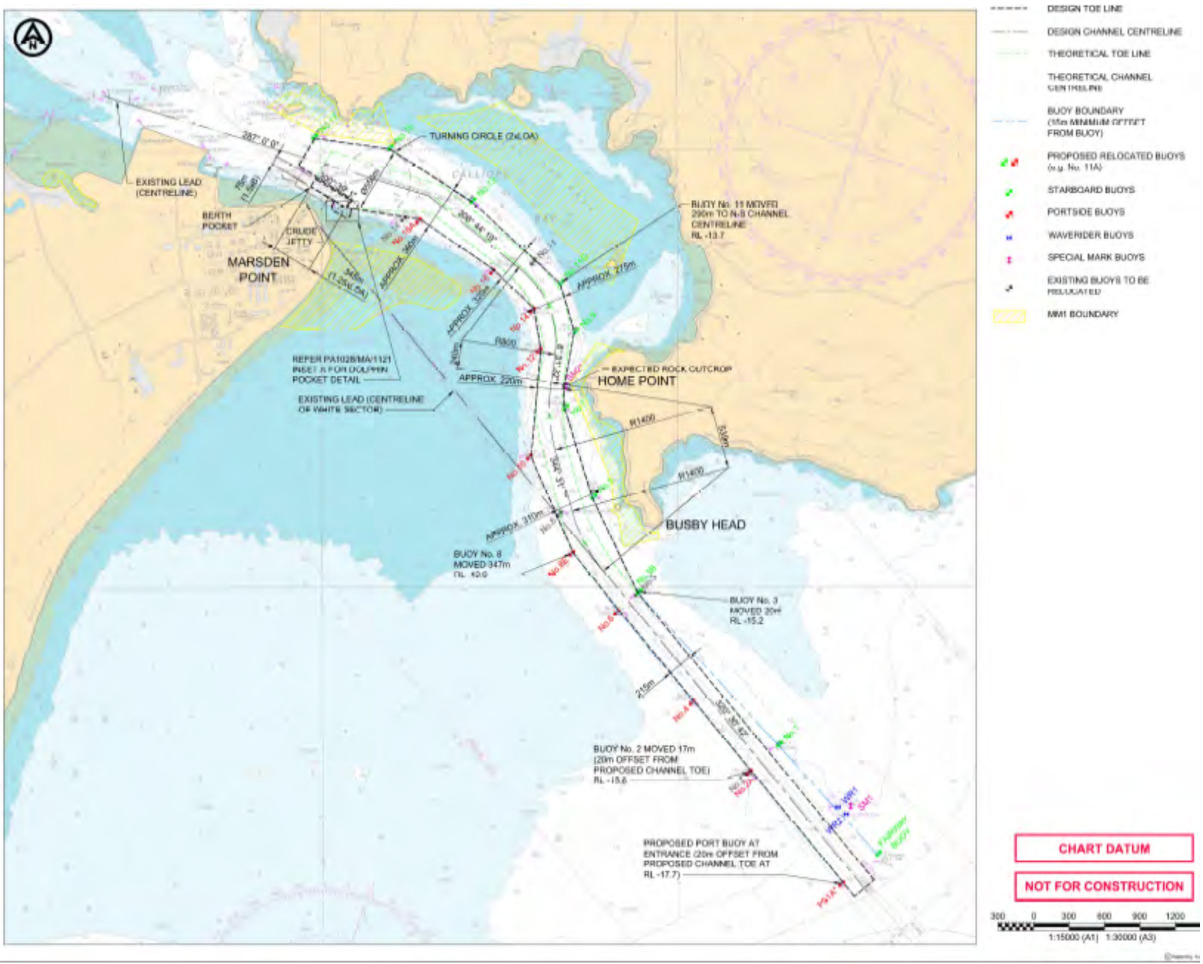


Figure 3 - Option 2 Channel

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.

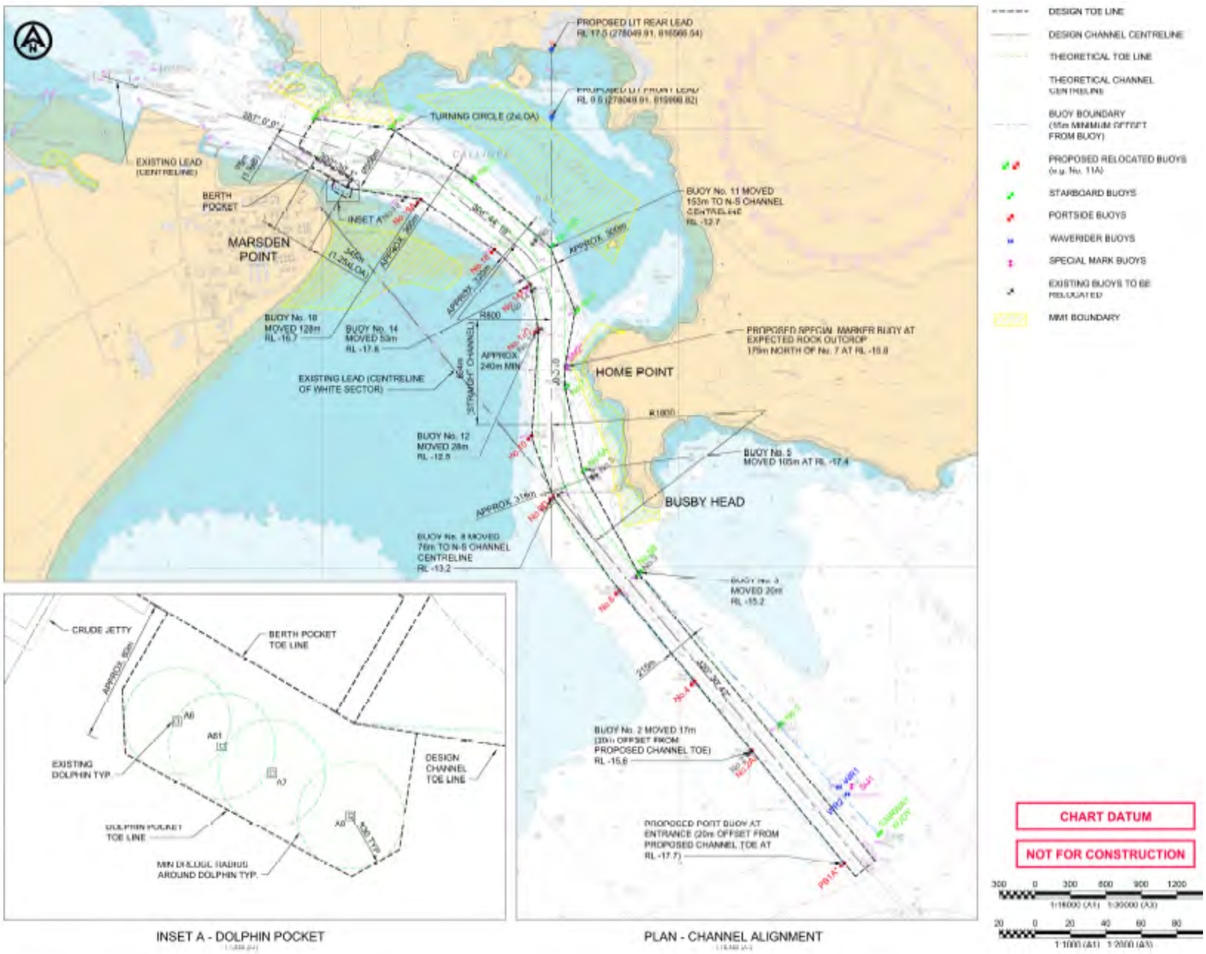


Figure 4 - Option 4.2 Channel

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

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

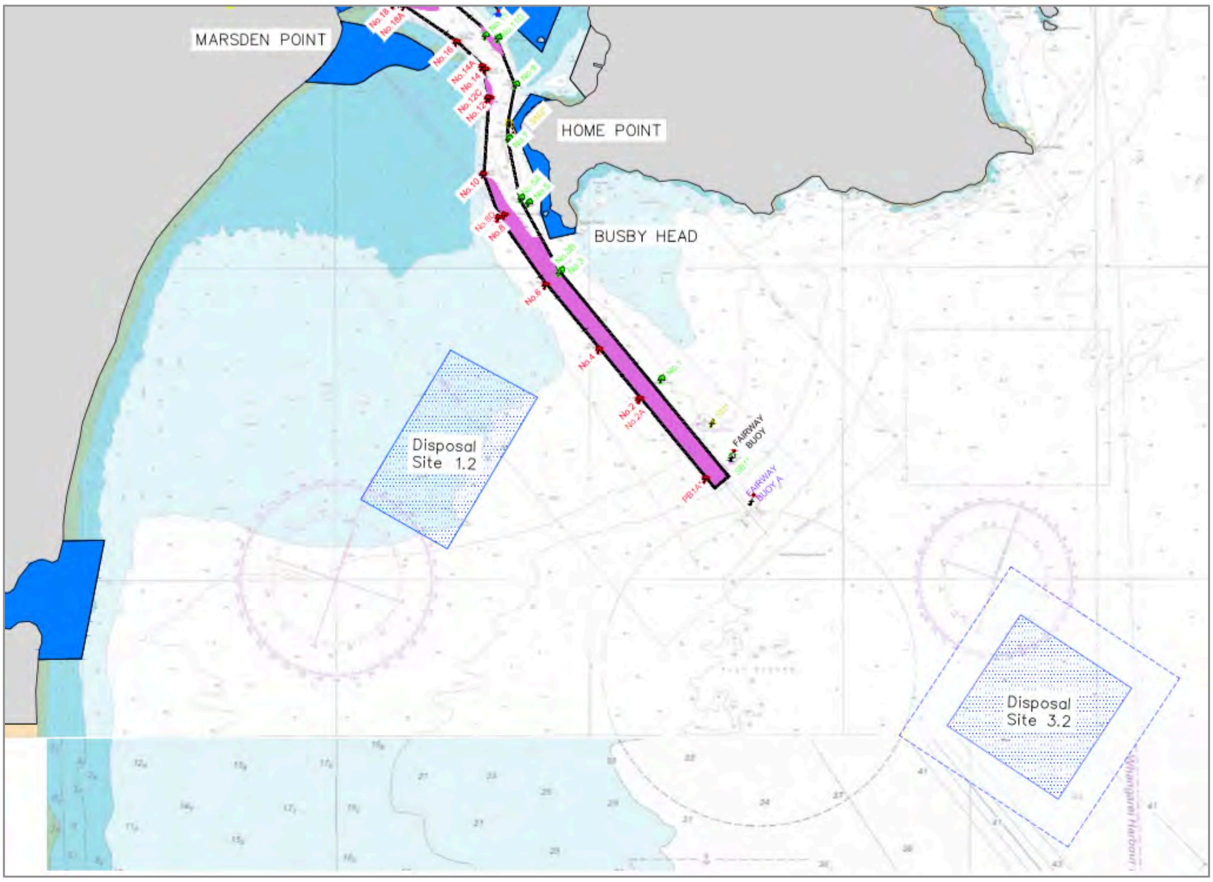

Figure 5 – Dredged material disposal areas

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

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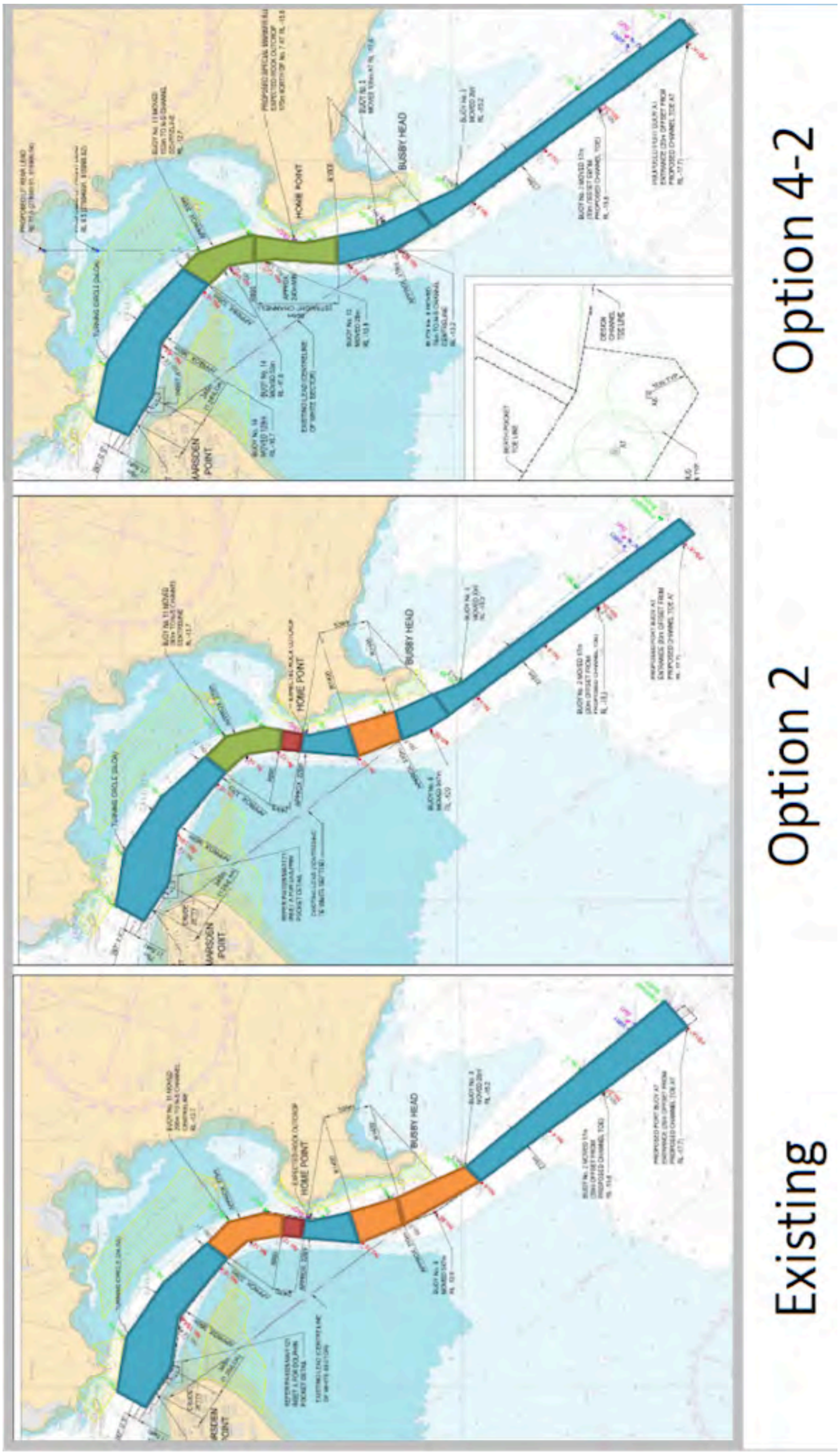
[19] Subsequent full bridge simulations were carried at the Marine Simulation Centre of New Zealand Maritime School, Auckland.
[19] Subsequent full bridge simulations were carried at the Marine Simulation Centre of New Zealand Maritime School, Auckland.

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
(blue)	Optimum	Ideal under both operating and extreme conditions, no issues encountered.	>5*LOA
(green)	Adequate	Very good under operating conditions, manageable under extreme conditions.	<5*LOA>2.5*LOA
(yellow)	Marginal	Adequate under operating conditions but poor under extreme conditions.	<2.5*LOA>1.25*LOA
(red)	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.

Existing	Option 2	Option 4.2
→	**Less complexity** →	→ **Least Complex**

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:

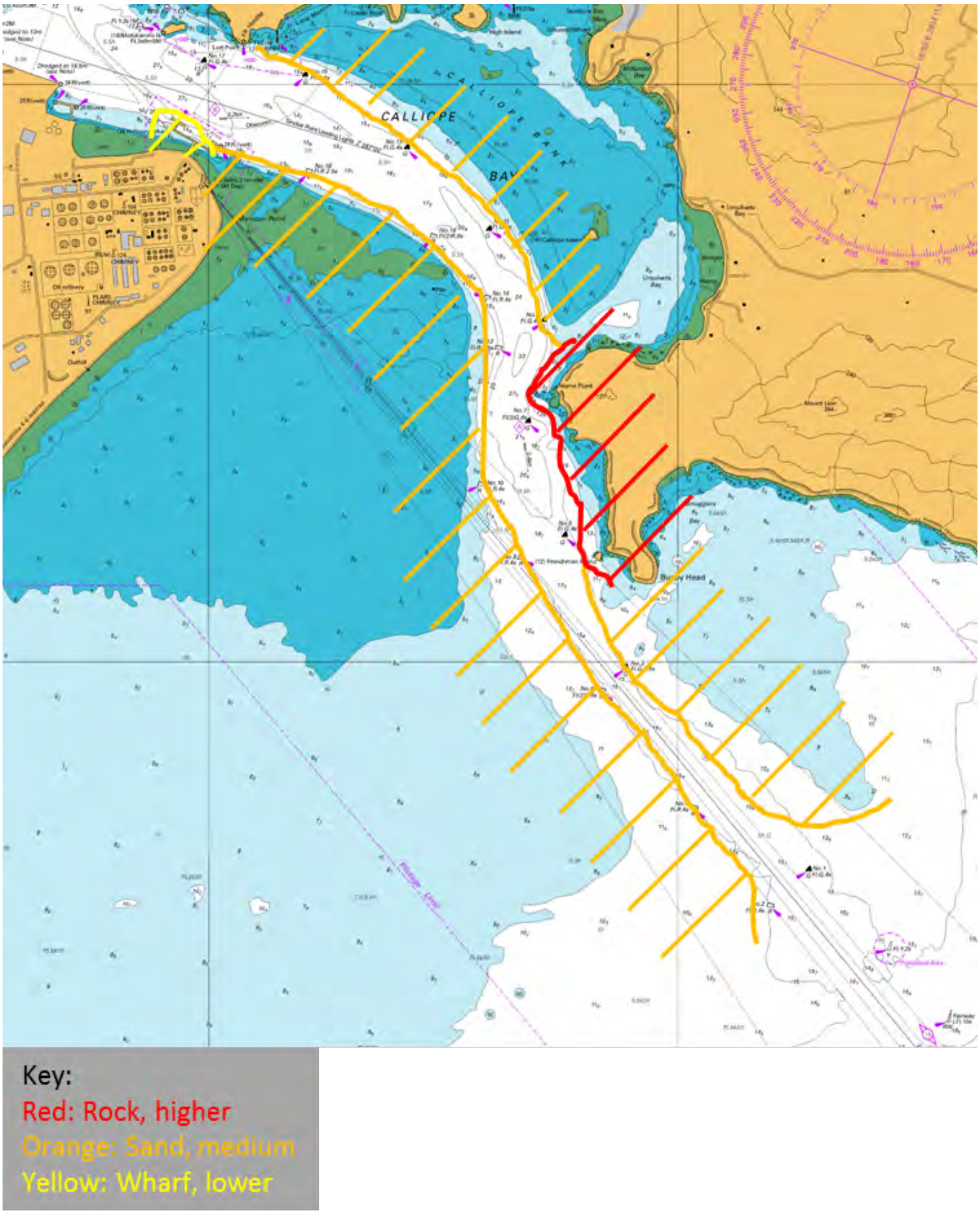


Figure 8 - Consequence Severity and Locations

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

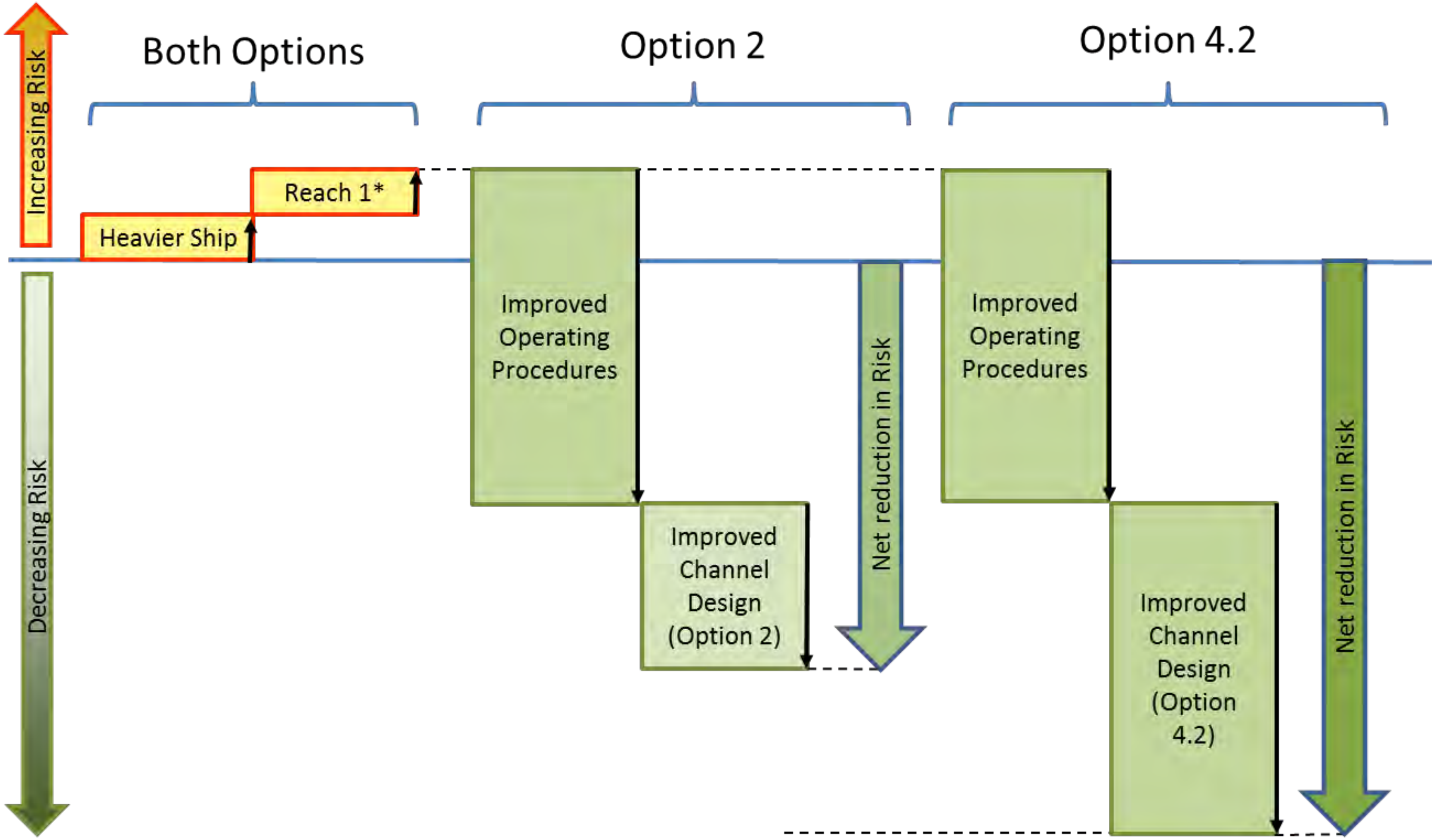
Arrivals – Proposed Tankers							
Reach	1	2	3	4	5	6	Overall Channel
Consequence	Orange	Orange	Red	Red	Orange	Yellow	Orange
Existing Channel							
Risk Factors	N/A						
PIANC	Blue	Blue	Orange	Red	Green	Blue	Green
Overall Risk	N/A						
Option 2							
Risk Factors	↑	↑	↓	↓	-	-	-
PIANC	-	-	-	-	↓	-	-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

NAVIGATUS
CONSULTING

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

Prepared for:

Refining NZ

Prepared by:

Navigatus Consulting Limited

Level 2, 347 Parnell Road

PO Box 137249

Parnell, Auckland 1052

+64 9 377 4132

www.navigatusconsulting.com

Quality Control

Prepared by: Kevin Oldham and Matt Bilderbeck (Navigatus Consulting)

Reviewed by: Geraint Bermingham (Navigatus Consulting)

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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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.

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Appendices:

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, <u>harbour or foreshore works</u>, 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 <u>obstructions to navigation</u>; 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.

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[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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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

Styles Group - Acoustics and Vibrations Consultants
www.stylesgroup.co.nz

BHD Inner Channel: Jetty Area

Easterly Wind

Industrial noise - ISO 9613.1/2, [Weather - Inner_NorthPort 3m/s] , Predictor V11.10

Styles Group - Acoustics and Vibrations Consultants

www.stylesgroup.co.nz

Industrial noise - ISO 9613.1/2, [Weather - Inner_NorthPort 3m/s] , Predictor V11.10

BHD Inner Channel: Jetty Area

Southerly Wind

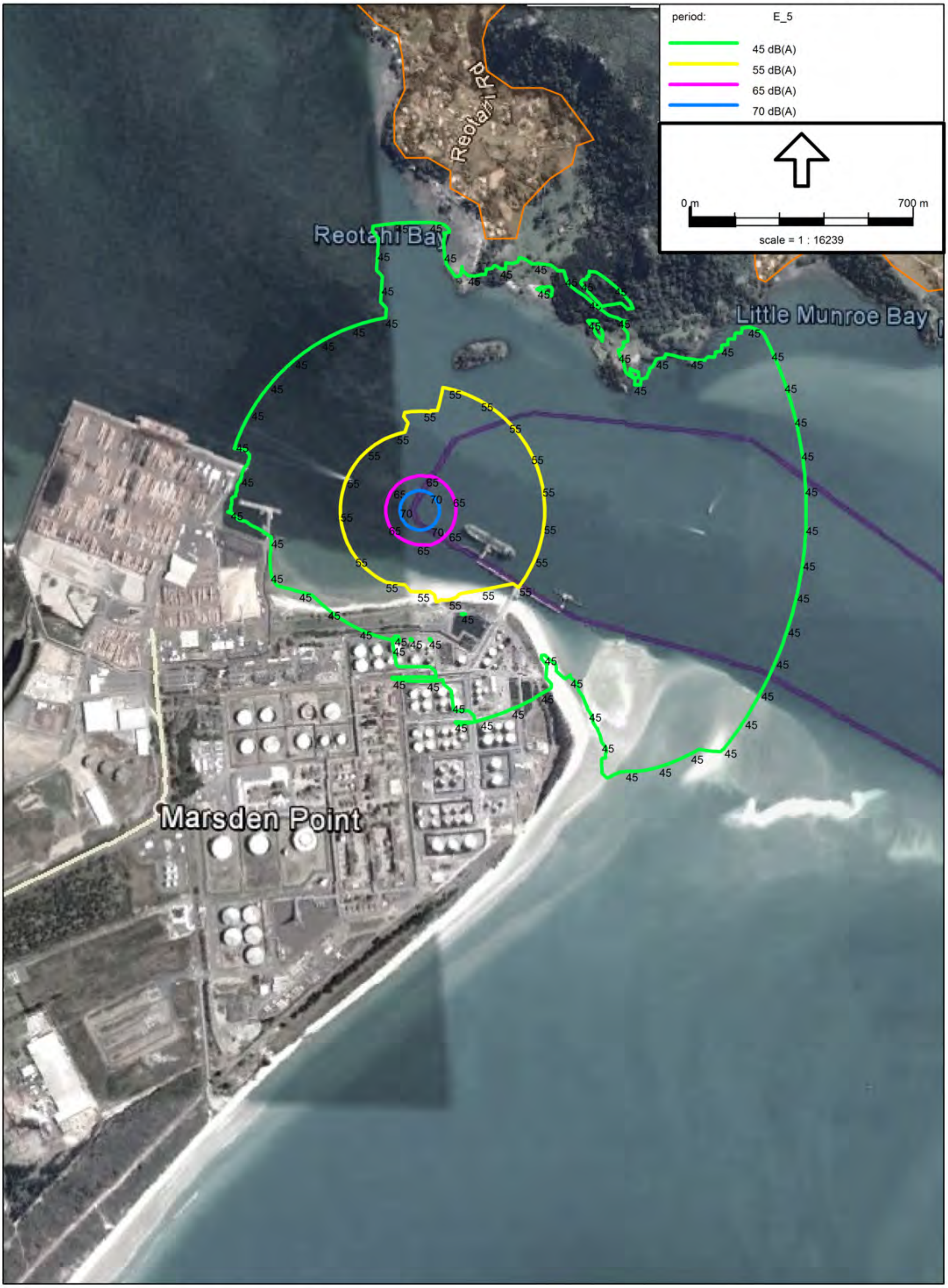
Industrial noise - ISO 9613.1/2, [Weather - Inner_NorthPort 3m/s] , Predictor V11.10

Styles Group - Acoustics and Vibrations Consultants

www.stylesgroup.co.nz

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

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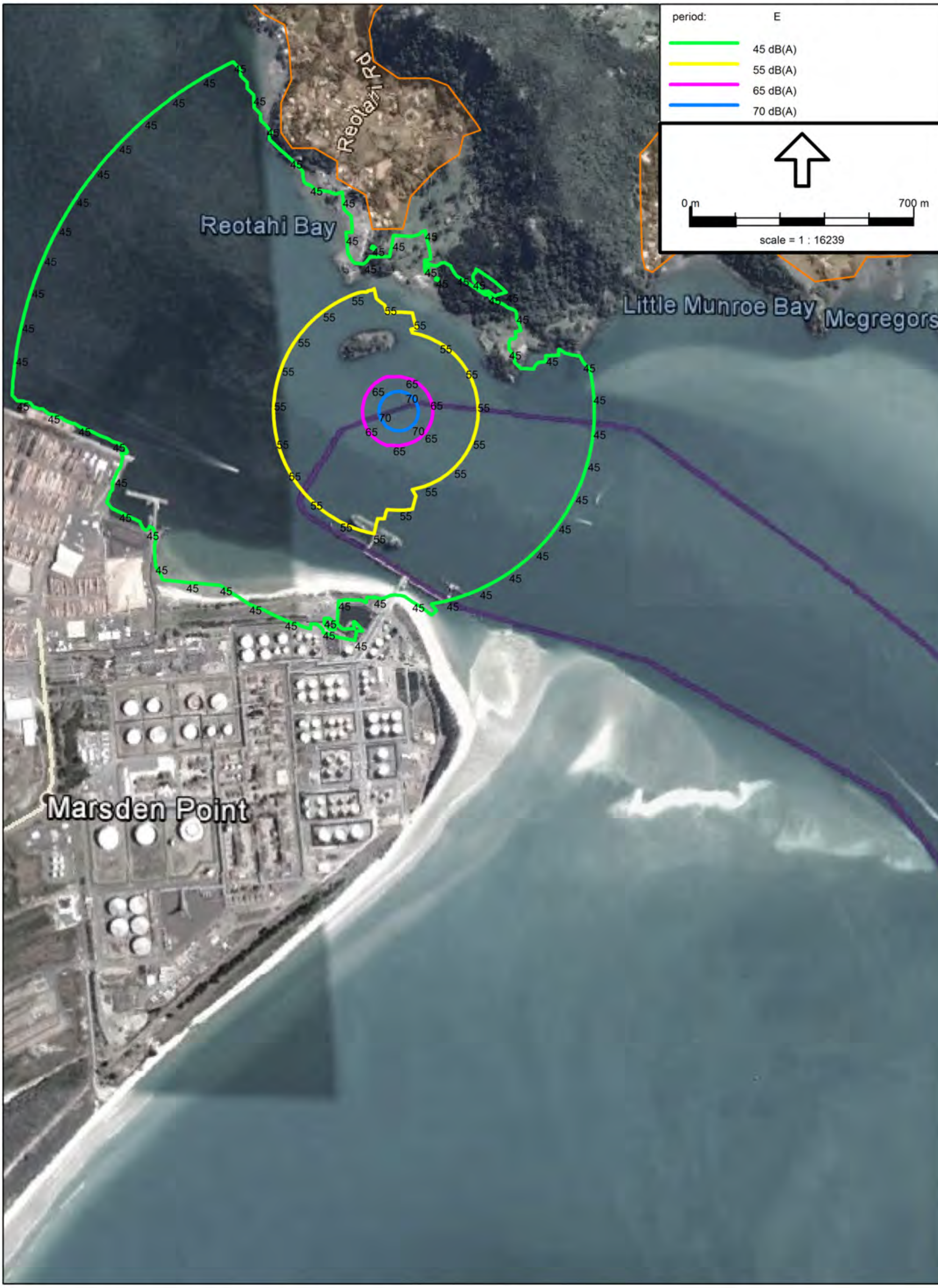
BHD Inner Channel: No.17 Buoy

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

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Industrial noise - ISO 9613.1/2, [Weather - Inner_Pos1a] , Predictor V11.10

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

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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

Styles Group - Acoustics and Vibrations Consultants

www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants

www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants
www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants
www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants
www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants
www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants

www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants
www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants
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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

Styles Group - Acoustics and Vibrations Consultants

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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

Styles Group - Acoustics and Vibrations Consultants

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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

Styles Group - Acoustics and Vibrations Consultants

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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

Styles Group - Acoustics and Vibrations Consultants
www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants

www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants
www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants
www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants
www.stylesgroup.co.nz

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

Styles Group - Acoustics and Vibrations Consultants

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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

Styles Group - Acoustics and Vibrations Consultants
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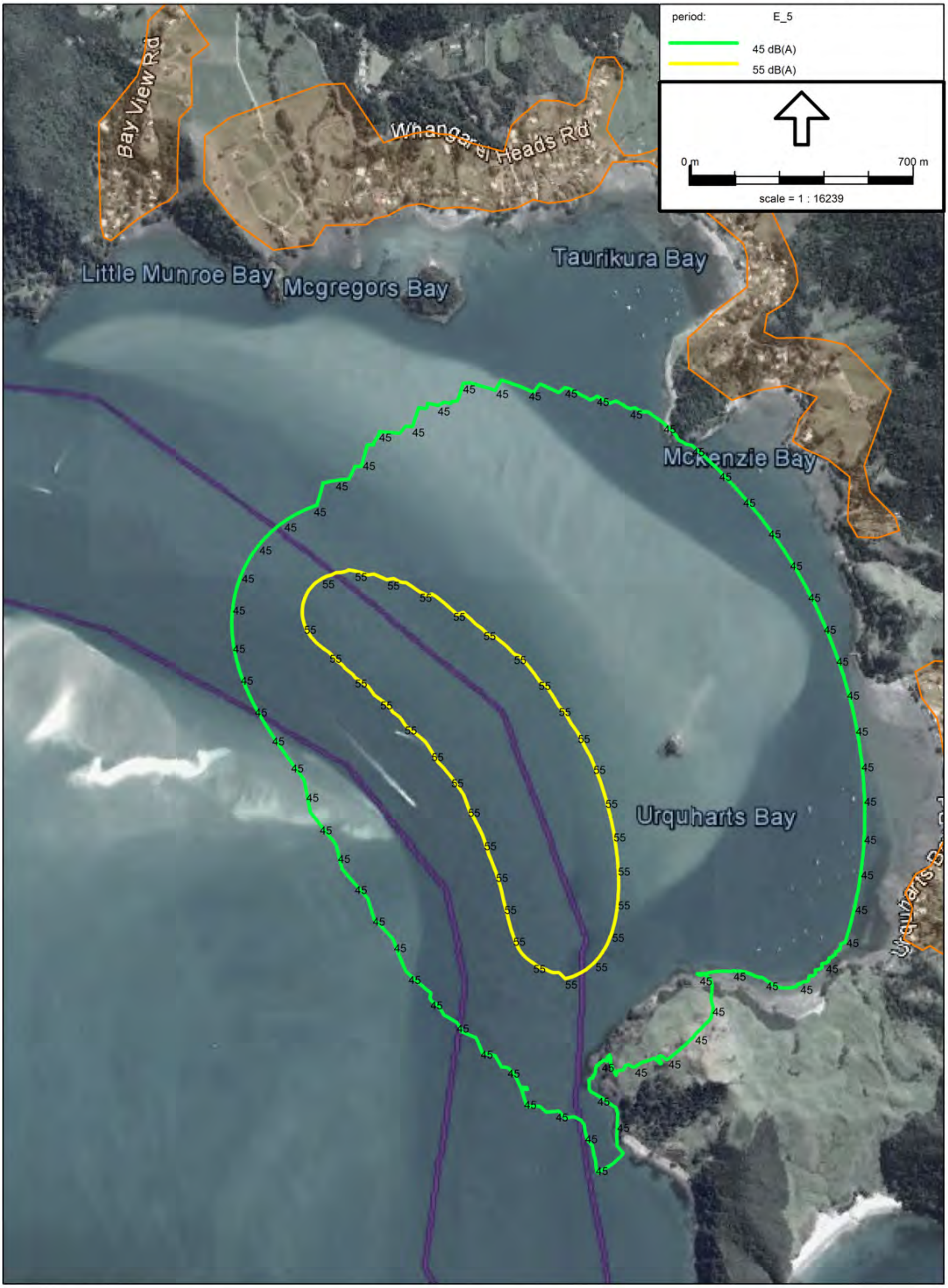
TSHD Mid Channel (Mair Bank): Worst Case Channel Position

Westerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_3_3m/s] , Predictor V11.10

Styles Group - Acoustics and Vibrations Consultants

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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

Styles Group - Acoustics and Vibrations Consultants

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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

Styles Group - Acoustics and Vibrations Consultants

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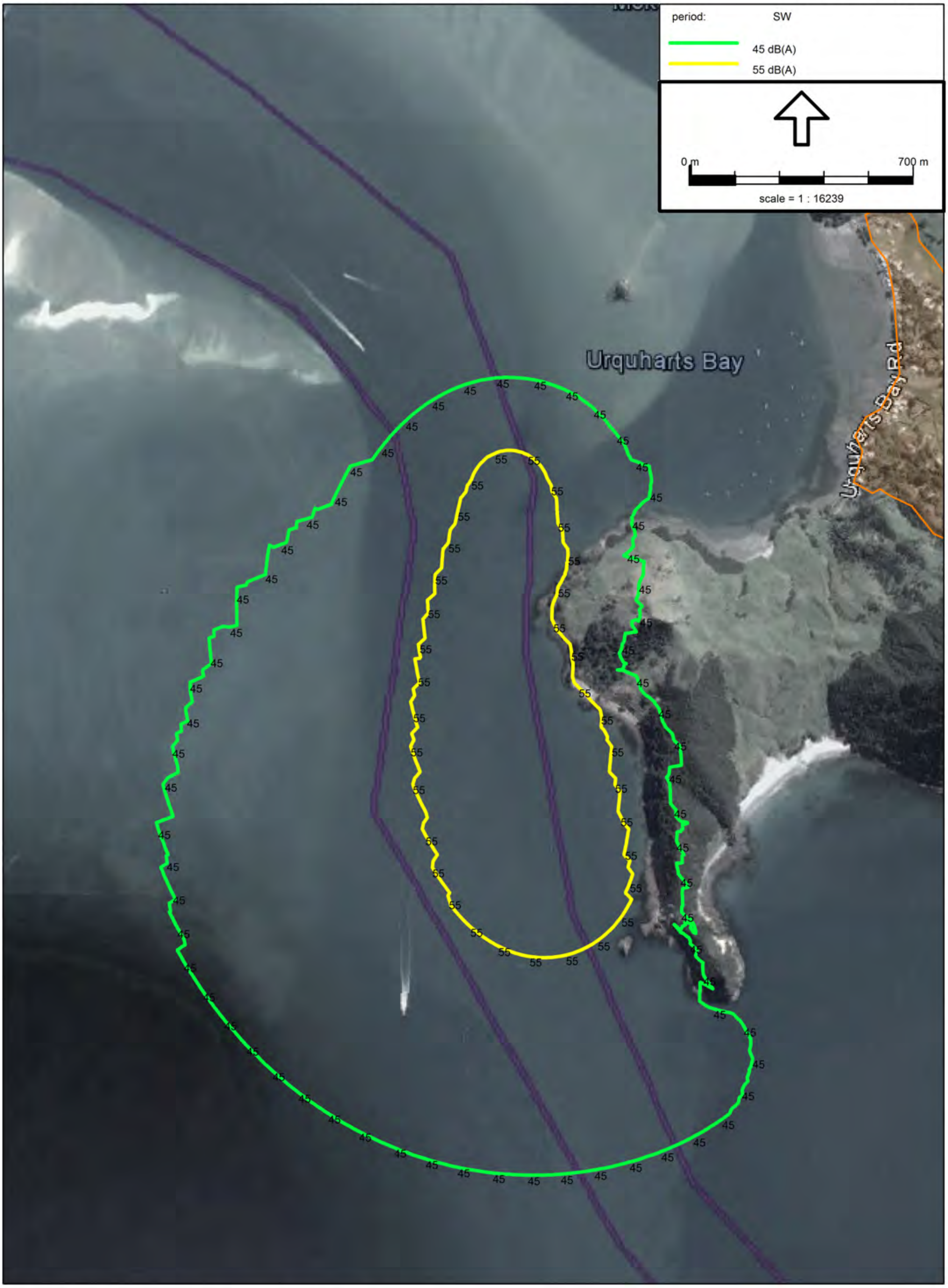
TSHD Mid Channel (Home Point): Worst Case Channel Position

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

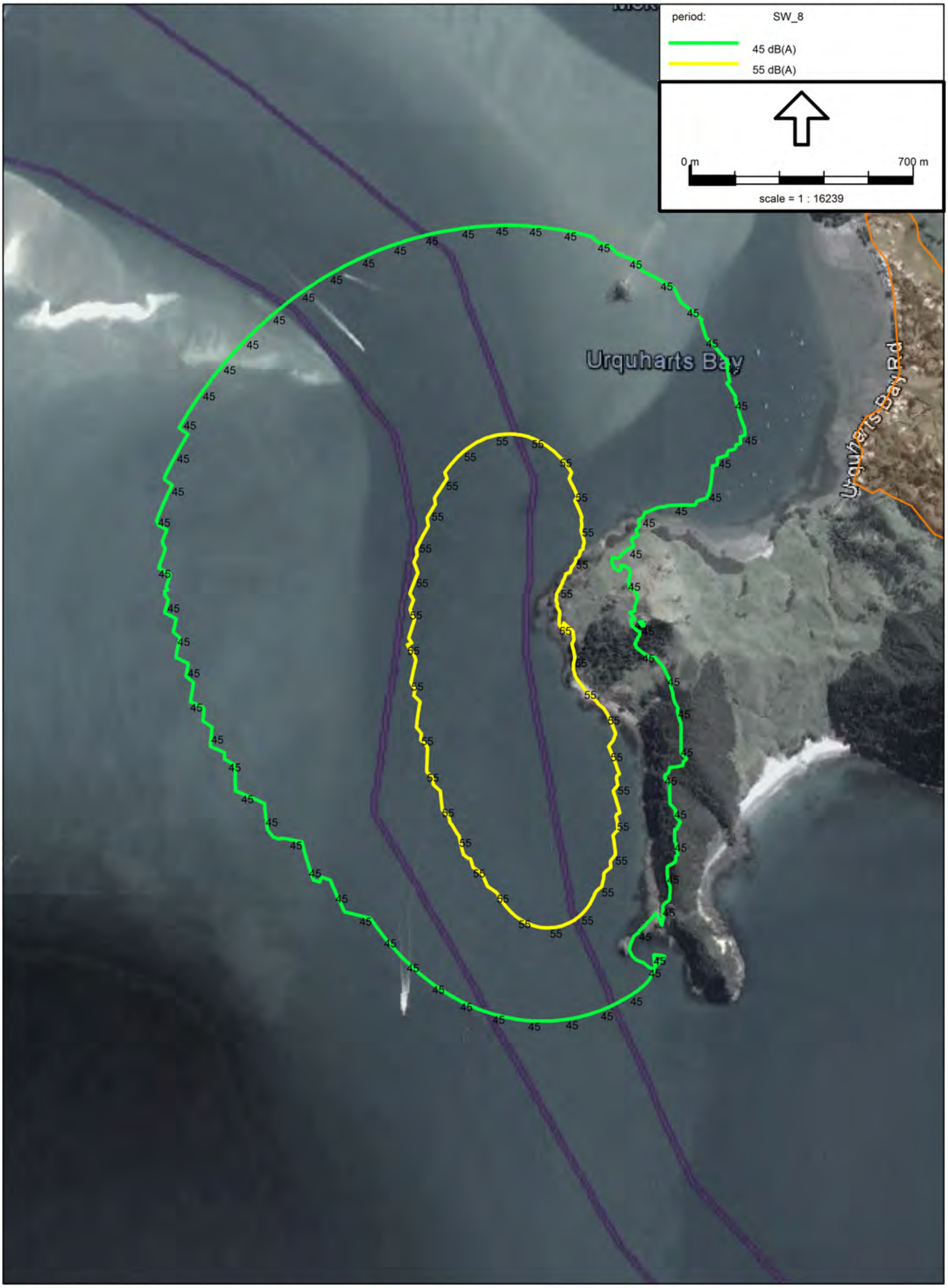


Industrial noise - ISO 9613.1/2, [Weather - Lines_4_3m/s] , Predictor V11.10

Styles Group - Acoustics and Vibrations Consultants

www.stylesgroup.co.nz

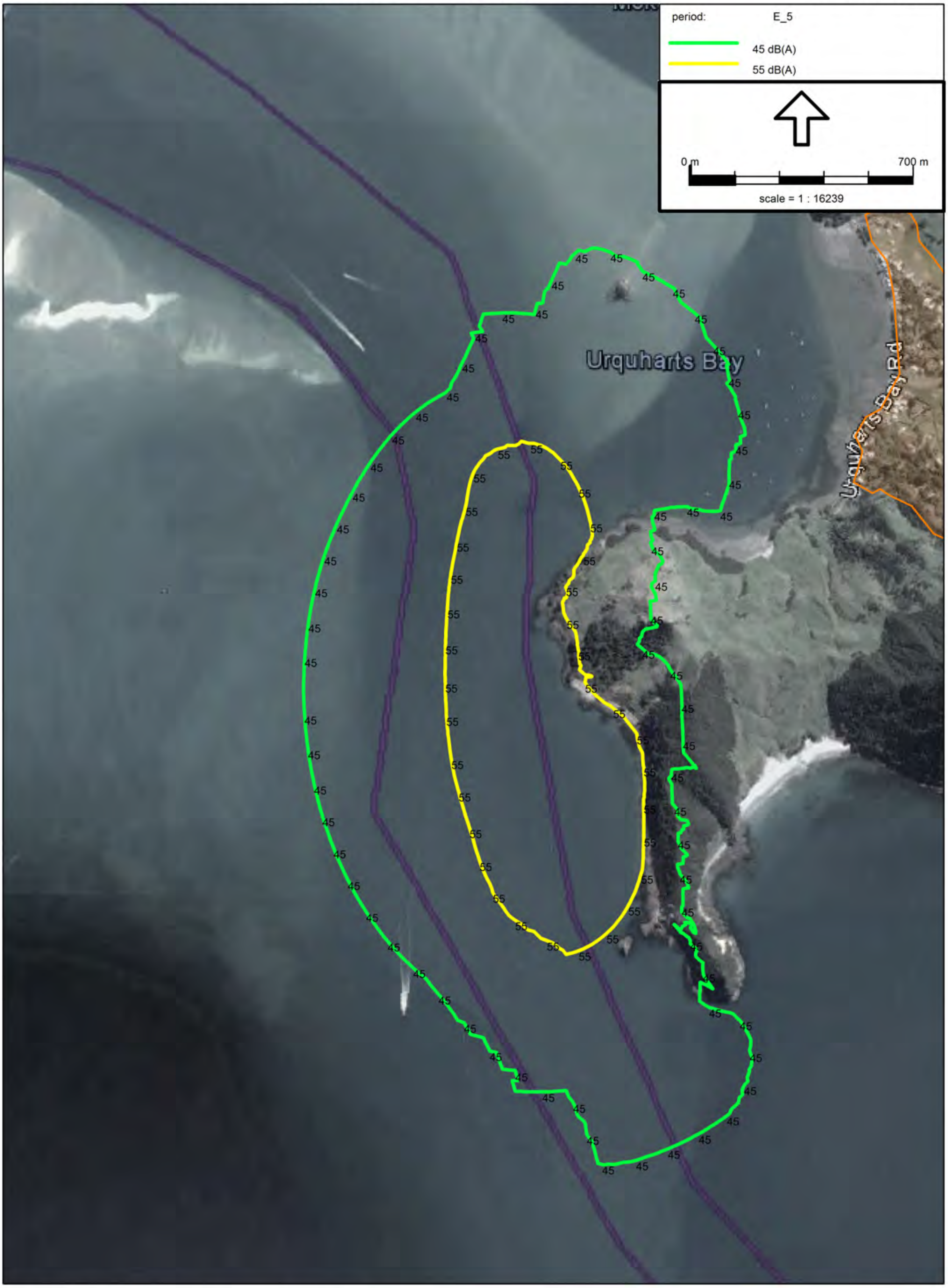
TSHD Mid Channel (Home Point): Worst Case Channel Position Southerly Wind



Industrial noise - ISO 9613.1/2, [Weather - Lines_4_3m/s] , Predictor V11.10

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

Styles Group - Acoustics and Vibrations Consultants

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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**