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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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.

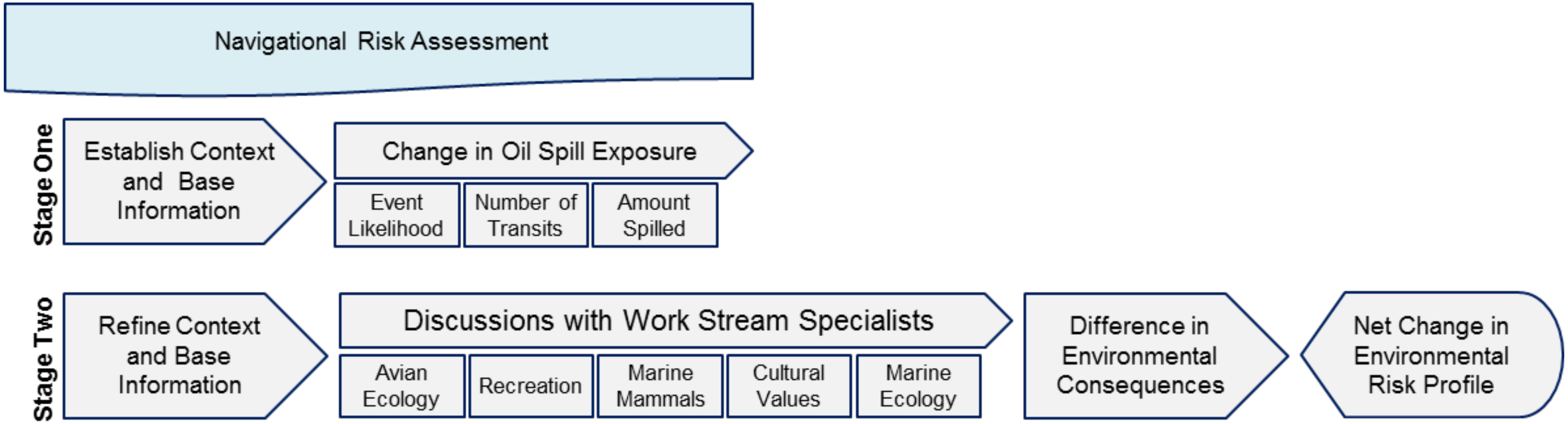
This study employs a differential assessment approach comparing two scenarios: essentially being operations with and without the engineered channel. The assessment addresses operating risk when the channel works are complete and is based on an assumption that any associated operational regime changes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

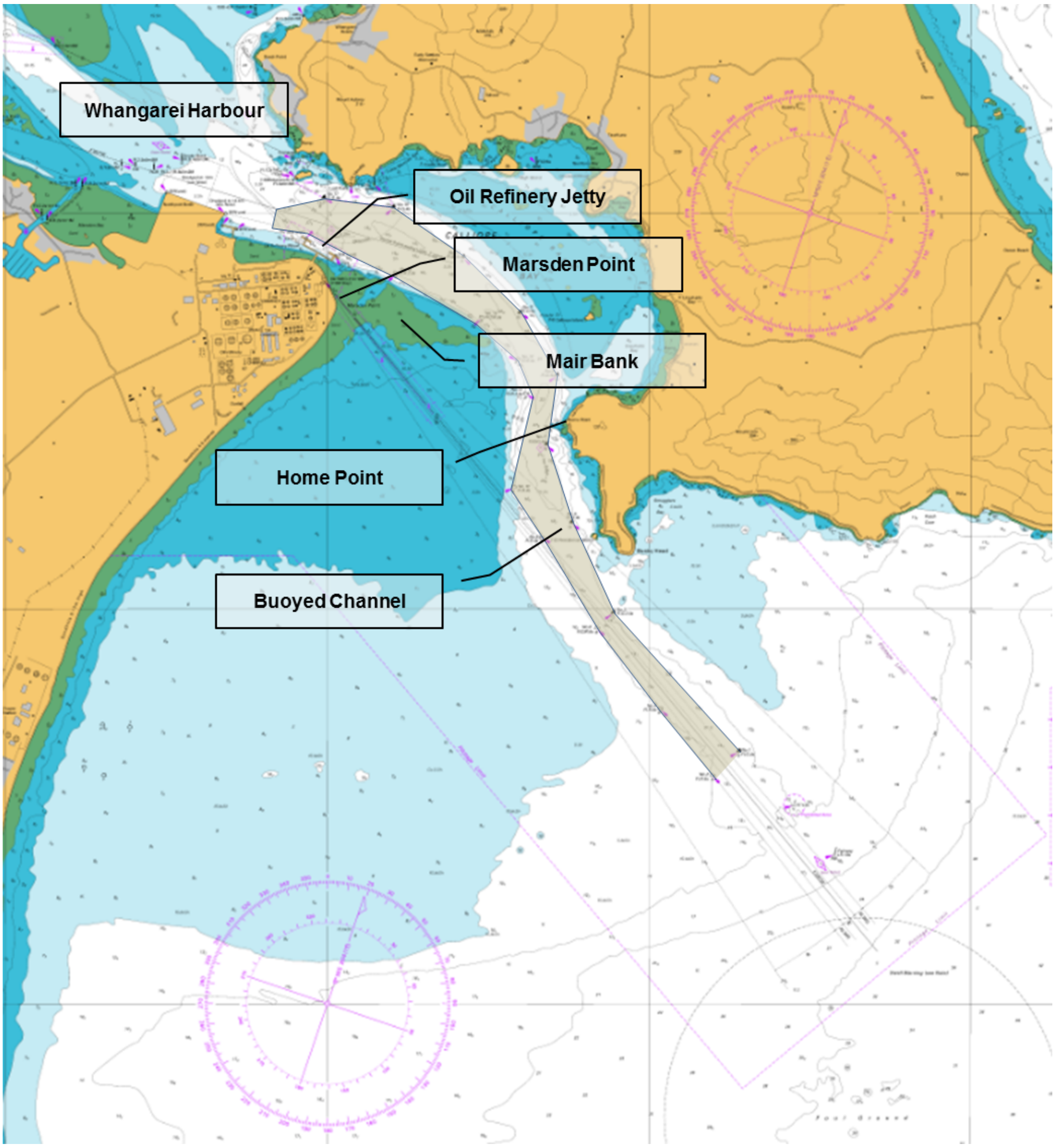
4.1. Background

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

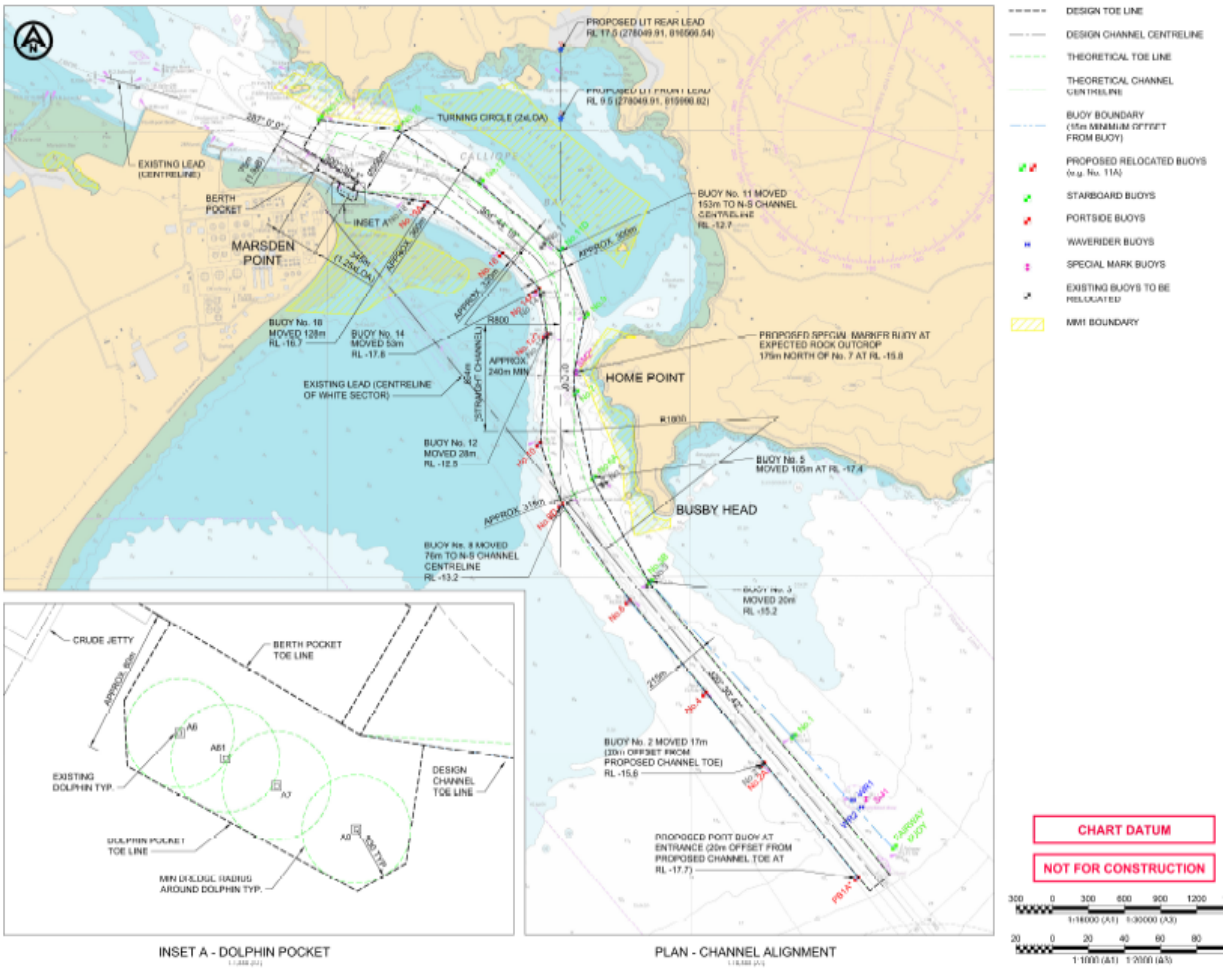
Refining NZ commissioned studies (Royal HaskoningDHV, 2016; Tonkin + Taylor, 2016) that considered several channel design options and led to a shortlist of two designs labelled Option 2 and Option 4-2. The navigational risk assessment undertaken by Navigatus considered the navigational risk profiles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

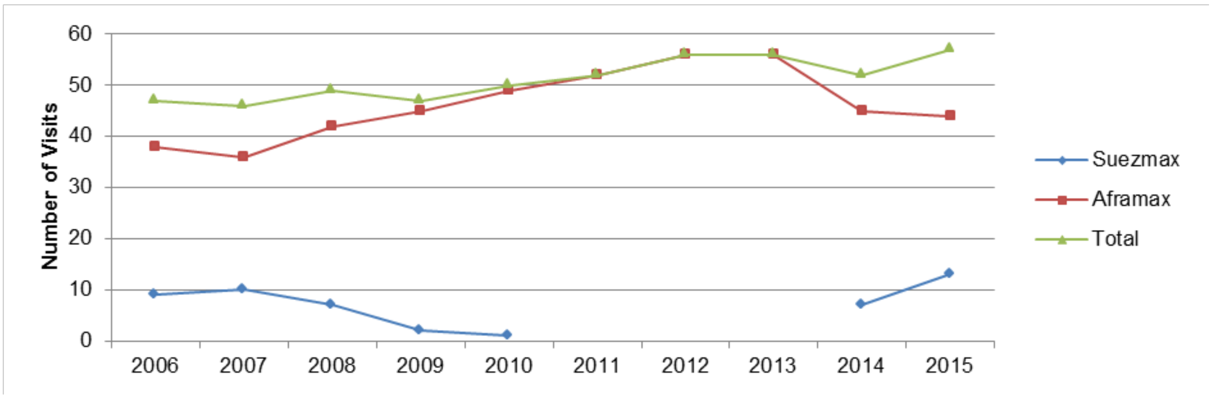
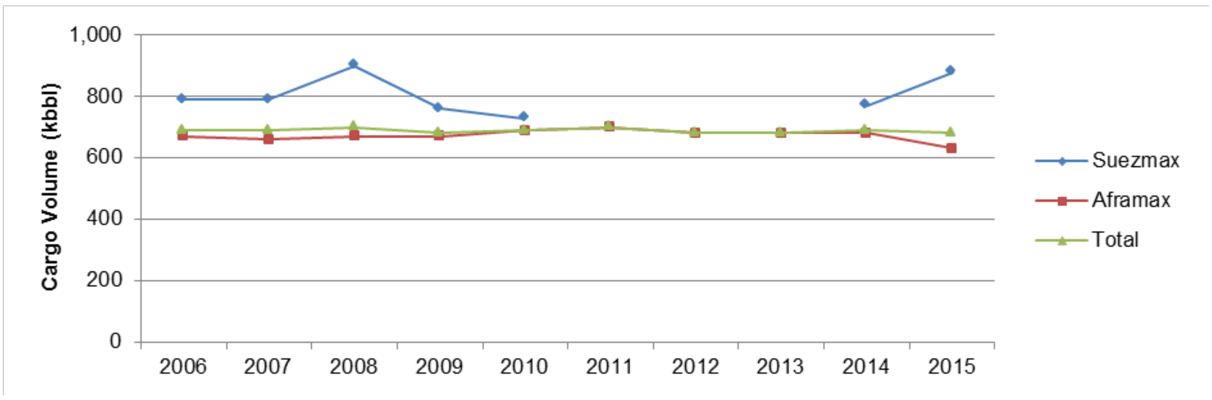


Figure 4.4 – Yearly Average Tanker Cargoes 2006-2015



[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

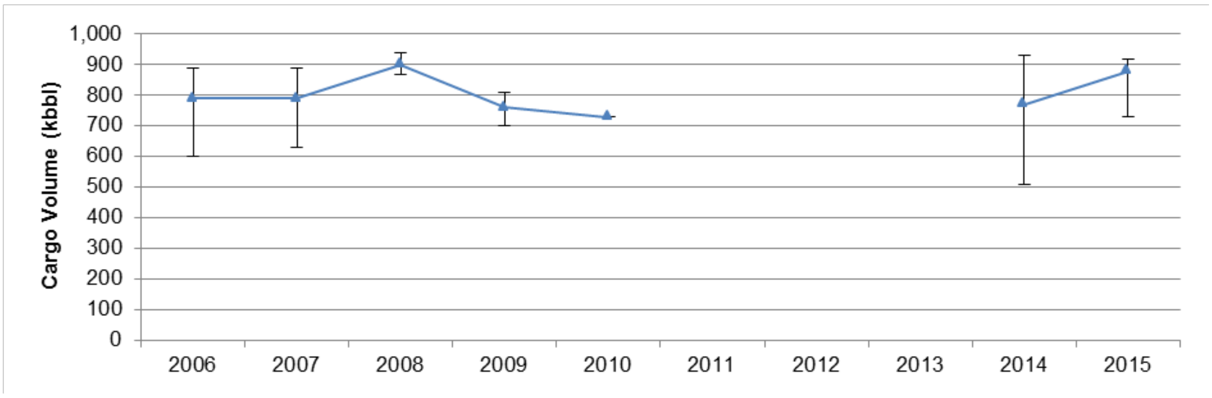
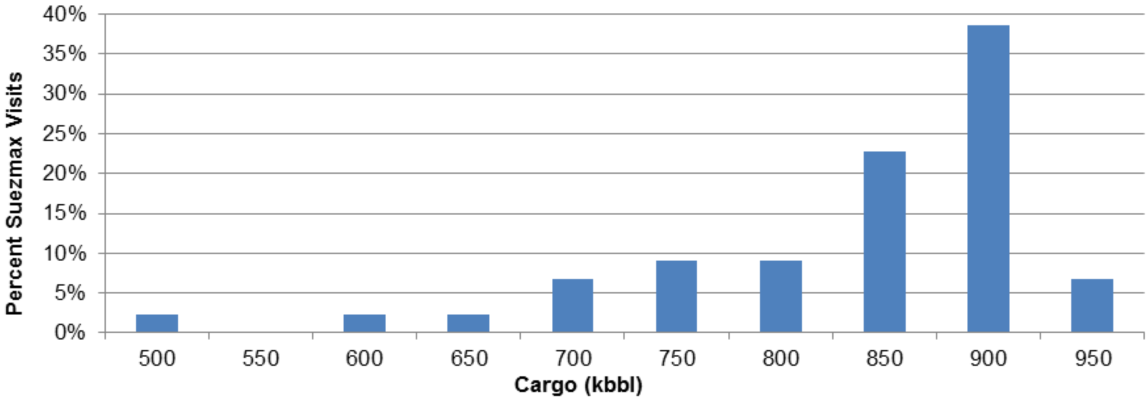


Figure 4.6 shows the distribution of historical Suezmax cargo size from 2006-2015.

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).*

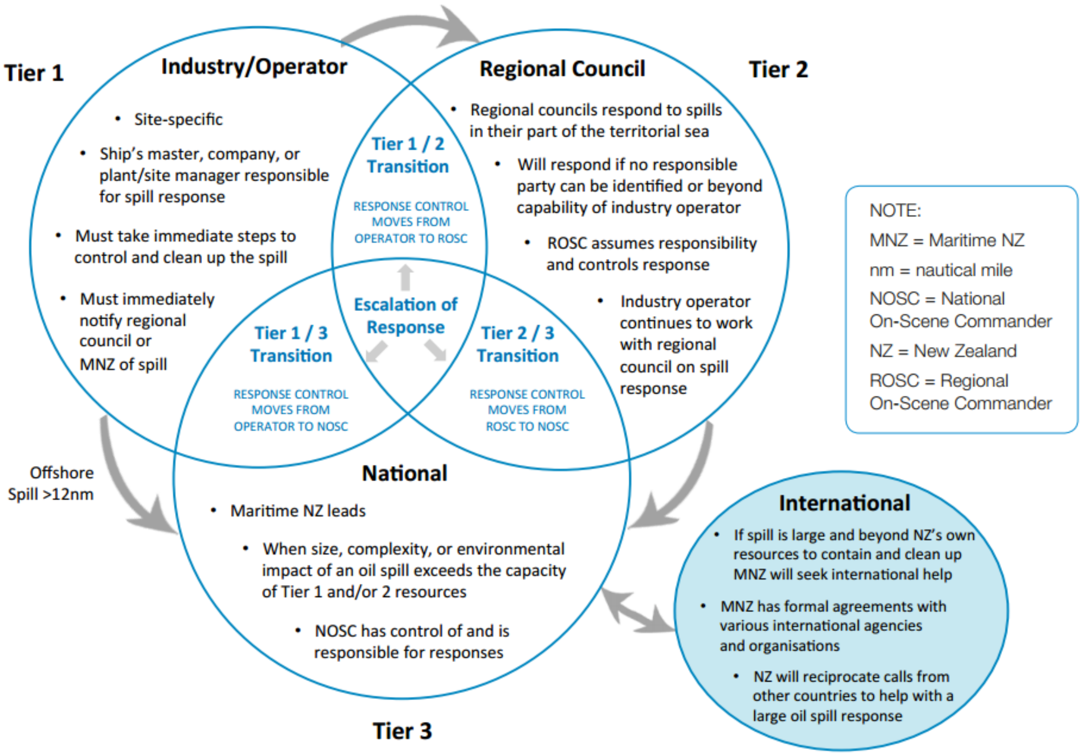
4.4. Response Capability

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.

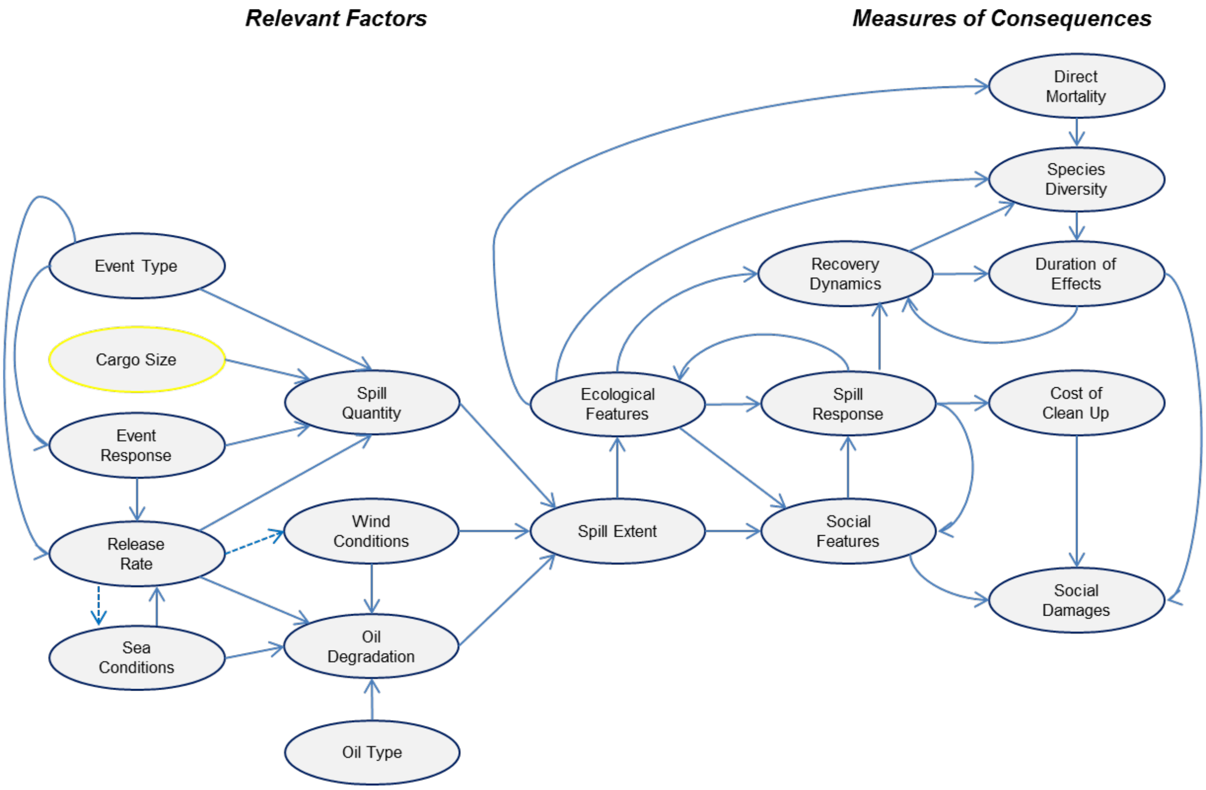
Social damages include:

- 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

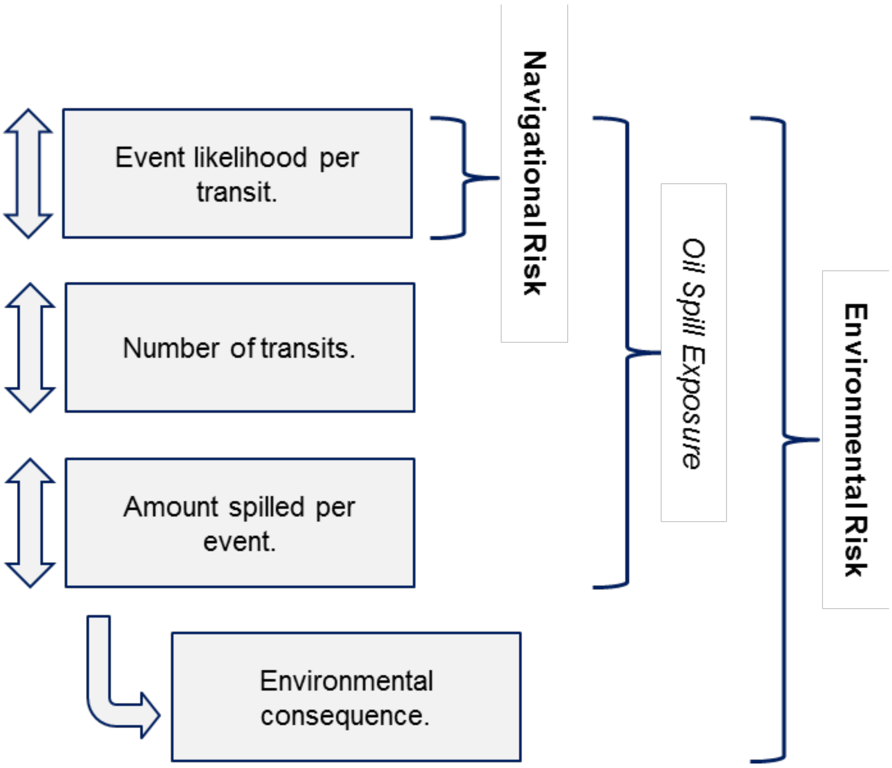
Risk is defined as the combination of likelihood and consequence. In the case of oil spills these elements can be further broken down to improve understanding.

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

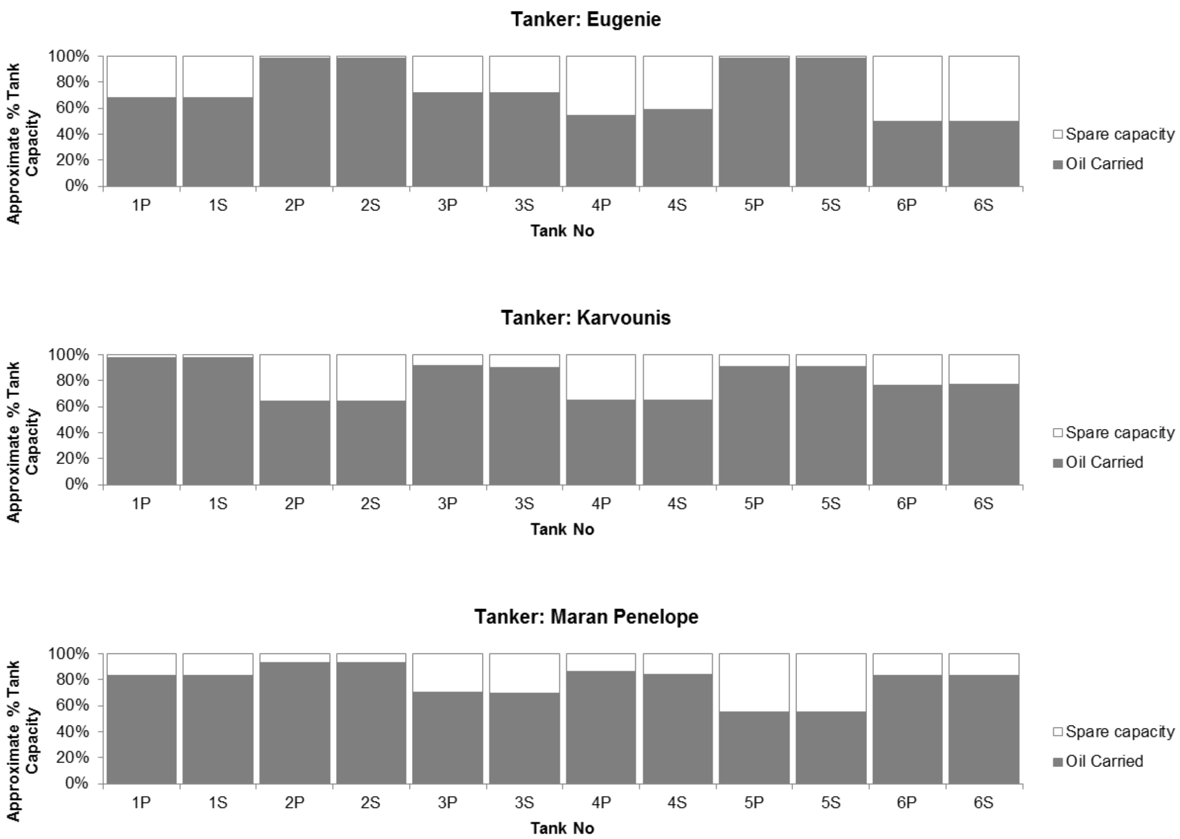
Overview

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.

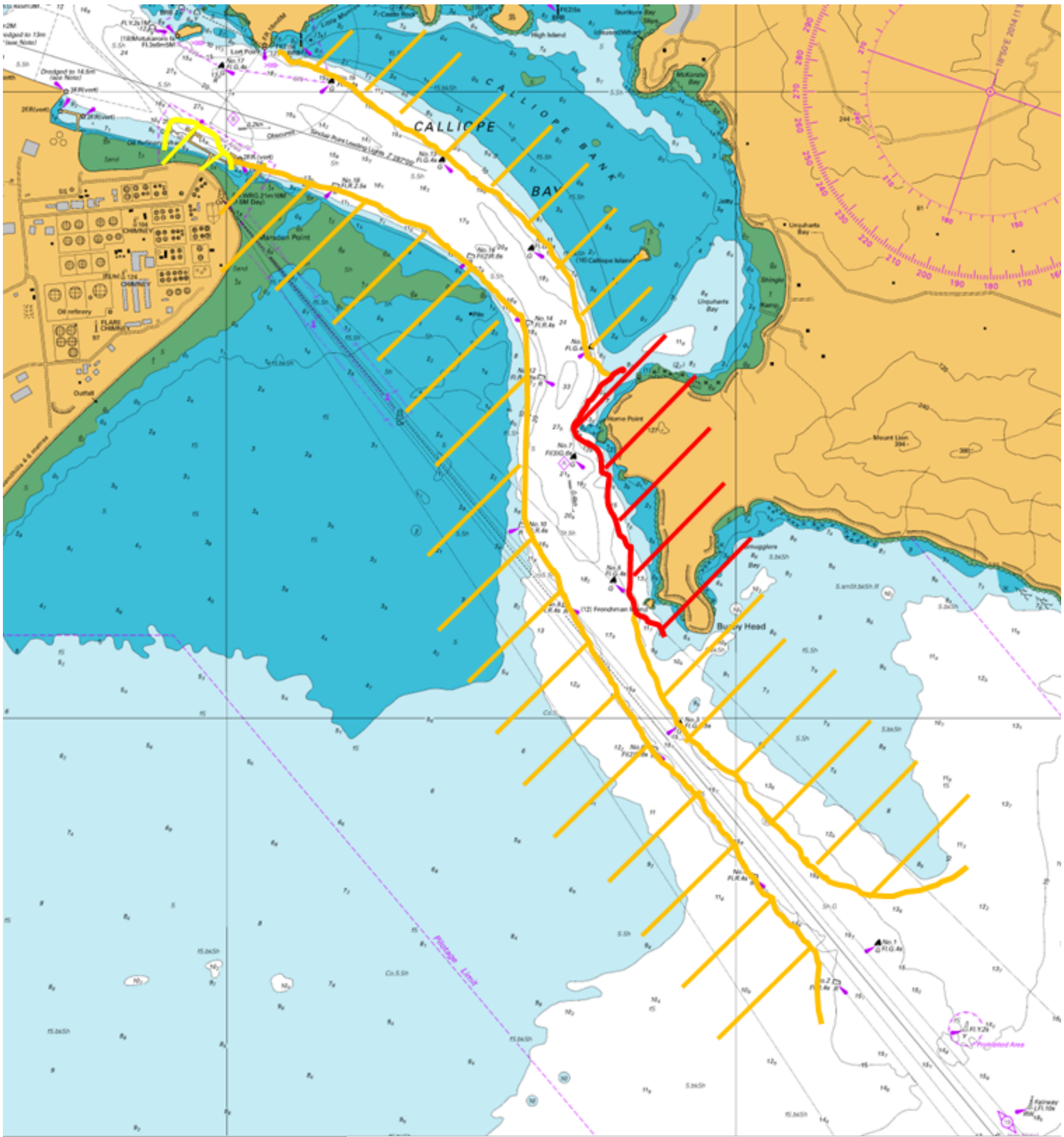
Although this contention has some validity, there are other significant factors to consider such as tides, oil being trapped in the double hull space, the effects of “pumping” due to wave action and the exact nature and location of the event.

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



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

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

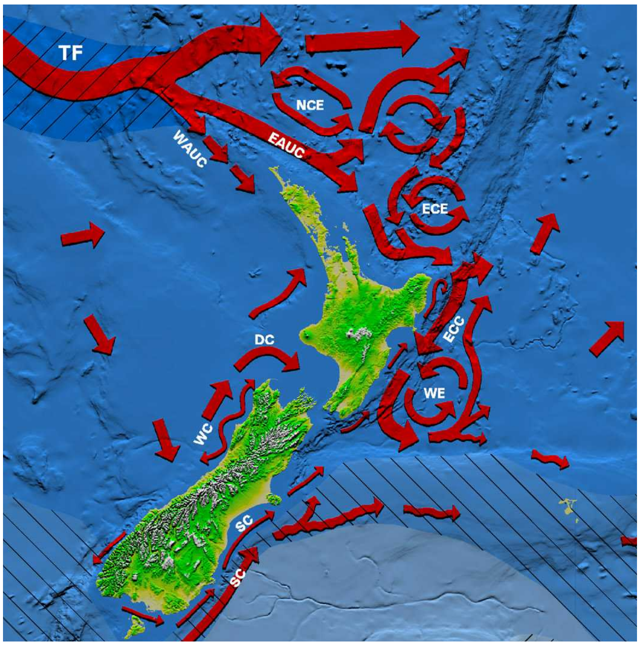
If oil is released at a rapid rate immediately following the spill then much of the oil spilled will travel out to sea on the ebb tide. This provides more time to mobilise oil spill response resources and will result in less oil arriving in the more sensitive inner harbour areas than would be the case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

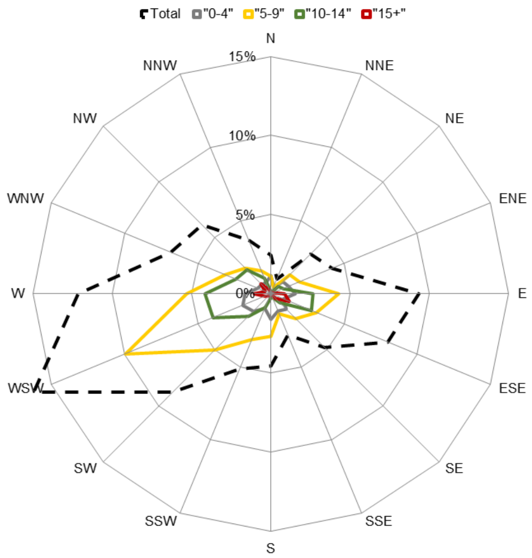
Wind Conditions

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.

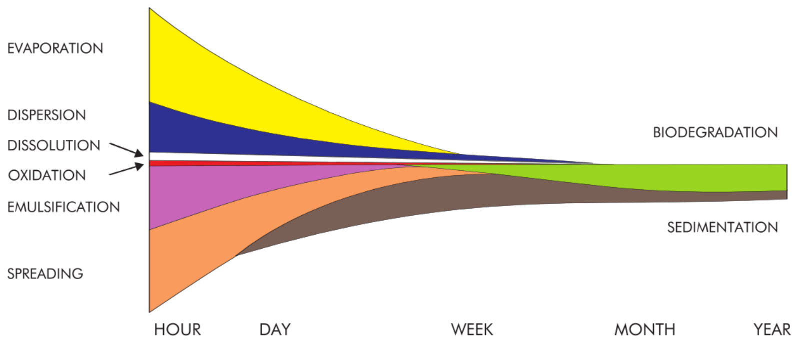
Figure 7.5 - Mokohinau AWS Wind Rose 2000-2012 Inclusive



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

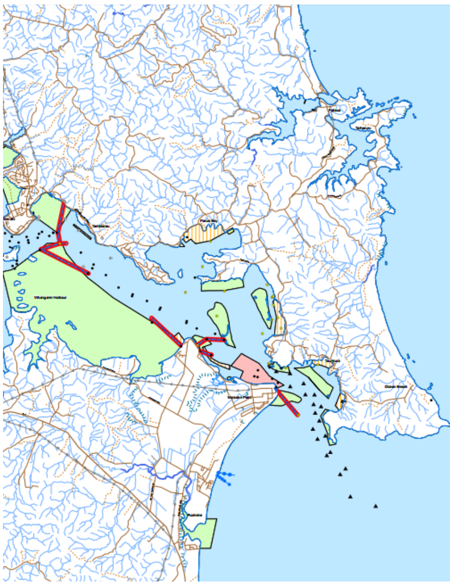
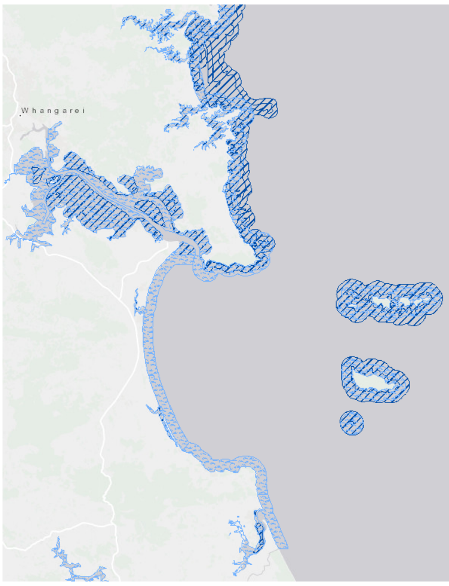


Figure **7.8 – Draft Sensitive Marine Ecological Areas**



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.

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[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

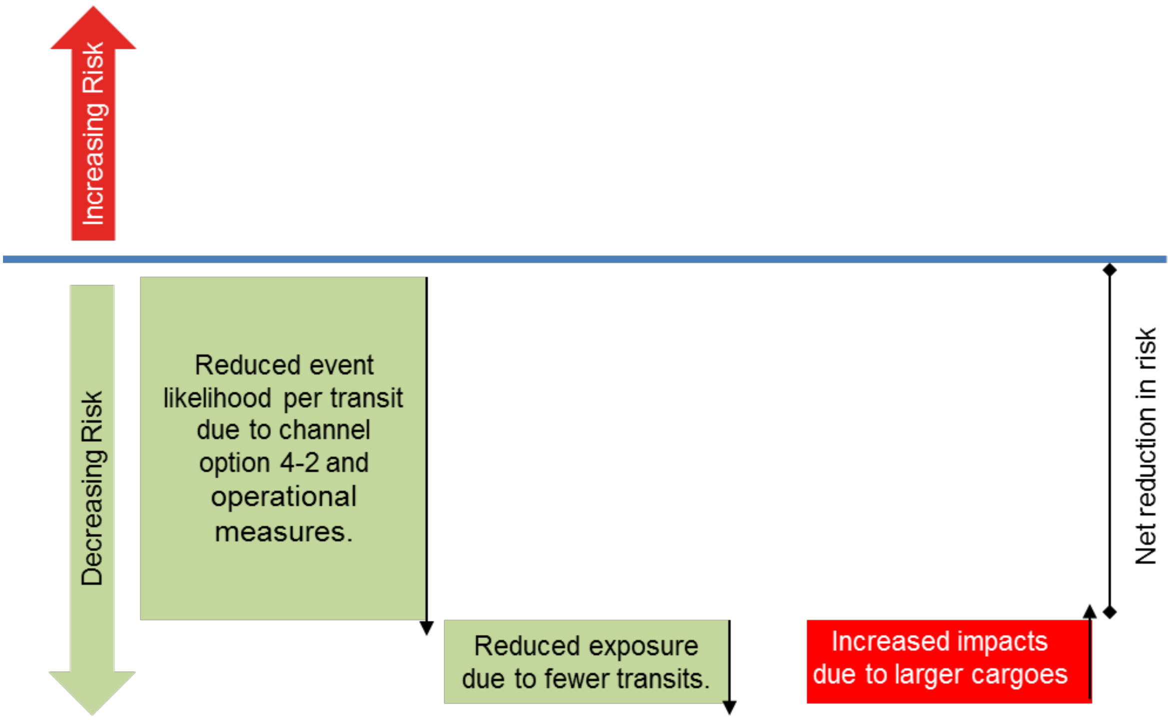
ID	Factor	Comment
A	Difference in event likelihood per transit.	Appendix A.1. Use Case A: Significant reduction in event likelihood. Use Case B: The implementation of Option 4.2 and operational measures will significantly reduce the likelihood of an event for each transit compared to current operations.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

10.References

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Appendix A: Economic Cost of Damages

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

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

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

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

Where the exponent is less than 1

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

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

Illustration of Damages vs. Volume Relationship, Exponent = 0.75

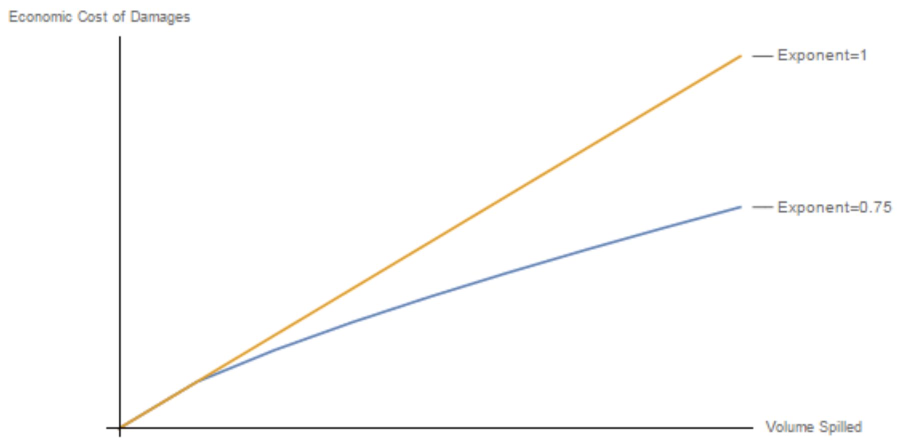


Table 10.1 – Example of Damages vs. Volume Relationship, Exponent = 0.65, 0.75, 0.85

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

Appendix B: Selected Case Studies

Sea Empress Spill

Overview

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

Spill Incident

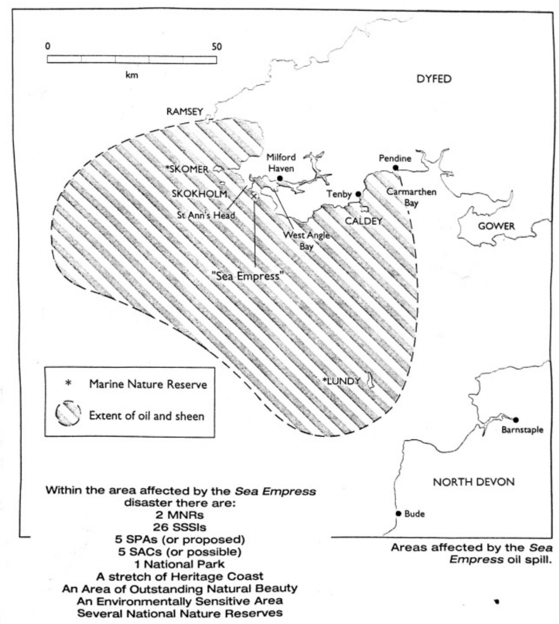
On 15 February 1996, the single hulled oil tanker Sea Empress, carrying 130,000 tonnes of Forties Blend North Sea crude oil, ran aground in the channel to Milford Haven refinery in South-West Wales.

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

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

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

Figure 10.1 Extent of oil and sheen



Source: Pembrokeshire Archives

Oil Ashore

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

Clean-up Costs

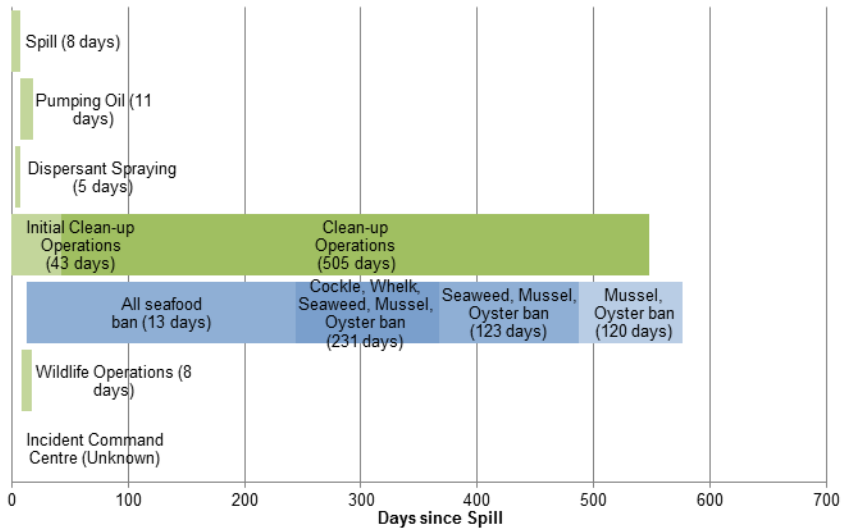
At that time, the site was the only coastal national park in the UK, with 35 Sites of Special Scientific Interest and one of only 3 UK marine nature reserves. It was also a site of special European status to conserve rare and vulnerable birds. Initial operations with 1,000 workers cleaned all amenity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

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

Marine Flora

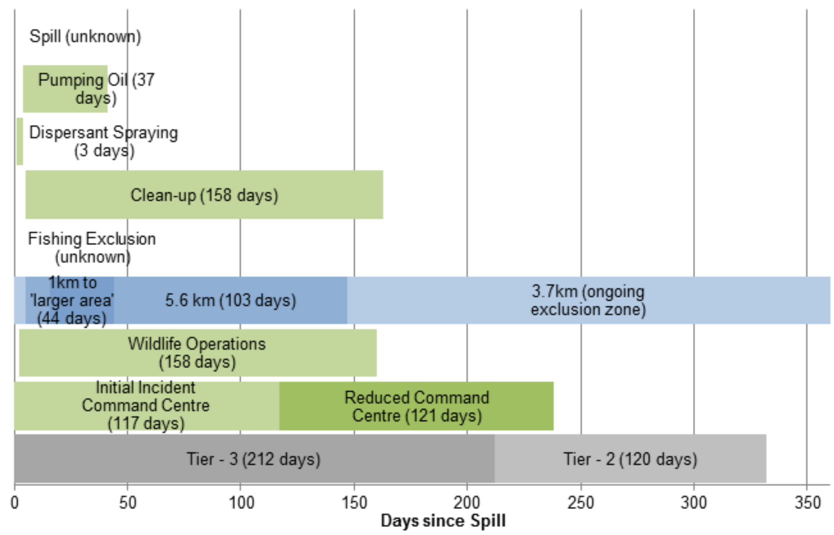
Flora	Short Term Effect	Recovery
Subtidal seagrass (*Zostera marina*)	No discernible effects.	Hydrocarbon analysis of sediment samples from the bed, found that concentrations were low and concluded that the growth of *Z. marina* was not adversely affected.
Intertidal seagrass (*Zostera angustifolia*)	Considerably oiled and then affected to some extent by vehicles driving across during the clean-up.	Surveys in 1996 found no discernible overall change in the extent of the beds compared to pre-spill conditions, but showed that ruts from vehicles had caused some lasting physical damage. Annual monitoring continued to show no discernible impact of the oil, but the vehicle tracks were detectable up to 1999/2000.
Fucoid algae (particularly *Fucus vesiculosus* var. *linearis*).	Massive growth, reaching blanket cover in spring 1997, maintained this cover into 1999, but then reduced rapidly on wave exposed areas. Much longer survival in sheltered areas, with some plants still present in 2005.	By February 2006 populations of these algae are essentially the same as they were before the spill, i.e. very sparse.

Flora	Short Term Effect	Recovery
Splash zone lichens *Caloplaca* spp.; *Xanthoria parietina Ochrolechia parella*	Very high tides and strong wind conditions during the first few days of the spill resulted in the oiling of many splash zone lichens, causing necrosis and bleaching in various species. In addition, high pressure washing and some other clean-up methods (eg wiping with sorbent rags) caused damage to lichen colonies in some locations.	No traces of oil could be seen on any of the sites after 2 years and recovery of the lichens was reported as well underway. Differential rates of growth have also been observed between different encrusting species. Where experimental trial plots with high pressure washing were established, it is clear that the colonisation and growth of *Caloplaca* spp. has been much faster on the areas that were left alone, than on the areas that were pressure washed.
Saltmarsh *(Atriplex portulacoides*, *Juncus gerardii*, *Puccinellia maritima*, *Triglochin maritimum* and *Carex extensa*	Some dieback of the vegetation where oiling had been substantial. Trampling damage during the clean-up response also noted. A re-survey in autumn 1997 found good recovery of most species in most locations, but continued reduction of *T. maritimum* and *A. Portulacoides*.	A comprehensive resurvey of all the saltmarsh in the waterway was carried out in 2002. No obvious differences found between sites affected by the spill and those either protected from its effects or situated beyond its zone of impact. Concluded that the saltmarsh vegetation of the Haven is no longer influenced by the effects of the oil spillage.
Coastal Plants	All studies concluded that there were no discernible impacts.	No *Sea Empress* related damage noted in various surveys and studies since the spill.

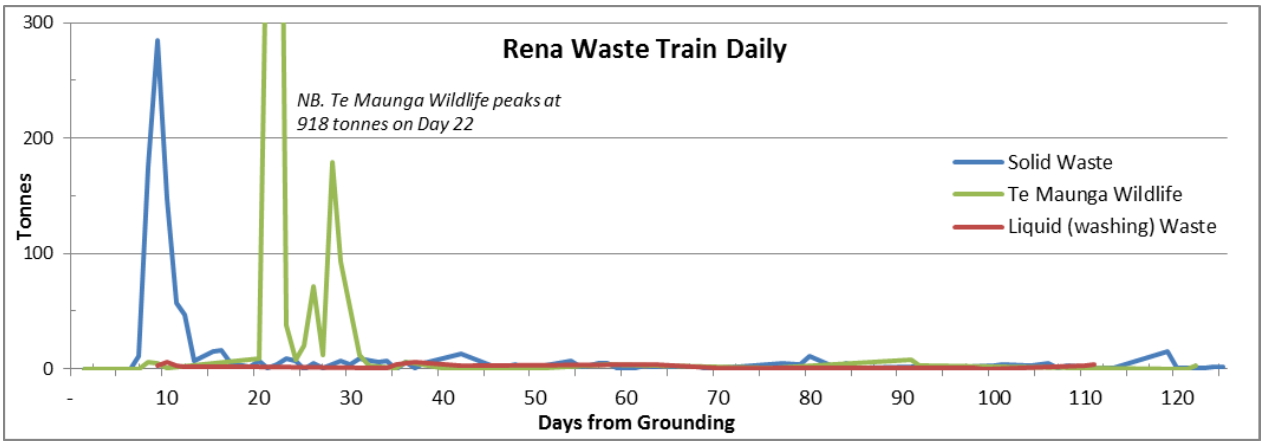
Ship/Installation	Sea Empress	**Location**	Milford Haven, South-west Wales	
Relevance	Large volume oil spill in temperate waters.			
Date	15 February 1996			
Timeline				
Spilled Oil	72,000 tonnes of light crude oil was released over a period of 7 days of which 3,700 to 5,300 tonnes reached 200 km of shore (Edwards & White, 1999).			
Duration of Clean –up operations	Initial operations with 1,000 workers cleaned all amenity beaches in six weeks. Overall clean-up including re-released oil from storm movement of sediments took place over 18.3 months (Edwards & White, 1999). The total cost was approximately £23million (GeoResources, n.d.-b).			
Environmental Sensitivity	The only coastal national park in the UK, with 35 Sites of Special Scientific Interest, and one of only 3 UK marine nature reserves. Also a site of special European status to conserve rare and vulnerable birds (Edwards & White, 1999).			
Environmental Impacts	No evidence of mass mortalities of commercial fin-fish or crustaceans. Significant mortality of mussels, star fish and heart-urchins. Amphipods, polycheate worms and brittlestars decimated in heavily contaminated areas but returned to pre-spill levels within five years. Known cushion starfish population reduced from 150 to 13 (Edwards & White, 1999). Intertidal communities on some severely impacted rocky, muddy and sandy shores, recovered rapidly. Impacts on subtidal seabed communities were limited geographically and to a few groups of sensitive species. Densities of tube dwelling amphipods (Ampelisca spp.) returned to pre-spill levels within five years. Some populations of burrowing echinoderms (Echinocardium cordatum) and spiny cockle (Acanthocardia echinata) have not recovered, although factors other than the oil spill may also be involved (Moore, 2006). Lichen communities in the splash zone of rocky shores reported as recovering; but some species are particularly slow growing and have not yet returned to pre-spill levels. Oiled saltmarsh areas showed very limited impacts beyond two years, and no effects could be detected in 2002. There was no evidence of significant spill-effects to coastal plants and terrestrial lichens (Moore, 2006).			
Impact on Birds	7,000 oiled birds were collected on shore, with an unknown number dying at sea. Of these birds, half were cleaned. However a study commissioned by the Sea Empress Environmental Evaluation Committee (SEEEC) to analyse previous data on guillemots (the most common species oiled around the UK, 23% of those collected after the Sea Empress (Edwards & White, 1999) showed that more than 70% of the cleaned birds died within 14 days of release and only 3% survived for two months or more (GeoResources, n.d.-b). Peak visiting population of a species of migratory sea duck, the scoter (Melanitta nigra) reduced from 15,000 to 4,300 in year following spill, representing 66% of those collected after the Sea Empress. Overall numbers of guillemots and razorbills reduced by 13% and 7% in 1996 (Edwards & White, 1999). The numbers of the majority of affected breeding seabird			

	colonies (primarily guillemots and razorbills) recovered to pre-spill values within two or three years. Slow recovery of two specific colonies of guillemots and razorbills. Subtle effects of large spills on guillemot populations suggested, but the long-term effects are unclear (Moore, 2006). Numbers of common scoter migrating through Carmarthen Bay rapidly returned to a level comparable with that present immediately before the spill. Total numbers of migratory wetland birds using the Milford Haven waterway were not apparently affected by the spill; and localised effects on their distribution within the waterway were not evident after two years (Moore, 2006).
Impact on Marine Mammals	No impacts were observed on grey-seals or cetaceans (harbour porpoises, otters, grey seals and bottleneck dolphins), and none have been reported in the following years (Moore, 2006).
Commercial Fishing and Shellfish Harvesting	Elevated levels of hydrocarbons were detected in crustaceans, fin fish, and especially molluscs. Fishing bans were implemented on 2,100 km^2 of coast for: finfish (3 months), crustaceans, cockles and whelks (8 months), and mussels and oysters (19 months). Hydrocarbon contamination of fish and shellfish returned to background levels in less than one year; and there was no evidence of any impacts to fish stocks after two or three years (Moore, 2006). Changes in the volume of harvests was not detectably attributable to the oil spill (Edwards & White, 1999).
Tourism	An estimate of the direct effects of the Sea Empress spill on the tourism spending in Pembrokeshire in 1996 was an average reduction of 12.9%, and slightly less for Wales overall. This equates to £20.64 million (Hill & Bryan, 1997).
Social Impacts	Profound attitudinal change to community perception of risks associated with transport of oil (Edwards & White, 1999).
References	Edwards, R. & White, I., 1999. The Sea Empress oil spill: environmental impact and recovery. International Oil Spill Conference. Available at: http://www.ioscproceedings.org/doi/abs/10.7901/2169-3358-1999-1-97. GeoResources, The Sea Empress Clean-Up Operation. Available at: http://www.georesources.co.uk/seclean.htm [Accessed January 12, 2015]. Hill, S. & Bryan, J., 1997. The Economic Impact of the Sea Empress spillage. International Oil Spill Conference. Moore, J., 2006. State of the marine environment in SW Wales, 10 years after the Sea Empress oil spill. Countryside council for Wales, pp.1–33.

Rena Spill

<table>
<tr><td>Ship/Installation</td><td>MV Rena</td><td>Location</td><td>Astrolabe Reef, Tauranga</td></tr>
<tr><td>Relevance</td><td colspan="3">Largest oil spill in New Zealand waters.</td></tr>
<tr><td>Date</td><td colspan="3">5 October 2011</td></tr>
<tr><td>Timeline</td><td colspan="3">
</td></tr>
<tr><td>Spilled Oil</td><td colspan="3">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).</td></tr>
<tr><td>Duration of Clean –up operations</td><td colspan="3">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).</td></tr>
<tr><td>Environmental Sensitivity</td><td colspan="3">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).</td></tr>
<tr><td>Environmental Impacts</td><td colspan="3">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.</td></tr>
<tr><td>Impact on Birds</td><td colspan="3">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).</td></tr>
</table>

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.*