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New Zealand Petroleum Supply Security 2017 Update

Prepared for Ministry of Business, Innovation & Employment

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Executive Summary

Petroleum is essential to the operation of modern economies so ensuring petroleum supply chains are secure and robust is of concern for governments and authorities. This applies both to global supply chains providing crude and product, along with the domestic infrastructure and its resilience to disruption. This report updates earlier reports on oil security (in 2005 and 2012) for the Ministry of Business, Innovation and Employment (MBIE). It assesses the resilience of the New Zealand petroleum supply chain in the context of supply and demand changes through to 2021, and updated information on risks, particularly recent studies relating to tsunami risks.

The scenarios analysed are the same as in earlier reports with the addition of a multiple terminal disruption. These are:

1. International disruption (major international event that disrupts 10% of crude oil supply for around six months)
2. Major (long term) disruption to the refinery at Marsden Point
3. Short term (three week) disruption to the refinery at Marsden Point
4. Major (long term) disruption to RAP/Wiri terminal
5. Short term (three week) disruption to RAP/Wiri terminal
6. Major disruption at Wellington
7. Major disruption at Lyttelton (Christchurch)
8. Multiple port disruption

The likelihood of major disruption for each scenario either has a similar risk of occurring as assessed in 2012 or increased risk due to a higher tsunami risk. Updated information from recent global earthquake/tsunami events has led to a reassessment that these events could be larger than previously assumed, albeit these large scale events are likely to be rare (the significant events are modelled on a 1 in 500 year or 1 in 2,500 year return period). The table shows the updated probabilities of each scenario occurring (on an annual basis) along with the level assumed in 2012.

Change in disruption probabilities

2012	**Scen. 1** Internatl. disruption	**Scen. 2** Long term refinery outage	**Scen. 3** Short term refinery outage	**Scen. 4** Long term RAP/Wiri disruption	**Scen. 5** Short term RAP/Wiri disruption	**Scen. 6** Long term Wellington disruption	**Scen. 7** Long term Christch. disruption	**Scen. 8** Multiple port disruption
Low probability of occurring	2.50%	0.20%	0.50%	0.20%	0.50%	0.15%	0.20%	n.a.
High probability of occurring	2.50%	0.25%	1.00%	0.30%	1.00%	0.25%	0.30%	n.a.
2017								
Low probability of occurring	2.50%	0.25%	0.50%	0.20%	0.50%	0.20%	0.30%	~0.10%
High probability of occurring	2.50%	0.33%	1.00%	0.30%	1.00%	0.30%	0.40%	~0.10%

The findings are similar to the 2012 report for how the industry will respond to disruption and in the case of petrol and diesel how much shortage there might be in each scenario. The main difference to earlier work is that major disruption to the jet supply through to Auckland Airport will now cause more significant problems and is likely to be more costly if that was assessed in an economic analysis. This effect is due to strong growth in jet fuel demand in recent years along with growth expected through to 2021. Other means of providing jet fuel (or transferring demand to other locations) remain limited.

The economic analysis of welfare loss and impact from each disruption scenario carried out by NZIER in 2012 has not been recalculated with this updated information (this is an economic analysis outside H&T's area of expertise). The expectation in discussions with MBIE is the earlier work is still likely to be valid given the limited inflation since 2012 and relatively minor changes in the probabilities of occurring. We assess there would likely only be a small increase in the probability weighted costs for scenarios 2, 4 (higher welfare losses for jet fuel disruption), 6 and 7. In all cases any variation would be within the range of variation calculated by NZIER using three different approaches for calculating the welfare loss[1].

Given an expectation that probability weighted costs will be similar, we can conclude the findings NZIER reached are still likely to be valid including:

- For compliance with New Zealand's international obligation, purchasing oil stock tickets remain the most cost effective approach.
- New domestic storage remains unappealing as its annual cost greatly exceeds the avoided cost (weighted probability), even when combining cases and the stock is held in a location where it could assist with multiple events (e.g. Auckland).
- Having spare trucks (and drivers) available for immediate use is still not justified against the alternative of obtaining them rapidly should there be an event.
- Building a connection between the RAP and WAP pipelines in advance of an event is not cost effective. However, it is probable that the consequence and cost of a jet supply disruption has increased with the higher jet demand, so having mitigation plans for responding should an event occur is even more important than previously found. MBIE and jet fuel suppliers did begin investigating this issue following the 2012 Report. H&T notes that mitigation options should be considered and evaluated in the context that a major disruption has occurred and it is costing the economy $2-3 million dollars a day in direct and consequential losses, rather than a business as usual situation.

The other issues reviewed in this update that should be monitored by officials include:

- The important role the Wynyard Wharf facilities in Central Auckland would play should there be a significant disruption to normal Auckland supply. This needs to be considered when Auckland Council makes decisions regarding the relocation of these key facilities.
- The sharp rise in jet demand along with possible plans for expanding facilities at Wiri terminal. Wiri throughputs have increased significantly, particularly for jet fuel. Constructing additional storage near the Roscommon Road boundary, as noted in the Auckland Council Planning Hearings, would greatly increase the terminal's resilience.

[1] The NZIER 2012 Results are included in Appendix 3.

Glossary

COLL	Coastal Oil Logistics Limited – joint venture company controlling the ships that move products from the refinery to ports around the country and the shared stock scheme. Participants in the Joint Venture are BP, Mobil and Z.
GNS	Geological and Nuclear Sciences Limited (GNS Science)
IEA	International Energy Agency
MMB	Million barrels
MMBD	Million barrels per day
RAP	Refinery to Auckland Pipeline (RAP) that takes product from Marsden Point to the Wiri distribution terminal in South Auckland
Wiri terminal	Wiri Oil Terminal in South Auckland
WOSL	Operating company for Wiri terminal

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1.0 Introduction

Hale & Twomey Limited (H&T) has prepared several reports for the Ministry of Business, Innovation and Employment (MBIE)[2] since 2004 on New Zealand's petroleum supply security. These include:

- The 2004/2005 Oil Security Report with Covec (2005 Report)
- RAP Contingency Report in 2011
- A 2012 update of the 2005 Report assumptions (the 2012 Report) that fed into an update of the 2005 Report economics completed by NZIER (the NZIER Report)[3]
- A 2014 update on a refinery outage (strike)
- Work on Wellington resilience to earthquakes in late 2016

MBIE has now requested H&T update the 2012 Report to take account of supply and demand changes since then, particularly the significant increases in jet demand, and build on recent studies and exercises relating to tsunami risks.

The 2005 and 2012 Reports covered the likely impact of international disruption as well as domestic events such as refinery outage, a RAP disruption[4] and Wiri terminal disruption. The 2012 Report added assessment of port disruption at Wellington and Lyttelton, along with investigating impacts from events such as tsunami which may impact multiple ports.

Recently the Ministry of Civil Defence & Emergency Management ran an emergency exercise (Tangaroa 2016) that assumed a magnitude 9.1 earthquake near the Kermadec Islands resulted in a series of tsunami waves that affected all the New Zealand coastline with major disruption at the Marsden Point refinery and most coastal ports.

This update covers similar events as assessed previously and draws on the Tangaroa exercise and updated research to consider in more detail the potential impacts and contingency options for a major tsunami event which might impact multiple ports. The role of Wynyard wharf as a resilience option in a major Auckland disruption event is also considered in more detail.

This report is not required to update the economic analysis carried out by NZIER in 2012. Where applicable the costs of disruption, mitigation and contingency measures are updated including the cost of storing fuel.

Relevant companies (key infrastructure owners and operators) were given an opportunity to comment on a final draft of this report, but no material changes were made.

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[2] Or its predecessor department, the Ministry of Economic Development (MED)

[3] *New Zealand Oil Security Assessment Update*, NZIER report to Ministry of Economic Development, June 2012

[4] The Refinery to Auckland Pipeline (RAP) analysis was based on the RAP Contingency Options report that H&T did for MBIE in 2011, this included details on how trucking might partially mitigate disruption impacts.

2.0 Scenario assumptions

The scenarios covered in this report are based on those in the earlier reports with an additional case looking at an event that might impact multiple terminals. The scenarios include:

1. International disruption (major international event that disrupts 10% of crude oil supply for around six months)
2. Major (long term) disruption to the refinery at Marsden Point
3. Short term (three week) disruption to the refinery at Marsden Point
4. Major (long term) disruption to RAP/Wiri terminal
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So it can be read as a standalone report, each scenario is summarised in this report with the impacts updated based on the latest (2016) calendar year demand with adjustments made to reflect forecast demand for 2021. Any known changes in infrastructure provision that may impact the response is also considered. Where the disruption case is similar to previous reports this reports uses the earlier descriptions updated as necessary.

While New Zealand has had several natural disasters in the past decade (particularly earthquakes) none of these have caused significant (medium or long term) impacts on the fuel supply network. The scope of the events covered here are major events that are best described as low probability, high impact events. There has not been an incident along the lines of those outlined in these scenarios in New Zealand's petroleum supply system to the knowledge of the authors.

2.1 Updated assumptions from previous reports

All the scenarios are reworked using updated assumptions. Changes in assumptions from the earlier reports that impact on the size of the disruption are covered in each scenario. Significant changes in assumptions include:

- Scale of Tsunami hazard – updated research has found that larger events are possible (covered in more detail in Section 2.2) so for the same return period an event will be larger
- Wynyard wharf – potentially greater throughput may be available (covered in more detail in Section 2.3)
- Higher truck utilisation – less surge capacity is available as trucks now load closer to their capacity in normal business following changes to heavy vehicles rules (covered in more detail in Section 2.4)
- Strong jet demand growth – demand for jet fuel has been strong, with national demand 30% higher than in 2010 (the period used for the 2011 and 2012 reports), this is covered in more detail in Section 2.5
- 2021 forecast for product demand (Section 2.6)

2.2 Tsunami risk

The tsunami analysis in the 2012 Report used a 2005 GNS Science[5] report on tsunami hazard along with work on infrastructure co-dependence and inundation modelling for relevant regional councils. This report was updated by GNS Science in 2013 (2013 GNS Report)[6]. The update was informed by recent changes in scientific knowledge from major events including the 2004 Indian Ocean tsunami, the 2009 South Pacific tsunami and the 2011 Tohoku (Japan) tsunami. In all cases these events were larger than had been considered likely to occur in these places. The updated GNS Science report concludes that:

> *"For most parts of New Zealand, the overall levels of hazard are quite similar to the assessed hazard levels in the 2005 report, but the estimated hazard has generally increased in those areas most exposed to tsunami from local subduction zones – notably the east-facing coasts of the North Island, and the southwest corner of the South Island."*[7]

Significant petroleum infrastructure including the refinery at Marsden Point, and the terminals at Tauranga and Napier are located on those east facing coasts, so tsunami are a relevant threat.

The 2013 GNS Report calculates hazard curves for the whole New Zealand coast, broken down into 20km sections. The size of the wave (maximum amplitude) is calculated against the return period for an event (the longer the return period the higher the maximum amplitude). Tsunami from all locations (local, regional and distant) go into making up the possible events for each return period. The 2013 Report assesses maximum wave amplitude which is defined as:

> *"the maximum height the tsunami would reach against an imaginary vertical wall at the coast"*[8]

In addition, the maximum amplitude given for each section should be:

> *"interpreted as the tsunami height measured at the location within the section where it is highest; the median tsunami height within the section may be significantly lower"*

The Tangaroa 2016 exercise was informed by this update using a very large 9.1 earthquake near the Kermadec Islands resulting in tsunami that impacted most of New Zealand's coast, particularly the north of the North Island. In terms of risk assessment, the scale of the event used in the exercise is a rare event, and while contributing to likely 1 in 2,500 year events at the locations it impacts, is only one of the contributors so is expected to be even rarer. Previously when evaluating tsunami risks at ports, the 1 in 100 and 1 in 500 year return period assessments have been used, because the risk of the 1 in 2,500 years event is so low that it has negligible impact on the economic assessment. In this report we note the size and possible impacts of major rare events (1 in 2,500 years), while the scenarios risk assessment remains based on the 500 year return period.

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[5] GNS Service (2005); Review of Tsunami Hazard and Risk in Zealand (September)

[6] *Review of Tsunami Hazard in New Zealand (2013 Update)*, Compiled by William Power, GNS Science Consultancy Report 2013/131 August 2013

[7] Ibid pg 173

[8] Ibid pg 130

Updated data from the GNS Science report is expected to be used for more detailed coastal planning and infrastructure assessment. This is currently happening at the University of Auckland where PHD students working with Dr Liam Wotherspoon of the University of Auckland have been disaggregating the GNS data to model ports and harbours in more detail, particularly the stresses tsunami can put on wharves and jetties. As the University of Auckland work is yet to be published it is not available for use in this report.

Dr Wotherspoon[9] noted the results to date generally indicate that the size of the waves expected in harbours will be smaller than for the same event on an exposed piece of coastline. This result would be expected by GNS Science in locations where there is some protection from direct impact of the waves[10]. Waves can resonate in harbours so it is not always the case that they will be lower (particularly if wave is in a similar direction to the harbour). Lyttelton is a location where waves are known to resonate. It is beyond the scope of this report but it seems sensible to encourage further modelling work around pieces of significant infrastructure (e.g. Marsden Point and Tauranga harbour for petroleum infrastructure), particularly where expected damage can be modelled for contingency planning. We understand that Marsden Point is already part of this work.

Another report that considers tsunami impacts is *An Analysis of Tsunami Impacts to Lifelines*[11]. This report assesses damage to lifeline structures from previous tsunami events. Unfortunately, the documentation and evidence relating to energy infrastructure is light. For petroleum infrastructure it notes:

- Damage typically related to coastal storage tanks and associated infrastructure (e.g. pipelines and facilities);
- Tanks can be damaged by hydrostatic forces (generally buckling) or impacted by buoyancy (floating from foundations);
- It was found that at flow depths of 1m there was little or no damage and at 7m there was always damage with a transition zone between the two;
- Tanks that are full are less likely to be impacted;
- Fires from petroleum spills are a major risk in a tsunami (petroleum floating on and being spread by the water flow); and
- From work with other infrastructure it appears that buried pipelines are quite resilient, although there are risks where these are exposed (e.g. attached to bridges) or where they cross waterways near the coast.

The details on tsunami hazard for each region is covered under the relevant scenario. The risk of a multi-port impact tsunami event is covered in scenario 8.

2.3 Wynyard Wharf

In the previous reports, H&T assumed more diesel could be put through Wynyard Wharf facilities should there be disruption to the normal supply of product into Auckland (either the refinery, RAP or Wiri). There are two 6,000 m^3 diesel tanks at Wynyard Wharf with a fill stand that is currently

[9] Telephone call Dr Wotherspoon with Ian Twomey 19 June 2017

[10] Discussion with William Power, GNS Science 27 June. For example, GNS modelling for Takapuna (Auckland region) is considerably lower than more exposed neighbouring coastlines for a similar event given the protection of the islands in the Hauraki Gulf. Auckland harbour would be expected to be lower than the wave height at Takapuna.

[11] *An Analysis of Tsunami Impacts to Lifelines*, N.A. Horspool and S. Fraser, GNS Science Report 2016/22 for the Auckland and Wellington Lifeline Groups, May 2016.

used for diesel supply (small volume). There are no facilities for petrol or jet fuel. The diesel facility is owned by Stolt-Nielsen (Stolt) and contracted for use by a participants in the COLL joint venture (so included in the national stock system)

Wynyard Wharf also contains facilities for chemicals and oils (multiple smaller tanks) owned by Stolt and Bulk Storage Terminals (BST). These are also generally under contract for use by third parties.

Stolt have now advised H&T there could be more throughput through the terminal than previously assumed should some of the chemical and oils facility be converted to petroleum use in an emergency. H&T has previously assumed that diesel could be put through the existing facility up to the capacity of the fill stand (2 trucks per hour with a 90% 24/7 utilisation); this is about 1.3 million litres/day. We have found this amount of diesel is sufficient to supply diesel to most of Auckland, given there will be the need to allocate available trucks across locations so any shortage is evenly spread across the region. Even once more trucks are available, we expect fully utilising the throughput at the existing Wynyard wharf facilities (1.3 million litres/day) and balancing the demand for the outskirts of Auckland to neighbouring terminals will be best strategy for diesel distribution given the terminal's central Auckland location.

Based on Stolt's updated advice, additional capacity might have more benefit if it could be used to supply a second petroleum product through a different fill stand. Ideally this would be jet fuel as there is no means of alternate supply for the region. Chemical tanks, while a lot smaller, are often built to a quality (e.g. epoxy linings) that would make them suitable for jet fuel. Additional equipment would be required (e.g. coalescer) as well as a complete terminal review to ensure all fittings and equipment are suitable (e.g. no brass fittings) so while this would not be an immediate option, it might be able to be done relatively quickly in an emergency.

Stolt advised there are a number of storage tanks around 500m^3 capacity that could potentially be used for jet fuel depending on availability. While these tanks are very small by normal petroleum standards, if coupled with a ship on the jetty, they might be able to provide a regular supply of jet fuel. Jet fuel requires quality testing at each stage of its supply chain (including holding periods) so at most this would only give use of one tank per day (probably a little less). As a base assumption these tanks should at maximum be able to provide 450,000 litres per day which is about 10% of expected Auckland Airport supply. There is likely to be some jet trucks available (e.g. normal refuelling trucks) that would be available for hauling jet fuel from central Auckland to the airport should normal supply through to the JUHI not be available. Should more storage be available, it would be possible to supply more (around 16% of expected airport demand, or 700,000 litres/day, before hitting constraints on the fill stand). It is also likely around that point jet truck availability might become a constraint.

2.4 Higher truck utilisation

Since the 2012 Report the rules for size and mass of heavy vehicles have changed. Previously fuel tankers were generally restricted to a gross mass limit of 39 tonnes[12], but new rules that took effect from 1 February 2017 will allow general access vehicles (including fuel tankers) from

[12] It was possible to load more if a suitable permit was obtained allowing the vehicle to use specified routes, but consultation with companies in 2011 indicated this was not practical for most fuel haulage tasks.

December 2017 to have a gross mass limit of 45 to 46 tonnes depending on vehicle configuration with some transitional arrangements in place prior.[13]

A key response mechanism in the prior work was allowing fuel tankers to be fully loaded as most newer fuel tankers had gross mass capabilities of around 44 tonnes compared to the legal limit of 39 tonnes. At that time allowing these vehicles to maximise loads, along with greater utilisation of other tankers in the fleet, allowed a further 20% volume to be moved. Discussions with some fuel suppliers and transport operators has indicated the more recent 44 tonne vehicles will be able to operate at capacity under the new rules (without permits). However some of the latest vehicle fleet additions have been larger (around 50 tonne gross mass limits) which may retain some spare capacity if not used with special permits.

As the changes to the gross mass limits are only changing this year we expect the current ability to carry more fuel is still be available (this is consistent with feedback received), but this will likely erode as demand continues to increase[14] and as older tankers are retired from the fleet, although there is likely to be some offsetting gain from some companies electing to upgrade their fleet with larger 50 tonne vehicles over time. Looking forward we expect there will still be some capability to maximise utilisation of the fuel tankers compared to normal operations (i.e. in an emergency there is likely to be less consideration of operational or economic drivers than would normally be the case) to the extent they can without compromising their own stringent safety requirements.

To adjust for the new rules of the size and mass of heavy vehicles for the updated report we have recalculated the utilisation factor to conservatively be ~11% more volume to be moved, primarily from better utilisation with a smaller uplift from being able to overload the vehicles. The volume increase could be higher (around 15%) if we assume a greater proportion of 50 tonne vehicles as part of the fleet.

2.5 Jet fuel demand growth

Demand growth for jet fuel has been strong since the last report with national demand in 2016 30% higher than in 2010 (the period used for the 2011 and 2012 reports), with most of that growth in the last couple of years. The main driver of aviation fuel consumption is passenger movements and in recent years New Zealand has had record growth in inbound tourism.

Jet fuel growth would normally lag passenger growth, reflecting increased efficiency of the airline industry over time. However, in the last two years fuel growth has exceeded passenger growth significantly driven by a large increase in long haul flights. A greater proportion of flights are now long haul increasing the amount of fuel used per passenger movement. In addition flight load factors (percentage of capacity used) have dropped with airlines adding capacity and new routes into New Zealand[15].

In time this trend should revert to a more normal growth pattern (and the load factors should improve again over time) although the passenger number forecasts still indicate continue strong growth. Therefore, our expectation is jet will continue to grow by about 20% from 2016 levels

[13] http://nzta.thomsonreuters.co.nz/DLEG-NZL-LTSA-T.LTR-41001a.pdf

[14] In the short term, larger fuel loads would reduce the number of trips made, but as demand grows companies will be able to increase tanker utilisation back towards previous levels, reducing spare capacity.

[15] For example Air New Zealand 2017 interim results show falling load factors on international flights.

over the next five years. We have used this figure to estimate jet fuel demand in 2021 for each of the scenarios analysed in this report.

With Auckland Airport flights consuming over 75% of New Zealand's jet fuel, most of the growth is on the jet fuel supply route from the refinery at Marsden Point, through RAP and the Wiri Terminal to Auckland Airport.

For the scenarios in this report there are limited alternative jet fuel supply options in the short term (other than for the Refining NZ scenarios where import cargoes are viable) so restoration of supply will be met by shifting demand to other offshore locations (i.e. aircraft would divert to other airports to refuel).

2.6 Petrol and diesel demand growth

The forecast used for petrol and diesel in this report (for 2021 demand) are based on those used by MBIE in its modelling of future energy demand[16]. These assume that petrol demand slowly declines (ay about 1% per year) while diesel demand slowly increases (by about 1% per year). As the total markets for petrol and diesel are similar the total volume of these products is expected to be similar to 2016 volumes in 2021.

2.7 Terminal disruption probability discussion

The 2012 Report assessed the probabilities of major disruption at individual terminals to be relatively low (e.g. 0.2-0.3% per year for Wiri). The statistics on oil terminals incident remain limited with the 2005 Buncefield terminal explosion (United Kingdom) still being the most recent major event informing terminal design. Within New Zealand, the most significant recent event impacting terminal capacity was a slip at Lyttelton during flooding (2014), which initially damaged (including rupture) two tanks and required more to be taken out of service. The balance of the port's tankage remained in service.

While the probability assessment for individual disruption events (in any one year) seems low, this should be understood in the context that such events (extended duration disruption) in well maintained petroleum facilities are low, even including the impact of natural disasters. This might best be understood in the context of operating terminals within New Zealand. On average over the past few decades there have been around 30 individual terminals operating in New Zealand at 13 different locations. Using the probability given for Wiri for a single terminal disruption, with 30 terminals this would imply that New Zealand would expect a 7.5% chance of one of these terminals been taken out of action for a long period (i.e. an expected rate of incidence of 1 every 13 years). The incident described above at Lyttelton is the most significant incident over the past couple of decades and that would be regarded as a partial closure of one of the three terminals at that location. This includes periods where there have been significant earthquakes impacting regions with oil terminals (Lyttelton and Wellington).

Viewed on this basis, the assumptions for terminal risk are reasonable despite appearing to be low when looked at on an individual basis. Natural disaster is as much of the risk as the inherent nature of the product being handled.

[16] These are titled "Electricity demand and generation scenarios" but do also cover liquid fuels.

3.0 Scenario details

3.1 International disruption

3.1.1 Probability of event

Both the 2005 and 2012 Reports used data from Oak Ridge National Laboratory (Paul Leiby) to develop probabilities for an international disruption scenario. The 2012 Report used information from 2005 when Oak Ridge National Laboratory updated earlier work using new methodology and more detailed build-up of the probabilities of disruption (Energy Modelling Forum report)[17].

In 2013 the International Energy Agency (IEA) undertook a study, *The Costs and Benefits of Stockholdings* (2013 IEA Paper).[18] The IEA used Paul Leiby and the Oak Ridge National Laboratory's team to develop a supply disruption simulation model to assess stockholding benefits. While this took the modelling forward (modelling the impact of emergency stockholding on market prices), they continued to use their 2005 work as the basis for the specific risk disruption probabilities. Given this information is still being used by the experts in the field, we consider the information used in the 2012 Report for risk assessment remains valid for this update.

The 2012 Report contain a full discussion, but in summary the output from the 2005 Energy Modelling Forum study assumes at least once during a 10-year timeframe:

- The probability of a net disruption of 2 MMBD (million barrels per day) or more lasting at least 1 month is approximately 80%[19]
- The probability of a net disruption of 2 MMBD or more lasting at least 6 months is approximately 70%
- The probability of a net disruption of 2 MMBD or more lasting at least 18 months is approximately 35%
- The chance of a 3 MMBD net disruption or more lasting at least 1 month is 65%; the chance of 5 MMBD or more is about 50%

The disruption probability curves from the 2005 Energy Modelling Forum study were used to develop probabilities for events of certain size and duration (Appendix 2). These need to be large enough so as to impact on New Zealand supply and international oil prices. An event that causes a disruption of 7MMBD or more for 6 months duration has a probability of approximately 25% over a 10-year period (2.5% per annum) with the probability taken from the data between the curves for a 1-6 month duration and 6-18 month duration. This probability covers an event of this size or larger. The weighted probability of the size of the events over 7MMBD is around an 8.4 MMBD disruption, which is an approximate 10% market disruption (using market size at the time of the study).

Event Summary:

- Disruption of 10% (net of spare capacity) to the international crude oil market
- Probability of 2.5% of this disruption in any one year (1 in 40 years)
- 6 month duration

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[17]Energy Modeling Forum, Philip C. Beccue and Hillard G. Huntington, 2005.*An Assessment of Oil Market Disruption Risks*, FINAL REPORT, EMF SR8, October 3.

[18] IEA/SEQ(2013)20 *Costs and Benefits of Stockholding (final Report)* (Note by the Secretariat)

[19] The disruption size calculation takes into account spare capacity available in the supply system for covering disruption events.

3.1.2 Market response

In the above event, while normal supply is disrupted by 10%, the actual shortage will be less as many countries will release their strategic reserves (both IEA countries and other countries with reserves such as China). Also, the price will increase which will help stimulate supply (i.e. rising prices will encourage additional supply as well as use of any spare capacity) and reduce demand.

The price rise will be a result of the net price elasticities of supply and demand. There is a thorough discussion on these elasticities in the paper by Brown et al. (2010)[20]. These elasticities are also in line with similar papers reviewed. In summary, the combination of supply and demand elasticities yields a midpoint elasticity of -0.136. That is crude oil prices will rise by 7.35% (=1/0.136) for every 1% reduction in oil supply.

To calculate price and disruption impacts, the response of countries that hold emergency stock needs to be considered. A 10% disruption for 6 months is a total disruption of approximately 1,600 MMB. This is less that the figure counted for IEA emergency stocks of 2,300 MMB (comprising government and public emergency stocks)[21]. However, given a disruption will likely be unknown in length and severity, we expect there will be caution in the rate of releasing reserves. For this scenario we assume the reserve release will be enough to offset half the base disruption leaving a net disruption of 5%.

Using the elasticity above, the price impact can be calculated. The initial shock of 10% disruption would be expected to see a price increase of around 74% but once emergency stocks begin to be released this would fall to an increase of 37%[22]. This has the following impact on international and local prices.

Table 1: Impact of International disruption

		Initial response (10%)	Likely settled response (5%)
Increase in base price		74%	37%
Crude oil price (assuming base price US$50/bbl)	US/bbl	$87	$68.5
NZ petrol price increase	Cpl (%)	+45 (22%)	+22 (11%)
NZ diesel price increase	Cpl (%)	+45 (34%)	+22 (17%)
NZ jet fuel price increase	Cpl (%)	+45 (75%)	+22 (37%)

The New Zealand price increases shown in Table 1 assumes refining margins and freight also increase due to the disruption. The local diesel and jet fuel increases are proportionally larger due to a lower tax charge in the total cost. The exchange rate assumption used was US/NZ 0.70.

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[20]Resources for the Future, Stephen P.A. Brown and Hillard G. Huntington, 2010. "Reassessing the Oil Security Premium", February

[21] IEA/SEQ(2013)20 *Costs and Benefits of Stockholding (final Report)*. This number excludes commercial stocks held outside an obligation in IEA countries (total IEA countries stocks are more than 4,000 MMB).

[22] This was done differently in the 2012 analysis for the IEA by Oak Ridge National Laboratory (*Benefits of Emergency Oil Stocks: A Study of IEA Stocks and Benefits)*. The net effect of a controlled stock release (covering about ½ the disruption) saw a similar increase of 35-40% in crude oil prices. They did calculate a higher increase (starting at 160% falling over a year to 100% increase) should there be no strategic stocks to release.

3.1.3 Impact and stockholding benefit

The 2012 NZIER Report assessed the economic consequences of the above scenario and concluded that while an international event was likely to have larger potential impact than domestic scenarios, it did not justify stock holding locally. This was because the main economic impacts would come from increased prices which are not prevented by local stockholding.

As the 2013 IEA Paper looks at a global response rather than a single country impact, it concludes that global stockpiles are worthwhile because of the damping impact they will likely have on prices in a disruption[23]. New Zealand contributes to these stockholdings through compliance with its commitment to hold stocks covering 90 days of net daily import. It meets that commitment by using stock tickets to hold stocks offshore in addition to the commercial stocks held in New Zealand. Stock tickets provide a cost-effective solution for New Zealand to ensure compliance and play a part by adding to global stocks for use to mitigate disruption as evaluated in the IEA Paper.

In the IEA Paper the benefit of stockholding was calculated on a global basis rather than an individual country basis. It found that stockholding had an average GDP saving to oil importers of approximately 0.75 percent of GDP and reduced their import costs by another 0.55 percent of GDP[24]. The expected benefits of IEA stocks (those above commercial stockholding) to global import regions was assessed to be US$51 per barrel per year. The annual cost of tickets purchased by the New Zealand Government to meet its commitment as part of that IEA response is currently just over US$1 per barrel per year. From the IEA analysis we can conclude that New Zealand's spend on stock tickets is worthwhile given the benefits from the stock holding.

The additional cost of holding physical stocks in New Zealand (above the ticket cost) would only be justified should that cost be justified by mitigation stock would provide for domestic disruption. This was analysed in the 2012 NZIER Report (and found not to be justified) with the impact of any updated assumptions discussed in Section 5.0.

3.2 Major Refinery Outage

The Marsden Point refinery is owned and operated by Refining New Zealand (Refining NZ). This is New Zealand's only refinery and remains a vital link in the local petroleum supply chain. The refinery has undergone three major investments since 2004 to maintain its share of around 70% of the New Zealand fuels market and to improve its capability to produce the high quality products now required for the New Zealand market. The demand balance is imported directly from refineries in the Asia-Pacific region (sourced primarily from South Korea and Singapore) to ports in New Zealand.

Approximately 50% of the refinery's production is supplied to Auckland through the RAP with the rest distributed by coastal tanker (two ships are used for this task) to ports around the country (10 ports in total – five in the North Island, five in the South).

The refinery is also a significant stock holding location and a key part of the supply chain, both to maintain Auckland supply and for maintaining coastal distribution to other ports. Disruption at the

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[23] It is reasonable to have a different conclusion to the NZIER study as global stockholdings are substantial and will have a damping impact on prices, whereas New Zealand stocks on their own won't change that impact as assumed in the NZIER study.

[24] *Benefits of Emergency Oil Stocks: A Study of IEA Stocks and Benefits,* Oak Ridge National Laboratory, October 2012, pg 6. At the time crude prices were more than twice the current level – we expect these benefits may be lower if calculated with current oil prices (the cost of stockholding has also reduced).

refinery may only impact on processing or, if the event is major, may also impact on stocks held and ability to distribute product from and through there.

The refinery continues to target (and achieve) reliable performance; Refining NZ noted in the 2016 Annual report in regards to minimising unplanned downtime that they had:

"a world-class unplanned downtime for the year of 0.85%"

Refining NZ's unplanned downtime since 2008 is provided in Table 2.

Table 2: Refining NZ unplanned downtime

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Reliability - Unplanned Downtime %	0.92%	0.53%	0.55%	1.37%	0.59%	1.11%	0.24%	0.33%	0.85%

Source: Refining NZ

The 2012 Report noted that Refining NZ performed in the top quartile for operational availability (reliability) in the Asia-Pacific region as benchmarked by Solomon Associates. While this information has not been updated the unplanned downtime measure is in line with the earlier period. Based on Refining NZ performance continuing in line with the earlier analysis, we can conclude that the risk of a major extended outage at Refining NZ is low, although with a high impact given its importance to the supply chain.

3.2.1 Outage scenario

The scenario assumes an incident (be it a natural disaster or internal event) takes the refinery out of action for an extended period requiring the refinery customers to re-establish supply routes using 100% import supply. While the refinery is off line, the scenario assumes within a couple of weeks refinery tankage and RAP will be available for imported cargoes. Any delay in using these facilities will not change the overall product shortage (from a national perspective), rather it would concentrate the shortage on the Auckland region. An extended outage of import facilities at Marsden Point would essentially be a more severe version of the extended RAP/Wiri outage (Scenario 3) with added severity for Northland supply.

The scenario calculation assumes:

- Imports already meet some of the market demand (35% petrol, 28% jet and 38% diesel based on the 2021 forecast data).
- It takes 6 weeks (42 days) for companies to re-establish full supply via imports.
- Some of the larger oil companies operating in New Zealand are able to secure additional short term imports by diverting cargoes from other destinations or securing very prompt cargoes (this would be the equivalent of two additional cargoes in two to three weeks and two more in four to five weeks). It may be that the fuel quality of these prompt imports may differ slighting from the New Zealand specifications, so importing companies may require a waiver on certain specifications before use.
- Companies will draw down existing buffer and safety stocks held in the system. We estimate this to be about seven to nine days consumption at normal rates. While there is more stock than this in the system this is required to keep the system operating - if some of this stock was able to be used it might alter the profile of when the stock shortage occurred but would not alter the size of shortage itself.

Petrol and diesel impact

The net impact over a two-month period is shown in Figure 1 with further details given in Appendix 1. Over the period about 25% of normal petrol and diesel demand would not be met. While the shortage is shown at its worst in the first two weeks, it might be possible to reduce the initial impact by drawing down inventories faster in the initial period (rather than evenly over 42 days). It is assumed the shortage is evenly spread over the country and the shortage for petrol/diesel is about 50/50.

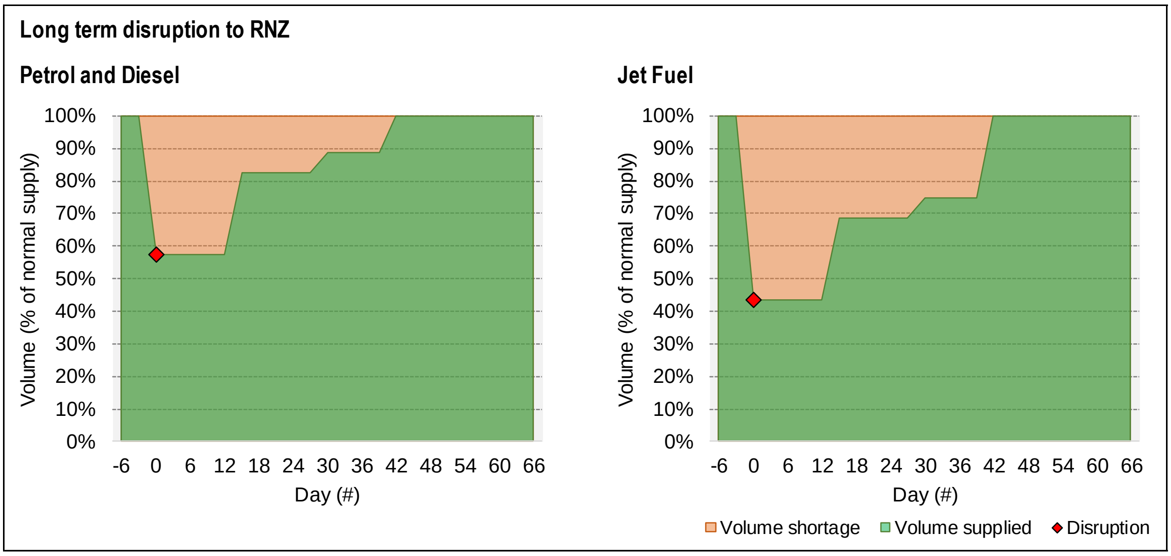
Jet fuel impact

The shortage for jet is worse as Refining NZ supplies more of the market (although by 2021 this is about 72%, rather than around 85% currently observed) so there are less imports to assist with meeting demand. As a result about 39% of normal demand is unable to be met over the period. As jet demand in New Zealand is weighted towards international (~79%) this will primarily affect international demand. The expectation is there will be some rationalisation of international and domestic flight timetables to better load aircraft and reduce fights and that most short haul international flights (e.g. Trans-Tasman) will tanker in fuel for their return journey when flying to New Zealand. Long haul traffic (New Zealand to/from Asia or North America) will not be able to tanker sufficient fuel so will need to stop elsewhere (e.g. Brisbane, Nadi) either before or after the New Zealand stop to load additional fuel. Some international flights might be rationalised and long haul passengers may need to depart through Australia.

The summary for the jet shortage impacts are:

- Demand still met: 61% or 3.36 ml/day
- Lower demand from rationalising flights: 10% or 0.55 ml/day[25]
- Tankering from Australia for trans-Tasman flights: 10% or 0.55 ml/day[26]
- Remainder of demand that won't be met locally: 19% or 1.02 ml/day

Figure 1: Major refinery outage - impact on supply over time



[25] Level chosen based on normal aircraft loadings around the 80-85% level

[26] Based on discussions with Air New Zealand and the Board of Airline Representatives New Zealand during the work on RAP contingency options, updated for 2021 demand situation.

3.2.2 Probability

The probabilities for an event of this scale were assessed at range of 0.20-0.25% per year (1 in 400 to 500 years) in the previous report based on analysis of international literature and possible local events (such as earthquake and tsunami). These sources have again been reviewed along with some additional information to provide an updated estimate.

The European Major Accidents Reporting System (MARS)[27] database was reviewed to add the most recent five years data to the previous analysis. The number of reported major incidents for oil refineries/petrochemicals in the last five years (only has reports available to 2015) is only 13 in comparison to 28 in the prior five year period and a higher number before that. As in the earlier analysis a considerable number of events (about half) related to petrochemical facilities rather than refining (these facilities are often co-located).

The incident mix was similar to previous reviews with the largest group being either liquid or gas releases to atmosphere (in most cases having limited or no impact on production). The most severe accidents were vapour leaks causing fire and explosions. Compared to the previous analysis there were less incidents causing fatalities and fewer with a significant impact on production (impacts were primarily on petrochemical plants).

Based on this sample and as there are approximately 100 refineries in Europe if there was one incident causing an extended shutdown over a 10 year period then the probability would be 0.1% for that period, in line with earlier assumptions. However, there may have been other shutdowns not detailed. Given Refining NZ's reliability and safety performance we would expect it to have a lower disruption probability than the European average, although it was not clear how long the resulting shutdown was with some of the reported incidents.

A paper by Jim Thomson (Safety in Engineering)[28] was also reviewed as this covered only oil refineries and listed major refinery accident losses from 1972-2011 (global list based on Marsh data of Value of Insured Losses). Based on his analysis and making allowances for underreporting, he concludes the in a 50-year life "any given Refinery has about a one in ten chance of suffering a major accident during its operation lifetime".[29] This is equivalent to a 0.2% chance in any year, higher than derived from the European data but with the same provisos when applying to Refining NZ. Analysis of the incidents in the Marsh document, *The 100 Largest Losses 1974-2015*[30], would give a ratio for refineries of ~0.14% per year for major incidents recorded, calculated on the same basis as Jim Thomson's work. Based on the variety of these sources and there level we conclude our earlier assumption for Refining NZ is still valid.

The internal incidents covered above need to be combined with other incidents than might happen such as marine oil spill, external supply problem (e.g. electricity) or natural disaster. For natural disasters, one of the reasons Marsden Point was chosen for the refinery site was due to the region's lower risk to natural disasters (e.g. lowest earthquake risk within New Zealand).

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[27] https://emars.jrc.ec.europa.eu/

[28] Refineries and Associated Plant: Three Case Studies, Jim Thomson, Safety in Engineering 2013

[29] Ibid pg 3

[30] The 100 Largest Losses 1974-2015, Large property damage losses in the hydrocarbon industry, Marsh, March 2016

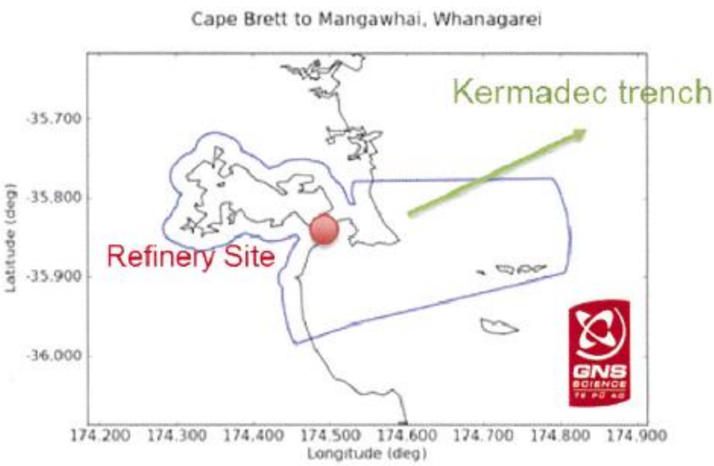
The 2012 Report highlighted that the Northland Lifelines Group Infrastructure Resilience Plan[31] identified infrastructure co-dependences as a key risk to manage (including the refinery's dependence on electricity and water supply) and assesses infrastructure failure scenarios and the risk posed by natural hazards. With the update of the tsunami information since the last report we consider how this might have changed the refinery disruption risk.

The tsunami risk is considerably higher than the earlier assessment with the maximum amplitude wave along that coastline for a 500 year return period now modelled as 4.8 metres (50 percentile) with a 2,500 year return period event being around 7.5 metres. More distant events (e.g. South America) are the main contributors to the shorter return period (500 years), whereas the local/regional Kermadec trench event would be a rare but severe event (contributes 50% of the cases for the 2,500 year return period).

However, as discussed in Section 2.2, the actual wave at the refinery might be considerably lower than the maximum estimated on the coast. Figure 2 shows the refinery is protected from direct impact from a Kermadec event, as it would be for many South American events.

Without detailed modelling it is difficult to estimate the likely impact other than to note that a 2,500 year event would still be expected to cause considerable inundation and damage, whereas for a 500 year event, it may well be below the level (say under 4 metres) where it would cause major damage.

Figure 2: Direction of tsunami wave



Source: Refining NZ/GNS Science

Refining NZ noted[32] it has tsunami event plans and for distant events will have the time to make the refinery safe which may make it easier to recover from any damage. A local/regional event is more difficult to manage and may result in the refinery being unavailable for a period of time, although as noted above this is expected to be a rare event. It may also be that associated infrastructure damage (e.g. electricity supply) is the reason for the refinery outage.

With events now expected to be larger (particularly rare events), there is greater risk that the refinery could be damaged, although the return periods are still considerable (i.e. rare). We therefore update the risk range assessed of between 0.04-0.20% to the higher end of that range; 0.10-0.20% (i.e. 500 to 1000 years rather than 500-2500 years). It would be useful if more detailed modelling of the Marsden Point coast could refine this risk a little more.

When combining the various risks, the 2012 Report gave this major refinery outage scenario a risk range of 0.20-0.25% (1 in 400 to 500 years). With a higher tsunami risk and a higher major event

[31] Northlands Lifelines Group: Infrastructure Resilience Plan (October 2009). Part B: Infrastructure/Hazard Risk Profile.

[32] Call Julian Young/Ian Twomey 16 June 2017

risk from the global data in comparison to the European, we have now increased this slightly to 0.25-0.33% (1 in 300 to 400 years).

3.2.3 Additional supply costs during disruption

This section covers additional costs incurred by the suppliers to minimise the disruption rather than the cost of not meeting demand. For this scenario the oil companies re-establish supply using imports, so while they are likely to face some increased costs to access prompt cargoes, ultimately supply via import will use the same benchmark level used to price into the market. Therefore, there will not be significant incremental costs to consider.

We do not consider the cost to the refinery from the disruption (they carry business interruption insurance) nor do we consider loss of refining margin to the refinery users.

3.3 Short refinery disruption

This scenario assesses a shorter duration outage of the refinery when it commences operation again within a timeframe that is not worth establishing full re-supply using imports. In effect this is a more severe version of refinery upsets that happen from time to time and are managed by companies using inventories they carry (Table 2) but of a smaller scale than the previous scenario.

3.3.1 Outage scenario

This scenario assumes some incident (be it a natural disaster or internal event) takes the refinery out of action for three weeks, although in practice it may be a shorter refinery outage with one unit down for an extended period because of an incident on one unit. While it won't be known immediately, it is expected the approximate timeframe for restart would be known within a few days after the incident so companies will know they are not switching to a complete import supply. In this case it is assumed that other than for a relatively short period (a few days), the refinery tankage and RAP pipeline will be operational.

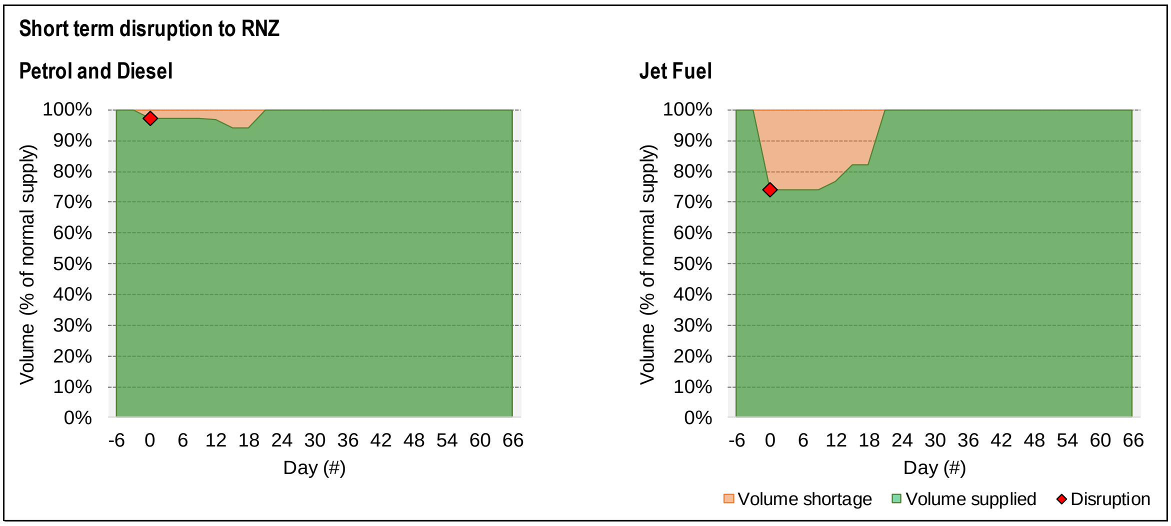
The scenario calculation assumes:

- Imports already meet some of the market demand (35% petrol, 28% jet and 38% diesel).
- Some of the larger oil companies operating in New Zealand are able to secure additional short term imports by diverting cargoes intended for other destinations (this would be the equivalent of two additional cargoes in two to three weeks), although some of these cargoes may require a waiver on certain specifications before use.
- Companies will draw down buffer and safety stocks in the system, but because the duration is shorter these will likely be drawn down more quickly than in the long term disruption case.

The net impact over the two month period is shown in Figure 3 with further details given in Appendix 1. Use of inventories (including buffer stocks) and a couple of very prompt imports could mean the actual stock shortages could be minimal (approximately 4% for petrol and diesel and about 23% for jet fuel). In practice there will be stock outs in certain areas for short periods as suppliers ration available product around the country. It is likely the actual shortage will occur from week two through to week four or five rather than over the immediate three week period as shown in Appendix 1 (although the magnitude of the shortage will be similar).

The shortage of jet fuel will require action to be taken by the airline industry. The assumption is this will largely be managed by short term rationalisation of flights and tankering of jet fuel from Australia for the trans-Tasman flights – this would mitigate about 20% of the shortage leaving a 3% shortage to be covered by adjusting how some of the long-haul flights are fuelled.

Figure 3: Short refinery outage - impact on supply over time



3.3.2 Probability

The probability of a shorter term outage is higher than for an extended outage. Several incidents reported in the MARS database on refineries involved short term refinery shutdowns or extended shutdowns of some units (around 10 over the 10 year period). Assuming Refining NZ was in line with average performance this would imply a 1% chance of an incident of this magnitude although as noted, its performance has been in the top quartile of refineries.

There is also the possibility that the more likely natural disasters (e.g. cyclone/flooding) could cause short term disruption, particularly if they also impacted critical infrastructure (e.g. electricity network) as well as the refinery itself. Because these are more likely than the natural disasters considered in scenario 1 (earthquakes/tsunami) the probability will be higher, although the impact smaller. We consider the estimate developed for the 2012 report remains valid to cover all these events, which is 0.5 to 1.0% (1 in 100 to 200 years) for a short term (three week) outage.

3.3.3 Additional supply costs during disruption

In this scenario the oil companies are likely to face increased costs to access prompt cargoes although that will be minor in terms of the overall disruption. They will also face increased costs trying to manage the disruption (e.g. extra port calls on vessels, some extra trucking) but again this would be expected to be low in the context of the cost of the actual outage.

3.4 Long term disruption to RAP/Wiri

This scenario is a regional infrastructure disruption rather than nationwide. There will be product available in the country, but it may be difficult getting it to where it is needed (Auckland). This scenario is based on the RAP Contingency Review[33], now assessed with forecast demand for 2021. Feedback from the oil companies in the original review highlighted the most severe contingency analysed would be long term disruption to the Wiri terminal as that removes both the terminal and stock in the terminal for an extended period. In the short term (one to two months) companies will not be able to fully meet market demand with more trucking and driver resource needed from

[33] H&T: RAP Contingency Options for Ministry of Economic Development (October 2011)

offshore to meet the increased distribution task and re-establishing jet fuel supply would be challenging.

3.4.1 Outage scenario

The scenario assumes an incident (most likely an event that destroys a significant part of the asset) takes the Wiri terminal out of action for an extended period requiring the companies who use Wiri to re-establish supply into Auckland from neighbouring terminals. For petrol and diesel ultimately 100% of the supply can be met from neighbouring terminals but it will take time to put the assets (trucks and driver) in place to enable this supply to be met.

The scenario calculation assumes:

- While Auckland itself faces the shortage, transportation assets from Northland, Bay of Plenty and Waikato will be used to assist in resupply. Rather than having normal supply in those regions and a serious shortage in Auckland, the shortage will likely be spread across the regions, although we expect the shortage in Auckland will still be more severe.[34]
- Wynyard wharf will be used for diesel supply to Auckland.
- Over the first week spare trucks and drivers (equivalent to 10 units[35]) are relocated and assigned to the new task.
- Utilisation of the trucking fleet will be maximised to increase the total volume of fuel moved, this will likely commence after about six days and reach full effect by day 15.
- Other measures like shifting demand from the region and improving distributor fleet utilisation (in addition to the initial utilisation gains) take effect in the third and fourth weeks.
- Offshore trucks and drivers start arriving after one month gradually building up to the full requirement over the next month.[36] In total 14 extra trucks would be required from offshore.
- In practice the impact of each action will overlap although the profile is likely to be similar (unless the offshore trucks and drivers can be secured more quickly).
- As there is little stock to cushion the impact the disruption impact will be felt within a couple of days (there is likely to be one to two days of jet supply at the airport).

Petrol and diesel impact

The petrol and diesel disruption will be at its worst in the first couple of weeks (Figure 4) and then gradually ease. Over the whole period (60 days) the short is 14% of the upper North Island demand (80 million litres), although taken over the first two weeks the short is 29% (36 million litres). Without Wynyard Wharf to supplement supply in Auckland the shortage would increase from 14% to 23% and would require 30 offshore trucks rather than 14 to fully restore supply of petrol and diesel. Modelling indicates this increase in trucks would also put pressure on the truck loading gantries at both the TLF and Mount Maunganui terminals.

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[34] This would result in a slightly higher shortfall volume (the trucking assets will be doing longer journeys), but is expected to be economically rational as costs for each region will increase as the shortage becomes more severe in that region (i.e. the cost of reducing Auckland supply by a further million litres will be a lot higher than shorting other markets by one million litres from a full supply situation).

[35] Consultations with companies in 2011 identified the equivalent to 10 spare trucks available for use in an emergency and communications with companies for this report confirmed these assumptions are still valid.

[36] Timeframe for importing trucks and getting offshore drivers was verified during the 2011 consultations.

Jet fuel impact

The jet shortage is more severe as Wiri terminal provides the only real means of getting jet fuel to Auckland Airport. This is approximately 80% of the national demand. The impact will be almost immediate as the airport facility (JUHI) only carries a couple of days stock.

The summary for the jet shortage impacts are (% of normal Wiri throughput):

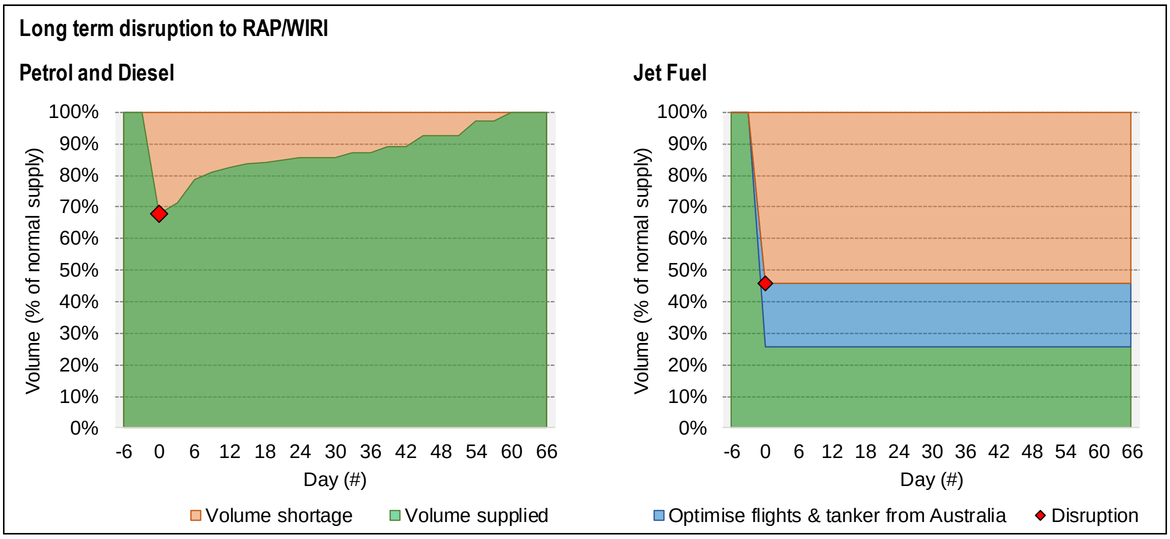
- North Island regional airport demand met from Wellington: 2.5% or 0.11 ml/day
- Domestic aircraft demand shifted to Wellington and Christchurch: 10% or 0.44 ml/day
- International demand shifted to Christchurch: 13% or 0.57 ml/day
- Tankering in from Australia for trans-Tasman flights: 9% or 0.38 ml/day
- Lower demand from rationalising flights: 9% or 0.38 ml/day
- Remainder of demand that won't be met locally: 57% or 2.49 ml/day

In summary, only 26% of normal Wiri demand will be met through other New Zealand airports with the rest met by avoiding throughput, rationalisation or shifting demand offshore. The loss of the ability to meet 57% of normal demand (long-haul international demand) would only partially be managed by limited tankering and diverting flights via Australia so it is likely major adjustments to schedules would be required with impacts on the capacity of movements in and out of Auckland Airport over the period.

Should the Wynyard wharf facility become an option for jet fuel imports (Section 2.3), we estimate this could initially meet 10% of the normal Auckland Airport demand (2021 forecast) and possibly up to 16%. At best, if all used for refuelling long haul flights, it would mitigate about one quarter of the shortage identified above.

Unlike petrol and diesel, the jet supply disruption won't reduce overtime, instead it will continue until a solution is put in place. From the earlier RAP Contingency Study the best option to restore supply was having a system to directly connect the RAP to the WAP (the pipeline between Wiri and the airport). While this would restore 100% of supply, previous estimates were that it may take up to six months to put that in place, or a bit less if some preparatory work had been done.

Figure 4: Major RAP/Wiri outage - impact on supply over time



3.4.2 Probability

The 2012 report assessed the probability of a major Wiri terminal outage at 0.2-0.3% (1 in 333 to 1 in 500 years) and the review of terminal events (covered in Section 2.7) concludes that terminal disruption is likely to be similar. WOSL has completed significant additional safety upgrades in the past few years based on the findings from the Buncefield incident such that it now has industry leading safety facilities. These were detailed in the statement of evidence by David Goodwin for the Auckland Council's designation hearings for the Wiri site. David noted that the safety systems at Wiri "exceed international industry best practice requirement"[37], as shown in the following table.

Table 3: Wiri Oil Terminal safety features

Safety Feature	International Practice	Installed at the Wiri Terminal
Independent high-high level alarm	Yes	Yes
Independent extra high level alarm	No	Yes
Automatic closing of tank inlet valve for high-high or extra level alarm	No	Yes
Full SIL 2 approval for high-high or extra high level alarm	No	Yes
Ducted overfill on tanks	No	Yes (Mogas only)
Gas detection system	No (but being adopted by some oil companies)	Yes
Fixed foam fire protection	Yes	Yes

Source: David Goodwin Statement of Evidence

These safety additions were taken into account when the probability of disruption at Wiri was reduced in the 2012 Report.

Complete disruption of throughput at the Wiri terminal would be less likely if the tanks weren't all in the same area of the terminal site. The designation hearing for Wiri referred to above, considered Wiri terminal's ability to expand terminal storage in future with new tanks (if required) close to Roscommon Road boundary (front of the site). This would provide tanks with significant separation distance from the existing tanks, greatly minimising the chance of a single incident affecting the whole site. Both David Goodwin and Ian Twomey[38] in their statements of evidence, noted the improvement in resilience that would be provided by new tanks in this area (this would lead to a reduced risk for the scenario being considered here). In addition, Ian Twomey's statement of evidence noted his expectation was that new tank investment would need to be considered before 2020 (diesel initially). We are not aware of any current plans for investment

[37] Statement of evidence of David John Goodwin on behalf of Wiri Oil Services Limited, April 2015; Auckland Council designation hearing for Wiri terminal. Page 15.

[38] Statement of evidence of Ian Hamilton Twomey on behalf of Wiri Oil Services Limited, April 2015; Auckland Council designation hearing for Wiri terminal. Page 4.

although these issues are always under review by fuel suppliers particularly at times of changing demand like the sharp increase of jet throughput in recent years.

Given no forecast change to the terminal facilities, we have not changed the likelihood of major disruption for this scenario. We note also that the updated tsunami risk assessment for the Manukau harbour entrance has a much lower wave amplitude that for east coast locations, and it is expected within the harbour it would be lower again. Therefore Wiri is not seen as a high risk location for a tsunami.

3.4.3 Additional supply costs during disruption

The internal cost of the disruption (to oil companies) for petrol and diesel can be calculated in terms of the additional trucking cost. Once supply is fully re-established (100% of demand met) the companies are estimated to be spending an additional $55,000 to $60,000 per day (cost of the additional trucks and the extra distance travelled). This cost will ramp up (assume linearly) over the 60 days it takes to re-establish supply. This cost is lower than assessed in 2011 reflecting the currently lower cost of fuel than in 2011. While there will be extra shipping cost this should be largely offset by not paying pipeline fees.

The 2012 Report used the figure of $0.5 to $1.0 million per day relating to the extra costs involved in tankering fuel for airlines. The 2012 NZIER Report looked at the welfare loss from disruption to jet fuel (cost to the economy) and calculated this as accruing at $1.2 million per day.[39] This is additional to the direct cost to the airlines in maintain the amount of supply we have assumed in the scenario. It is likely the welfare cost is now higher as the shortage/ international tankering requirement for jet fuel has increase between 2012 and the expected 2021 situation (was 40% of demand, now expected to be 57% of normal demand). This could increase the welfare loss by around 50% (to ~$1.8 million/day).

3.5 Short Term Disruption to RAP/Wiri

This scenario reflects disruption to the RAP pipeline rather than Wiri terminal. During the RAP Contingency Review, discussions with Refining NZ (owners of the RAP) and the Wiri terminal operators indicated RAP disruptions should be resolved quickly (less than seven days). Scenarios which might take the pipeline out for longer periods would involve severe natural disasters that would also remove much of the demand (e.g. volcano forcing evacuation of Auckland and closure of the airport). Therefore to model a severe scenario we assume a nine day shutdown of the RAP.

3.5.1 Outage scenario

The scenario assumes an incident or natural disaster causes damage to RAP that would take nine days to restore operation. The scenario calculation assumes:

- Unlike the long term outage in Section 3.4, the stock at Wiri at the time of the incident will be available. While typically there is around six days stock at Wiri, we assume (on average) only four days stock for each product will be accessible without causing disruption while rebuilding stock again.
- Over the first week spare trucks and drivers are relocated and then used to truck fuel into Auckland from neighbouring terminals.
- Some of the fleet that normally uses Wiri will remain there to access the existing stock (about 50%), with the rest moving to neighbouring terminals to transport product into the region.

[39] NZIER 2012 Report pg. 41

- The scenario assumes spare RAP capacity can be used to rebuild stocks at Wiri in the period following the shutdown.[40]

Petrol and diesel impact

While the stock at Wiri can be used to smooth the disruption, in theory 13% of the normal petrol and diesel demand (11 million litres) won't be able to be supplied over the nine day period. This disruption could be minimised by encouraging consumers to defer demand, i.e. the product will be available, just in a few days' time. Given stock normally in the system (e.g. service station stocks) the main impact from the outage might be some service stations stocking out for a limited period rather than a severe market outage.

Jet fuel impact

The jet disruption will be severe as there is no ability to supplement available inventory with supply from neighbouring terminals or to defer demand. Based on typical inventories held at Wiri and Auckland Airport we assume about four days normal demand can be met (it may be a little higher if the normal testing cycle can be expedited).

The summary for the jet shortage impacts are:

- Demand met by drawing down Wiri/JUHI stocks: 44.5% or 1.95 ml/day
- North Island regional airport demand met from Wellington: 2.5% or 0.11 ml/day
- Domestic aircraft demand shifted to Wellington and Christchurch: 10% or 0.44 ml/day
- International demand shifted to Christchurch: 13% or 0.57 ml/day
- Tankering in from Australia for trans-Tasman flights 9% or 0.38 ml/day
- Lower demand from rationalising flights: 9% or 0.38 ml/day
- Remainder of demand that won't be met locally: 12% or 0.54 ml/day

In effect, 70% of normal demand will still be met from New Zealand airports.

3.5.2 Probability

The 2012 Report updated the probability for this scenario to 0.5-1.0% (1 every 100 to 200 years) due to updated pipeline loss statistics (reduced from the 2004 work). Statistics for the US pipeline system incidents over the last five years are similar to the previous data (which translated to RAP would be for an incident once every 15-20 years). Many of these outages and spills were short term/small rather than the significant outage being modelled here.

European data from CONCAWE[41] shows a declining trend for pipeline incidents with 2014 data being 0.12 spills per 1,000km down from the 5-year average of 0.18 and the long term average (from 1974) of 0.47. However this data excludes incidents from theft which in recent years has become the major source of spills (54 of 58 reported spills in 2014 relate to theft). Excluding theft, applying the last five year average to RAP would mean 0.03 spills/year or a spill every 33 years.

Natural disasters likely to cause damage to the pipeline are expected to be repaired within this timeframe assumed for this incident (the limited evidence available from tsunami damage is the buried pipelines do not suffer damage in tsunami). Given limited changes in the data, we continue with the same assumption for the probability of a nine day outage of RAP of 0.5-1.0% per year.

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[40] Refining NZ is currently investing to increase RAP capacity by 15% (2016 Annual report)

[41] European refiners' organisation.

3.5.3 Additional supply costs during disruption

The internal cost of the disruption (to oil companies) for petrol and diesel can be calculated in terms of the additional trucking cost. This is only for a short period - the cost is estimated at $30,000/day once all contingencies are in place or around $150,000 for the nine day disruption taking account of the ramp up in resource use and cost.

3.6 Long term disruption at Wellington

As with Wiri, this scenario is a regional infrastructure disruption rather than a nationwide event. Damage to the distribution facilities in Wellington would require product to be trucked into the region from neighbouring terminals. There are three berths and terminal locations in Wellington:

- Seaview for the main transportation products (petrol, diesel and some jet fuel);
- Kaiwharawhara for marine fuels (diesel - no truck loading, and fuel oil); and
- Miramar for jet fuel

At Seaview there are four terminals all with significant separation. Other than a natural disaster (e.g. major earthquake and/or tsunami) or major failure of the jetty, it is difficult to see how all these facilities could be taken out of service. With natural disasters, demand may be affected as much as supply so the scenario is often less severe in terms of product shortage.

To model a severe case we assume all Seaview terminals are taken out of operation, which given the dispersed location of the terminals would mean either an incident has damaged the jetty or a natural disaster has affected all four facilities. We assume both terminals and their stock are unavailable so there will be market demand that cannot be met in the short term while companies re-establish supply from neighbouring terminals. Ultimately more trucks and drivers will need to be brought in from overseas.

3.6.1 Outage scenario

The scenario assumes either the jetty is out of action (this would affect all Seaview terminals) or a natural disaster has affected all the Seaview terminals. Wellington (and Manawatu demand) would need to be transported from Napier (or Taranaki[42]) - this will require additional trucking resource which will take time to put in place. There would be severe pressure on the Napier terminal, but we assume this can be managed by rerouting import ships from Wellington to Napier instead.

The scenario calculation assumes the following:

- The supply envelope would normally reach from Wellington into Manawatu, Wairarapa and for petrol into Taranaki. The product short will be spread over the whole region rather than just Wellington including Hawkes Bay and Taranaki which become the supplying terminals.
- The extremities normally supplied from Wellington, New Plymouth and Napier (e.g. southern central high country, Gisborne north) will be shifted to supply from Mount Maunganui to ease pressure on throughput at Napier.
- Over the first week spare trucks and drivers are relocated and assigned to the new task.
- Utilisation of the trucking fleet will be maximised to increase the total volume of fuel moved - this will commences after about six days and reach full effect by day 15.

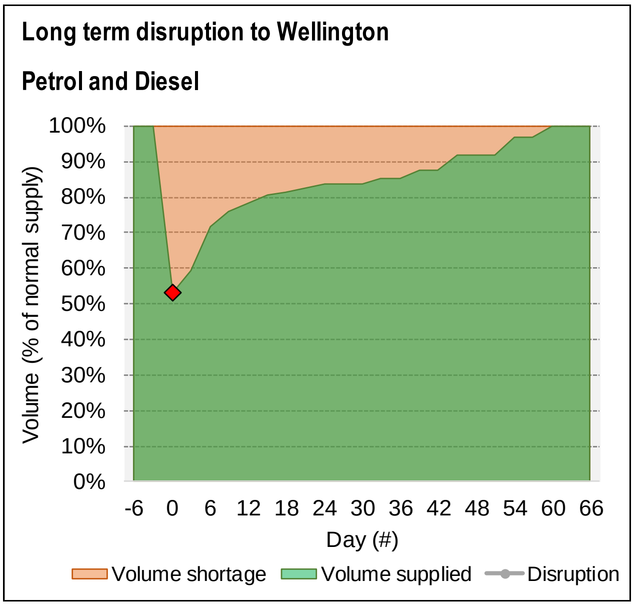
[42] Currently only diesel is available from New Plymouth, but BP/Port Taranaki are in the process of upgrading and recommissioning the old Caltex terminal – this is expected to be operational in October 2017

- Other measures like shifting demand from the region and improving distributor fleet utilisation will take effect in the third and fourth week.
- Offshore trucks and drivers start arriving after one month gradually building up to the full requirement over the next month. In total 12 extra trucks would be required from offshore.
- The impact would be almost immediate as the scenario assumes (pessimistically) that Seaview terminal stock is unavailable.
- As trucking resources increase we estimate the two Napier terminals will almost reach gantry throughput capacity assuming 24/7 operations. There would be a ship in port about every 10 days. While this would normally be infeasible, in this case it will be feasible as most import ships would now need to call at Napier instead of Seaview which is normally an import port. This will increase shipping costs through extra port calls.

The disruption will be worst in the first couple of weeks and then gradually ease. Over the whole 60 day period until full supply is re-established the short is 18% (of lower North Island demand) or 35 million litres, although looking at the first two weeks the short is 37% or 17 million litres.

Seaview disruption would not cause a major issue for jet as this is largely supplied through Miramar. The small amount of regional demand supplied from Seaview could be transported from Wiri or loaded out of the Wellington Airport tanks.

Figure 5: Major Wellington outage - impact on supply over time



3.6.2 Probability

The probability of an outage on this scale would be lower than Wiri as it is difficult to identify a scenario that takes out all Seaview terminals. Offsetting this is Wellington's natural disaster risk from earthquake or tsunami is higher than Wiri. For tsunami risk, Seaview is exposed, with high amplitude waves (6.2 meters) modelled for the 500 year return. How Seaview would be impacted (size of wave at Seaview relative to the maximum wave on the coastline) is unknown, but is likely to be higher than the assumption in the 2012 Report (3.6 metres for 500 year return). It is noted that more rare events (1 in 2500 years) could cause larger waves (over 9 metres).

Given the increase in the size of the tsunami expected on a 1 in 500 year cycle, along with the maximum size of the triggering event (earthquake), we assume an increase in risk of this event from the previous 0.15-0.25% to 0.20-0.30% (1 in every 333 to 500 years).

3.6.3 Additional supply costs during disruption

The internal cost of the disruption (to oil companies) for petrol and diesel can be calculated in terms of the additional trucking cost. Once supply is fully re-established (100% of demand met) the companies are estimated to be spending an additional $45,000 to $50,000 per day (cost of the additional trucks and the extra distance travelled). This cost will ramp up (assume linearly) over the 60 days it takes to re-establish supply. In addition there are likely to be some incremental port calls. We assume as extra port call (on import ships) every 10 days which is estimated at $50,000 a time (therefore a cost of $5,000/day).

3.6.4 Impact of disruption at Kaiwharawhara or Miramar

While not covered by the scenario above, disruption to either the Kaiwharawhara or Miramar terminals would also have a significant impact for the region. This was covered in detail in the Wellington Earthquake Petroleum Sector Resilience and Preparedness report[43]. In summary the key impacts would be as follows.

Kaiwharawhara Terminal

- Potential loss of ability to provide bunkers to the ferries and other vessels that would normally refuel at Wellington.
- Supply of fuel to the ferries would be the biggest issue as other vessels could obtain bunkers from other ports they call at.
- Some options for bunkering the ferries were identified including delivery of diesel (alternative fuel to fuel oil) via tank truck either at Aotea Quay or at Picton. Z Energy also indicated in an emergency it might be possible to bring the Awanuia (a marine fuel oil barge) to Wellington.

Miramar Terminal

- Loss of the Miramar terminal would quickly impact on jet supply to Wellington Airport. There are some day tanks located next to the airport. It was expected this fuel would be used to refuel aircraft already at Wellington airport so they can depart.
- Without alternative supply options for jet fuel to Wellington Airport, the expectation is that all aircraft coming to Wellington would be required to tanker fuel for the return journey until the Miramar terminal was again available.

3.7 Long term disruption at Lyttelton

This scenario is the most significant regional infrastructure disruption for the South Island as Lyttelton throughput is just under 50% of South Island demand. As with the other regional disruptions this is a distribution issue rather than a shortage of stock. Damage to the facilities in Lyttelton would require product to be trucked in from Nelson, Timaru and Dunedin. There are three terminals at Lyttelton and a pipeline over the Port Hills to another terminal at Woolston in Christchurch. Damage to any one of these facilities would affect supply, but to a lesser extent, as was seen with the damage to Mobil's Naval Point terminal in 2014[44].

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[43] Wellington Earthquake - Petroleum Sector Resilience and Preparedness | December 2016 for MBIE

[44] http://corporate.exxonmobil.com/en/company/worldwide-operations/locations/new-zealand/news/mobil-lyttelton-terminal-made-safe-following-march-landslide

The assessment assumes the most severe case where all Lyttelton supply is disrupted for at least two months while demand remains similar. We assume both terminals and stock are unavailable so there will be demand that cannot be met in the short term while companies re-establish supply from neighbouring terminals. In practice some stock is likely to be available which would help mitigate the initial shortage. Ultimately more trucks and drivers will be needed from overseas.

3.7.1 Outage scenario

The scenario assumes an incident takes out all Lyttelton terminals (or the port) so that no product can be received into the port. Timaru is the nearest terminal location but the two terminals are relatively small and will quickly reach capacity (both for resupply and gantry capacity). To the north, some demand can be shifted to Nelson but there is only one gantry so we expect these terminals to reach capacity. The balance would come from Dunedin (this is closer to Christchurch than Nelson). In practice Dunedin might supply in to South and Mid-Canterbury and all Timaru throughput would go north.

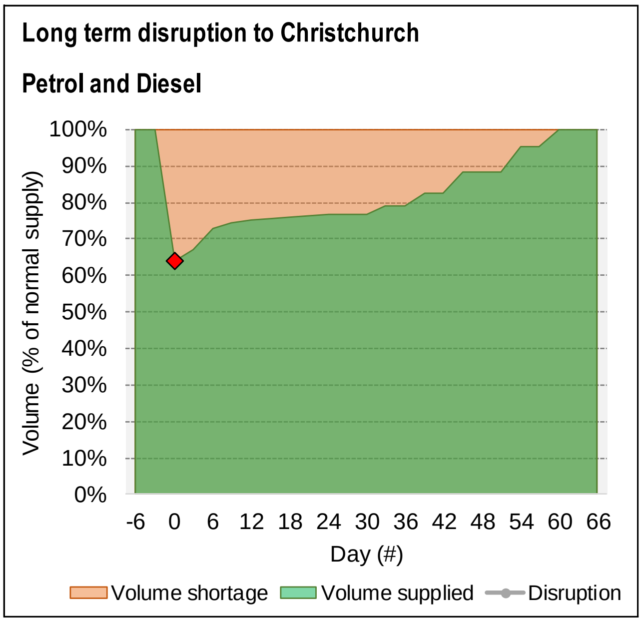
The scenario calculation assumes:

- The immediate impact will be mitigated by most trucking resources shifting to Timaru, with some additional West Coast volume delivered from Nelson.
- Over the first week spare trucks and drivers will be relocated and assigned to the new task. As Timaru will reach capacity some of the task will shift to Dunedin (e.g. supply into South Canterbury).
- Utilisation of the trucking fleet will be maximised to increase the total volume of fuel moved, again this will likely commences after about six days and reach fully effect by day 15.
- Other measures like shifting demand from the region, improving distributor fleet utilisation will take effect in the third and fourth week.
- Offshore trucks and drivers start arriving after one month gradually building up to the full requirement over the next month. Nearly all this volume will come from Dunedin as Timaru and Nelson will be at capacity. In total 25 extra trucks from offshore will be needed.
- This trucking task is expected to be more difficult than both Wellington and Wiri scenarios because of the longer distances between the terminals.
- As the stock in both Lyttelton and Woolston terminals is (pessimistically) assumed to be unavailable the impact would be almost immediate. In practice some stock may be available mitigating the initial impacts.
- It is likely extra port calls will be needed on import ships (using Timaru and Dunedin) to keep these ports supplied. The import ships would use these ports rather than Lyttelton which is normally the major South Island import port. This will increase shipping costs through extra port calls.

The disruption will be at its worst in the first couple of weeks and then gradually ease. Over the whole period (60 days) the short is 20% (of the Timaru north South Island demand) or 45 million litres, although for the first two weeks the short is 35% (18 million litres).

Jet supply to Christchurch airport will be severely disrupted and in practice only a small amount for small South Island only planes could be supplied (possibly from Wellington or more likely Dunedin). Most domestic demand would shift to Auckland or Wellington by tankering planes going to the South Island. International planes would either tanker fuel in (likely from Australia) or also call at Auckland to refuel.

Figure 6: Major Lyttelton outage - impact on supply over time



3.7.2 Probability

As with Wellington the probability of an outage on this scale would be expected to be lower than Wiri as it is difficult to come up with a scenario that takes out all Lyttelton and Woolston terminals. Again something that disrupts the port might be the most realistic example although in this case stock in port may still be available. It is worth noting that through all the recent earthquake activity in Canterbury, including the 22nd February 2011 earthquake which was centred in Lyttelton, the terminals have only been out of service for periods of days, not weeks as assumed in this severe scenario.

The Canterbury Lifeline Utilities Group has looked at the risk associated with the fuel terminals[45]. For natural disasters they assess earthquake as the highest risk. As noted above the infrastructure has proved to be very resilient through recent earthquake activity. Tsunami was at that stage assessed as medium risk; the updated 2013 GNS work models much higher maximum waves than the earlier work and higher waves than most other port locations in New Zealand (7 metres for a 500 year return period). Lyttelton harbour is a location where tsunami waves might resonate if they come in a certain direction. Therefore the tsunami risk is considerably higher than in the earlier assessment (i.e. a damaging wave is now expected in a shorter return period).

On balance we now assume a higher risk than other terminals due to the higher natural disaster risk (0.30-0.40% or 1 to 250 to 333 years).

3.7.3 Additional supply costs during disruption

The internal cost of the disruption (to oil companies) for petrol and diesel can be calculated in terms of the additional trucking cost. Once supply is fully re-established (100% of demand met) the companies are estimated to be spending an additional $65,000 to $70,000 per day (cost of the additional trucks and the extra distance travelled). This cost will ramp up (assume linearly) over the 60 days it takes to re-establish supply. In addition there are likely to be some incremental port

[45] Canterbury Lifeline Utilities Group Hazard Assessment for petroleum Storage, Transport and Supply - A summary (December 2011)

calls. We assume as extra port call (on import ships) every 10 days which is estimated at $50,000 a time (therefore a cost of $5,000/day).

3.8 Multiple terminal disruption

Exercise Tangaroa in 2016 assumed that most ports in New Zealand were damaged to the point where there was little the oil industry could do to re-establish supply in the short term. We noted in Section 2.2 that such a scenario is expected to be very rare (return period of over 1 in 2,500 years) so would be difficult to plan for. We have been unable to discuss details with those who developed the expected damage for the scenario, but the spread of damage (number of ports impacted) seemed surprising based on the information in the GNS report (e.g. a Kermadec event is not shown as a likely source of a major tsunami at Wellington, yet Seaview was assumed to be taken out of action in the exercise).

We comment that for future exercises there may be more learnings by having an exercise with a scale reflective of a return period between 100 to 500 years where a major response would be required but there will still be some means of responding.

It is clear that a tsunami could impact multiple petroleum terminals particularly for rare events. Examples include (only ports likely to be significantly impacted listed):

- A large Kermadec sourced tsunami (Refinery, Auckland, Tauranga)
- A large Hikurangi tsunami (Napier, Wellington)
- A large Peru event (Refinery, Auckland, Tauranga, Napier, Wellington, Lyttelton, Timaru, Dunedin, Bluff)
- A large Chile event (Refinery, Auckland, Tauranga, Napier, Lyttelton, Timaru)

These substantial events are all expected to be rare (1 in 2,500 years). Smaller but still very major events (500 year return periods) could also impact multiple ports although significant damage is more likely to be limited to one or two ports in those events. For the South American events, the warning available due to the distant source gives more time to prepare the facilities and temporarily relocate trucking resources outside of the tsunami zone which may help minimise damage.

In terms of individual terminal exposure, the list below details each port and its exposure to tsunami based on the updated GNS information (based on the 1 in 500 year return period).

- Refining NZ: Covered in scenario 2.
- Wiri: Few issues as wave likely to be low in Manukau harbour (West Coast).
- Mt Maunganui: Larger forecast wave now could cause some damage on a 500 return period (depending on tide) – position of terminals gives a lot of protection from wave front although other material at the port (e.g. logs) can cause damage if swept into the terminals.
- Napier: Exposed to large wave both from local and distant event (together with Lyttelton largest individual exposure).
- New Plymouth: Little risk as forecast wave low and terminal located up the hill.
- Wellington: Covered in scenario 6 – risk has increased.
- Nelson: Relatively smaller wave predicted so lower risk location.
- Lyttelton: Covered in scenario 7 – high risk location particularly for large South American events.
- Timaru: Now predicts a much smaller wave than Lyttelton so risk has reduced from earlier work (for 500 year return period).

- Dunedin: Reasonable size wave but due to harbour shape and protection it is unlikely to cause major issues at the oil terminal locations.
- Bluff: Could have damaging wave from a local or distant event. Impact at terminal location difficult to predict due to harbour shape (may depend on source of tsunami and direction of travel).

3.8.1 Outage scenario

The fact that multiple locations might be affected means we have not developed a single scenario for investigation. We consider the implications for a likely worst case (New Zealand's most populated area with the highest petroleum demand) which would be an event that impacted both the refinery and Tauranga. In effect this is like scenario 2 (major refinery disruption) without the ability to resupply through Tauranga. While the same event is less likely to impact the Auckland facilities due to the smaller wave expected in that region, for this scenario we assume Auckland is also unavailable.

In terms of North Island petroleum infrastructure that would just leave Napier, Wellington and New Plymouth terminals available. Wiri may be available but with the refinery out of action (for imports as well as processing) only the stock at the terminal will be available.

We do not take the same modelling approach as the other scenarios, as without that infrastructure there is no way normal supply can be re-established in the region until import terminal capacity is able to be restored. Instead we look at the northern region critical service demand and see whether that is able to be met from remaining terminals.

The Auckland Engineering Lifelines group calculates fuel demand for CDEM-critical customers in its region (most recently updated in 2013). This includes the higher level of demand expected in response to a Civil Defence emergency. We have assumed that neighbouring regions will have a similar level of critical demand relative to their total demand. If the fuel transport capacity in that region (assuming operational after the emergency) is shifted to lift product from the remaining terminals in the North Island (Napier, New Plymouth and Wellington), that critical demand can be met along with an additional 50% demand (approximately 19% of normal demand in total). This is without impacting supplies in the southern North Island which could be reduced if more product was needed to be shifted north.

In addition, stock at Wiri could be used for immediate response (average Wiri diesel stock would meet about 20 days of CDEM emergency response demand, petrol a lot more). In practice the CDEM critical demand would start to drop over time and the additional supply could be used for second order requirements such as food distribution. The southern North Island terminals are capable of handling the higher throughput – it is trucking that limits the amount that can be moved north.

Protecting trucking assets so these are able to be deployed after a major tsunami event will be critical. While temporarily locating the trucks outside of any tsunami zone would be logical, this might require companies to park the trucks in yards without the required bunding. If not already the case it would be useful for companies to have plans in place for relocation of trucks should there be a major tsunami alert.

We therefore conclude that if a major emergency impacted multiple ports, until facilities were re-established in the region it is unlikely normal demand could be met. However emergency demand and demand for second order critical needs (like food distribution) would be able to be met.

4.0 Contingencies

4.1 Strategic importance of the Wynyard terminals

The scenarios where disruption impacts supply into Auckland (particularly scenarios 3 and 4) rely on the Wynyard Wharf Central Auckland terminals to help mitigate the shortage, particularly for diesel. Should disruption be related to a civil defence emergency, diesel supply will be a critical feature of the response. Our analysis of the shortage in scenario 3, is that without Wynyard Wharf the shortage of product would be more severe (23% short rather than 14%), with more pressure on neighbouring terminals (Marsden Point/Mt Maunganui) and the trucking resource.

In addition, as discussed in Section 2.3, the Wynyard wharf facility provides one of the few options that might allow some jet fuel supply to Auckland Airport should there be a major disruption to supply through Wiri.

The terminals at Wynyard Wharf are due to be removed in future as part of the redevelopment of the Auckland waterfront (this has been delayed in the past but leases now extend to 2022). We understand Auckland Council is committed to finding an alternative location for the import of products currently supplied through Wynyard Wharf. In our view any discussion on alternate locations for import terminals in Auckland also needs to consider the role these facilities could play in a supply disruption, particularly the option for jet fuel import in an emergency.

4.2 Trucking

For the regional disruption cases (Wiri, Wellington and Lyttelton) additional trucking and driver resource would solve the disruption more quickly. Therefore the probability of a contingency such as spare trucks is more valuable than assessed by looking an individual event. While extra trucking would also help in with other terminal disruptions, the impact of these outages is much smaller. When assessing the value of having a spare trucking/driver resource we think it is reasonable to look at a scenario that:

- Averages the impact/cost of the Wiri/Wellington/Lyttelton scenarios (i.e. expected cost of one incident if it happens)
- Combines the probability of the three cases (i.e. ~0.8% being the probability of any one event happening)

This was done as part of the NZIER 2012 economic evaluation of contingency options.

4.3 Storage location

Storage of crude or product as a contingency for use in emergencies was assessed in the 2005 and 2012 Reports. Fuel storage also contributes to meeting New Zealand's IEA commitments. The 2012 Report found the additional cost of fuel storage in New Zealand (relative to the cost of ticket stocks that meet NZ's IEA requirement) was not justified by the mitigation it provided, as the probability of its use was very low.

Storage of fuel could be used as a contingency both for international events and to provide domestic security. However, the following should be considered:

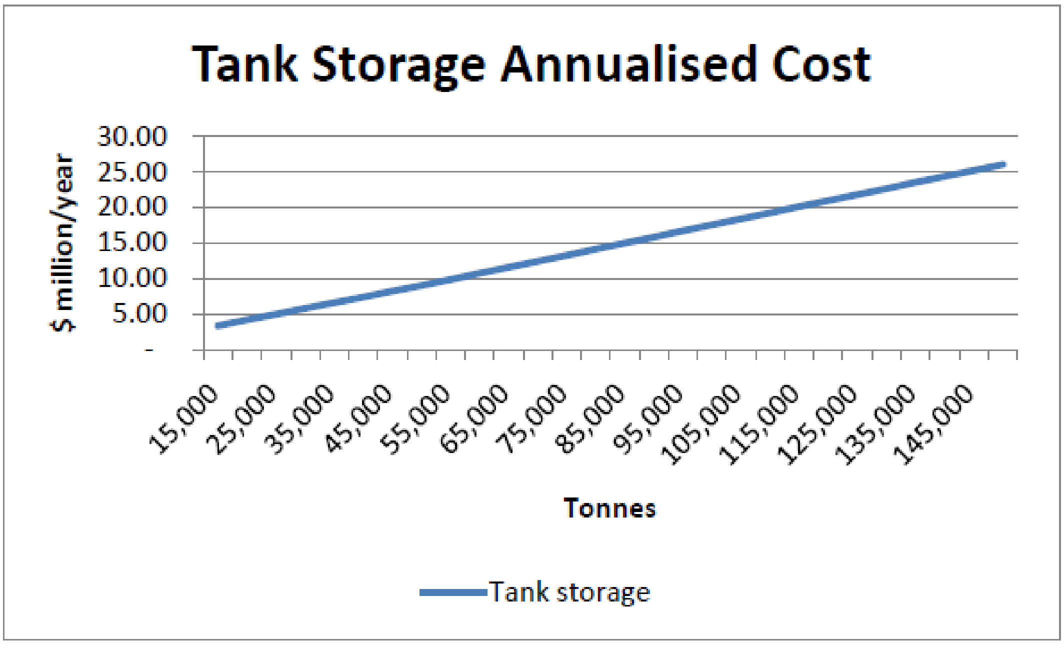
- If an international disruption is likely to be managed by price (i.e. price rising to a level where demand drops by an equivalent amount), then the only value of the emergency stock is as part of the country's contribution to its IEA stock holding commitments. In this case storage is no more valuable than ticket stocks held offshore and should be evaluated on that basis.

- Physical emergency stock held in New Zealand can also provide domestic security, assuming this can be used for a domestic disruption. The value of the security it provides needs to cover the cost increment above the cheapest option that meets New Zealand's IEA commitments.
- Location of stock will be important:
  - The refinery is a logical location in terms of ease of distribution to the whole country in an emergency, but as a key vulnerability is a natural disaster affecting the Marsden Point area, it would not provide any security against that event. It would also not provide any security for a Wiri terminal disruption, the next worst disruption event.
  - Stock in the Auckland area (at a suitable separation distance from the current tanks at Wiri) will provide security against both a refinery disruption and a Wiri terminal disruption. This might be the most logical location (highest probability of use). All other locations can be reached by import/shipping volumes more rapidly and easily.
  - Emergency stock held in bulk at the other ports (e.g. Wellington or Lyttelton) could also be affected by the event affecting that location so may not provide additional security. These incidents are general better handled by responding quickly to more product to neighbouring terminals through which resupply is likely to come.

4.4 Storage cost

The 2012 NZIER Report used costs for strategic storage provided by H&T in the *Petroleum Reserve Stock Review 2010* updated using Treasury's public sector discount rate of 8% real. The supply curve NZIER developed is shown below.

Figure 7: Cost of new storage and stock



Source: NZIER from Hale & Twomey data

The physical cost of tanks and ongoing operating costs are now likely to be higher than 2010, while the cost of stock has reduced (this analysis used an US$80/bbl crude price). The lower stock cost would more than offset the increases in tank costs and likely reduce the overall cost by about 10-15%. As a result the expected annual cost of a 50,000 tonne storage terminal would now be around $8 million/year based on similar assumptions to those used by NZIER (same discount rate, 40 year life).

5.0 Comment on the likely impact on economic assessment

This report was not required to update the economic analysis carried out by NZIER in 2012[46]. However, we summarise the expected impacts given the update in assumptions.

The updated probabilities for the disruption event scenarios are shown in Table 4. These are either the same or have increased slightly (events more likely). It is the locations most exposed to the rare but major tsunami risk (refinery, Wellington, Lyttelton) where the risk has increased.

Table 4: Change in disruption probabilities[47]

2012	**Scen. 1** Interntal. disruption	**Scen. 2** Long term refinery outage	**Scen. 3** Short term refinery outage	**Scen. 4** Long term RAP/Wiri disruption	**Scen. 5** Short term RAP/Wiri disruption	**Scen. 6** Long term Wellington disruption	**Scen. 7** Long term Christch. disruption	**Scen. 8** Multiple port disruption
Low probability of occurring	2.50%	0.20%	0.50%	0.20%	0.50%	0.15%	0.20%	n.a.
High probability of occurring	2.50%	0.25%	1.00%	0.30%	1.00%	0.25%	0.30%	n.a.
2017								
Low probability of occurring	2.50%	0.25%	0.50%	0.20%	0.50%	0.20%	0.30%	~0.10%
High probability of occurring	2.50%	0.33%	1.00%	0.30%	1.00%	0.30%	0.40%	~0.10%

We are not able to update the weighted risk assessment carried out by NZIER in the 2012 Report, but understand (from MBIE) the most conservative approach would be to inflate the welfare loss parameters which is the approach NZIER used for updating the analysis from the 2005 Report. While inflation in New Zealand has been low since 2012, there has been a significant decline in the price of fuel (mitigated in terms of the consumer cost by an increase in tax take). We would not expect either change to significantly impact the previously calculated welfare loss.

The shortages calculated in this report are similar to the 2012 Report, except for jet fuel, where a major disruption (particularly Scenario 4) is expected to cause a more significant shortage (due to the very strong growth from 2010 through to 2021 ~ 60% increase for Wiri). This is likely to increase the welfare loss for Scenario 4 and to a lesser extent for Scenario 5.

Overall we would expect a small increase in the probability weighted costs for scenarios 2, 4, 6 and 7. In all cases any variation would be within the range of variation calculated by NZIER using three different approaches to calculating the welfare loss.

[46] The results from NZIER's 2012 analysis are in appendix 3

[47] Note the scenario numbering in this report is different to that used by NZIER in their 2012 Report.

Given an expectation that the probability weighted cost will be similar, we can conclude the findings NZIER reached are still likely to be valid including:

- New domestic storage remains unappealing as its annual cost greatly exceeds the avoided cost (weighted probability), even when combining cases should the stock be in a location it could assist with multiple events (e.g. Auckland).
- Having spare trucks available for immediate use is still not justified against the alternative (obtaining then rapidly should there be an event).
- Building a RAP-WAP connection in advance of an event is not cost effective. It is probable that the consequence and cost of such a disruption has increased with higher jet demand, so mitigation work in terms of response options should an event occur is even more important. MBIE and jet fuel suppliers began investigating this issue following the 2012 Report. H&T notes that mitigation options should be considered and evaluated in the context that a major disruption has occurred, and it is costing the economy $2-3 million dollars a day in direct and consequential losses, rather than a business as usual situation.

The other issues reviewed in this update that should be monitored by officials include:

- The important role the Wynyard Wharf facilities in Central Auckland would play should there be a significant disruption to normal Auckland supply. This needs to be considered when Auckland Council make decisions regarding the relocation of these facilities.
- The sharp rise in jet demand along with possible plans for expanding facilities at Wiri terminal (Section 3.4.2). Throughputs at Wiri have increased significantly, particularly for jet fuel. If additional storage was built there, adding it near the Roscommon Road boundary as noted in the Auckland Council Planning Hearings, would greatly increase the terminal's resilience.

Appendix 1: Scenario impacts

Long term disruption to Refining NZ

Day	Petrol + Diesel Total supply (kl/d)	Petrol + Diesel Shortfall (kl/d)	Jet Total supply (kl/d)	Jet Shortfall (kl/d)	Major refinery outage
-6	17,930	0	5,480	0	0%
-3	17,930	0	5,480	0	0%
0	10,318	7,612	2,386	3,094	46%
3	10,318	7,612	2,386	3,094	46%
6	10,318	7,612	2,386	3,094	46%
9	10,318	7,612	2,386	3,094	46%
12	10,318	7,612	2,386	3,094	46%
15	14,784	3,146	3,752	1,728	21%
18	14,784	3,146	3,752	1,728	21%
21	14,784	3,146	3,752	1,728	21%
24	14,784	3,146	3,752	1,728	21%
27	14,784	3,146	3,752	1,728	21%
30	15,900	2,030	4,093	1,387	15%
33	15,900	2,030	4,093	1,387	15%
36	15,900	2,030	4,093	1,387	15%
39	15,900	2,030	4,093	1,387	15%
42	17,930	0	5,480	0	0%
45	17,930	0	5,480	0	0%
48	17,930	0	5,480	0	0%
51	17,930	0	5,480	0	0%
54	17,930	0	5,480	0	0%
57	17,930	0	5,480	0	0%
60	17,930	0	5,480	0	0%
63	17,930	0	5,480	0	0%
66	17,930	0	5,480	0	0%
Total shortfall		185,722		88,974	
% of demand		25%		39%	

Short term disruption to Refining NZ

Day	Petrol + Diesel Total supply (kl/d)	Petrol + Diesel Shortfall (kl/d)	Jet Total supply (kl/d)	Jet Shortfall (kl/d)	Short term refinery outage
-6	17,930	0	5,480	0	0%
-3	17,930	0	5,480	0	0%
0	17,461	469	4,060	1,420	8%
3	17,461	469	4,060	1,420	8%
6	17,461	469	4,060	1,420	8%
9	17,461	469	4,060	1,420	8%
12	17,369	561	4,211	1,269	8%
15	16,908	1,022	4,512	968	9%
18	16,908	1,022	4,512	968	9%
21	17,930	0	5,480	0	0%
24	17,930	0	5,480	0	0%
27	17,930	0	5,480	0	0%
30	17,930	0	5,480	0	0%
33	17,930	0	5,480	0	0%
36	17,930	0	5,480	0	0%
39	17,930	0	5,480	0	0%
42	17,930	0	5,480	0	0%
45	17,930	0	5,480	0	0%
48	17,930	0	5,480	0	0%
51	17,930	0	5,480	0	0%
54	17,930	0	5,480	0	0%
57	17,930	0	5,480	0	0%
60	17,930	0	5,480	0	0%
63	17,930	0	5,480	0	0%
66	17,930	0	5,480	0	0%
Total shortfall		13,445		26,656	
% of demand		4%		23%	

Source: H&T

Note: Volumes shown are for 'that day', for the purposes of analysing the total impact the two days following 'that day' can be assumed to be similar to 'that

Long term disruption to RAP/WIRI

Day	Petrol + Diesel		Long term disruption to Wiri
	Total supply (kl/d)	Shortfall (kl/d)	
-6	9,350	0	0%
-3	9,350	0	0%
0	6,330	3,020	32%
3	6,667	2,683	29%
6	7,350	2,000	21%
9	7,585	1,765	19%
12	7,703	1,648	18%
15	7,820	1,530	16%
18	7,879	1,471	16%
21	7,941	1,409	15%
24	8,000	1,350	14%
27	8,000	1,350	14%
30	8,000	1,350	14%
33	8,135	1,215	13%
36	8,135	1,215	13%
39	8,338	1,013	11%
42	8,338	1,013	11%
45	8,675	675	7%
48	8,675	675	7%
51	8,675	675	7%
54	9,080	270	3%
57	9,080	270	3%
60	9,350	0	0%
63	9,350	0	0%
66	9,350	0	0%

Total shortfall	79,788
% of demand	14%

Short term disruption to RAP/WIRI

Day	Petrol + Diesel		Short term disruption to RAP/Wiri
	Total supply (kl/d)	Shortfall (kl/d)	
-6	9,350	0	0%
-3	9,350	0	0%
0	7,672	1,678	18%
3	8,009	1,341	14%
6	8,692	658	7%
9	9,350	0	0%
12	10,269	0	0%
15	10,269	0	0%
18	10,269	0	0%
21	10,269	0	0%
24	9,350	0	0%
27	9,350	0	0%
30	9,350	0	0%
33	9,350	0	0%
36	9,350	0	0%
39	9,350	0	0%
42	9,350	0	0%
45	9,350	0	0%
48	9,350	0	0%
51	9,350	0	0%
54	9,350	0	0%
57	9,350	0	0%
60	9,350	0	0%
63	9,350	0	0%
66	9,350	0	0%

Total shortfall	11,030
% of demand	13%

Long term disruption to Wellington

Day	Petrol + Diesel Total supply (kl/d)	Petrol + Diesel Shortfall (kl/d)	Long term disruption to Wellington
-6	3,290	0	0%
-3	3,290	0	0%
0	1,750	1,540	47%
3	1,951	1,339	41%
6	2,360	930	28%
9	2,505	785	24%
12	2,578	713	22%
15	2,650	640	19%
18	2,683	607	18%
21	2,717	573	17%
24	2,750	540	16%
27	2,750	540	16%
30	2,750	540	16%
33	2,804	486	15%
36	2,804	486	15%
39	2,885	405	12%
42	2,885	405	12%
45	3,020	270	8%
48	3,020	270	8%
51	3,020	270	8%
54	3,182	108	3%
57	3,182	108	3%
60	3,290	0	0%
63	3,290	0	0%
66	3,290	0	0%

Total shortfall	34,663
% of demand	18%

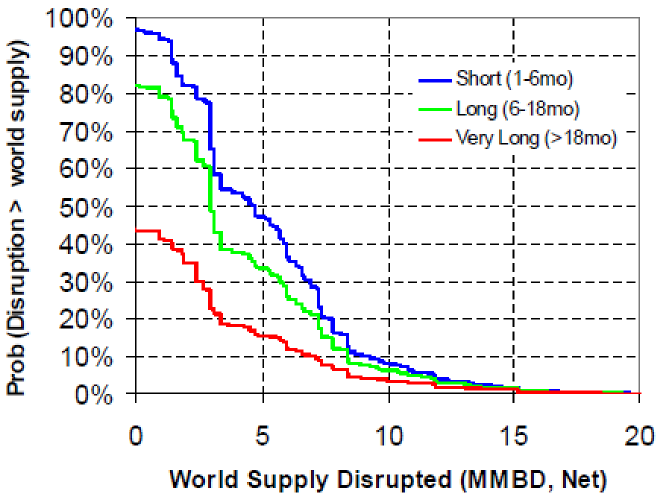
Long term disruption to Christchurch

Day	Petrol + Diesel Total supply (kl/d)	Petrol + Diesel Shortfall (kl/d)	Long term disruption to Lyttelton
-6	3,670	0	0%
-3	3,670	0	0%
0	2,350	1,320	36%
3	2,456	1,214	33%
6	2,670	1,000	27%
9	2,725	945	26%
12	2,753	918	25%
15	2,780	890	24%
18	2,793	877	24%
21	2,807	863	24%
24	2,820	850	23%
27	2,820	850	23%
30	2,820	850	23%
33	2,905	765	21%
36	2,905	765	21%
39	3,033	638	17%
42	3,033	638	17%
45	3,245	425	12%
48	3,245	425	12%
51	3,245	425	12%
54	3,500	170	5%
57	3,500	170	5%
60	3,670	0	0%
63	3,670	0	0%
66	3,670	0	0%

Total shortfall	44,991
% of demand	20%

Appendix 2: Global oil market disruption risk

Figure 13. Probability of a Disruption for All Durations



Source: Energy Modelling Forum, Stanford University (2005)

Appendix 3: NZIER Results 2012 Report[48]

The following table are the results from the 2012 NZIER Report on Oil Security. The three estimates used are as follows:

- An update using the 2005 Report's consumer impact assumption adjusted by consumer price-index
- An update basing consumer impacts on fuel price-elasticity estimates
- An estimate using consumer impacts and other inputs from the 2005 Report.

		Scenario 1 Long term Refinery Outage	Scenario 2 Short term Refinery Outage	Scenario 3 Long term RAP/Wiri Disruption	Scenario 4 Short term RAP/Wiri Disruption	Scenario 5 Long term Wellington Disruption	Scenario 6 Long term Christchurch Disruption	Scenario 7 International Disruption Event
Low probability of occurring		0.20%	0.50%	0.20%	0.50%	0.15%	0.20%	2.50%
High probability of occurring		0.25%	1.00%	0.30%	1.00%	0.25%	0.30%	2.50%
New scenarios updated input								
Consumer surplus	$m	1,093.6	57.8	452.2	84.6	169.5	183.8	1,971.9
Tax losses	$m	138.0	8.9	65.1	10.9	20.2	22.7	39.8
Externalities	$m	-139.3	-6.0	-50.5	-10.5	-22.7	-23.8	-44.5
Combined	Total $m	**1,092.3**	**60.7**	**466.8**	**84.9**	**167.1**	**182.7**	**1,967.2**
Probability weighted costs								
Low probability	$m/year	2.18	0.30	0.93	0.42	0.25	0.37	49.18
High probability	$m/year	2.73	0.61	1.40	0.85	0.42	0.55	49.18
New scenarios alternative update								
Consumer surplus	$m	815.56	30.93	551.89	49.24	59.73	75.43	1,932.05
Tax losses	$m	137.99	8.86	65.11	10.92	20.18	22.71	39.26
Externalities	$m	-139.3	-6.0	-50.5	-10.5	-22.7	-23.8	-44.5
Combined	Total $m	**814.3**	**33.8**	**566.5**	**49.6**	**57.2**	**74.3**	**1,926.8**
Probability weighted costs								
Low probability	$m/year	1.63	0.17	1.13	0.25	0.09	0.15	48.17
High probability	$m/year	2.04	0.34	1.70	0.50	0.14	0.22	48.17
New scenarios 2005 inputs								
Consumer surplus	$m	896.2	47.4	370.6	69.3	138.9	150.6	1,919.0
Tax losses	$m	127.9	7.9	59.0	10.1	18.9	21.1	34.9
Externalities	$m	-41.1	-1.8	-14.9	-3.1	-6.7	-7.0	-13.1
Combined	Total $m	**982.9**	**53.6**	**414.7**	**76.3**	**151.1**	**164.7**	**1,940.7**
Probability weighted costs								
Low probability	$m/year	1.97	0.27	0.83	0.38	0.23	0.33	48.52
High probability	$m/year	2.46	0.54	1.24	0.76	0.38	0.49	48.52

[48] New Zealand Oil Security Assessment Update, Report to the (then) Ministry of Economic Development, June 2012, NZIER